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HOW DO MARKET FACTORS INFLUENCE THE DEVELOPMENT OF NEXT-GENERATION BROADBAND?

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This thesis is the result of the author’s original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.

Signed: Date:

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Abstract

In recent years, the delivery of telecommunications services has shifted towards the use of the Internet Protocol (IP). Increasingly, new access mechanisms promise the capability and potential to deliver progressively higher speed and bandwidth-intensive applications. Moreover, this next generation of telecommunications infrastructure has been embraced by network operators in order to enhance their competitiveness. Though it is widely accepted that next-generation broadband will realize numerous commercial and socio-economic benefits, the investment uncertainties are many. For example, the financial requirements for network deployment are substantial and current-generation broadband services are still deemed adequate for many economies. The desire to understand these investment differences that exist across telecommunications markets motivates this research.

The overarching research question is 'how do market factors influence the development of next-generation broadband?'. With a focus on Europe, the research explores the investment decisions made by market players in The Netherlands, Sweden and the United Kingdom. Through semi-structured interviews, the study investigates the definitions of Next-Generation Networks (NGN) and Next-Generation Access (NGA), the benefits associated with these network paradigms, and the drivers for investment and technological choice. Drawing on academic literature, the research builds on studies that describe the macro-economic impact of markets on investment in NGN and NGA by providing an in-depth analysis underpinned by an empirical base. For the telecommunications industry, the study provides insight and guidelines for policymakers and network investors.

The research confirms the existence of a pronounced relationship between market factors and investment decisions. Path dependency, for example, plays an important role in defining NGA for market players while regulation, competition and geographic conditions are primary informants to the investment decision. A market-investment conceptual map highlighting the interplay between these issues is proposed, revealing the existence of reinforcing relationships in NGN and NGA development. More importantly, the detailed investigation into specific market conditions shows that it is the combination and interaction of the existing market factors that ultimately shape the investment decision.

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LIST OF ACRONYMS

2G - 2nd. Generation mobile technology

3G - 3rd. Generation mobile technology

3GPP - 3rd. Generation Partnership Project

4G - 4th. Generation mobile technology

AAS - Adaptive Antenna System

ACIF – Australian Communications Industry Forum

ADSL - Asymmetric Digital Subscriber Line

AES - Advanced Encryption Standard

ANI - Application-Network Interface

API - Application Programming Interface

ATM - Asynchronous Transfer Mode

BDUK – Broadband Delivery United Kingdom (UK)

BIS - Department for Business, Innovation and Skills (UK)

BPON - Broadband Passive Optical Network

BSG - Broadband Stakeholder Group

BT - British Telecommunications

C&W - Cable and Wireless

CapEx - Capital Expenditure

CAT5 – Category 5 cable

CATV - Cable Television

CAQDAS - Computer Aided Qualitative Data Analysis Software

CLPS - Connectionless Packet-Switched

CMTS - Cable Modem Termination System

CO-CS - Connection-Oriented Circuit-Switched

CO-PS - Connection-Oriented Packet-Switched

CPE - Customer Premise Equipment

DMS-CC – Digital Storage Media Command and Control

DOCSIS - Data Over Cable Service Interface Specifications

DSL - Digital Subscriber Line

DWDM - Dense Wavelength Division Multiplexing

E-DCH - Enhanced Dedicated physical Channel

EkonL - Electronic Communications Act

EICTA – European Information and Communication Technology Association

ENPV - Expanded (strategic) Net Present Value

EPON - Ethernet Passive Optical Network

ERG – European Regulators Group

ETP – European Telecommunications Platform

ETSI – European Telecommunications Standards Institute

EC – European Commission

EU – European Union

FDC - Fully Distributed Cost

FGNGN - ITU Focus Group on NGN

FMC - Fixed-Mobile Convergence

FTP – File Transfer Protocol

FTTB - Fibre-To-The-Building

FTTC - Fibre-To-The Cabinet

FTTCurb - Fibre-To-The-Curb

FTTH - Fibre-To-The-Home

FTTN - Fibre-To-The-Node

GERAN - Global System for Mobile communications (GSM) Enhanced Data GSM Environment (EDGE) Radio Access Network

GPO - General Post

GPON - Gigabit Passive Optical Network

GW - Gateway

HARQ - Hybrid Automatic Repeat Request

HDSL - High-bit-rate Subscriber Line

HDTV - High-Definition Television

HFC - Hybrid Fibre Coaxial

HSDPA - High-Speed Downlink Packet Access

HSPA - High-Speed Packet Access

HSS – Home Subscriber Server

HSUPA - High-Speed Uplink Packet Access

ICMP – Internet Control Message Protocol

ICT - Information and Communications Technology

IDSL – Integrated Services Data Network (ISDN) Digital Subscriber Line

IEEE - Institute of Electrical and Electronics Engineers

IETF - Internet Engineering Task Force

IGMP – Internet Group Management Protocol

ILEC - Incumbent Local Exchange Carriers

IMS - Internet Protocol Multimedia Subsystem

IN - Intelligent Network

IP - Internet Protocol

IPng - Internet Protocol next generation

IPTV - Internet Protocol Television

ISDN - Integrated Services Data Network

ISP - Internet Service Provider

ISUP – Integrated Services Data Network (ISDN) User Part

ITU – International Telecommunications Union

KBG - KabelTV Brabant-Gelderland

KPN - Royal KPN N.V.

LAN - Local-Area Network

LER - Labeled Edge Router

LR-PON - Long-Reach Passive Optical Network

LSP - Labeled Switched Path

LSR - Labeled Switched Router

LTE - Long-Term Evolution

MAN - Metropolitan Access Network

MDU - Multi-Dwelling Unit

MGCP – Media Gateway Control Protocol

MIMO - Multiple Input Multiple Output

MPLS - Multi-Protocol Label Switching

MVNO - Mobile Virtual Network Operators

NACF - Network Attachment Control Functions

NGA- Next-Generation Access

NGN - Next-Generation Network

NGN GSI – Next-Generation Network (NGN) Global Standard Initiative

NID – Network Interface Device

NMa - Nederlandse Mededingingsautoriteit (Dutch Competition Authority)

NNI - Network-Network Interface

OC - Optical Carrier

OECD – Organization for Economic Co-operation and Development

Ofcom – Office of Communications (UK)

OFDMA - Orthogonal Frequency Division Multiple Access

OLT - Optical Line Terminal

OMA – Open Mobile Alliance

ONU - Optical Network Unit

OpEx - Operational Expenditure

OPTA - Onafhankelijke Post en Telecommunicatie Autoriteit (Dutch Independent Post and Telecommunications Authority)

PC – Personal Computer

PDA - Personal Digital Assistant

PON - Passive Optical Network

POTS - Plain Old Telephone Service

PTP - Point-To-Point

PTS - Post-och telestryrelsen (Swedish Post and Telecom Authority)

QAM - Quadrature Amplitude Modulation

QoS - Quality of Service

R-ADSL – Rate-Adaptive Digital Subscriber Line

RACF - Resource and Admission Control Functions

RPC – Remote Procedure Call

RRM - Radio Resource Management

RT - Remote Terminal

SC-FDMA - Single Carrier Frequency-Division Multiple Access

SDH - Synchronous Digital Hierarchy

SDMA - Space Division Multiple Access

SDSL – Symmetric Digital Subscriber Line

SGCP – Simple Gateway Control Protocol

SIP – Session Initiation Protocol

SOFDMA - Scalable Orthogonal Frequency Division Multiple Access

SONET - Synchronous Optical Network

STB - Set-Top Box

STM – Synchronous Transport Module

STS – Synchronous Transport Signal

TCAP – Transaction Capabilities Application Part

TCP/IP- Transmission Control Protocol/Internet Protocol

TDMA PON - Time Division Multiple Access Passive Optical Network

TMF – TeleManagement Forum

UDP – User Datagram Protocol

UMB - Ultra Mobile Broadband

UMTS - Universal Mobile Telecommunication System

UNI - User-Network Interface

USA - United States of America

UTP - Unshielded Twisted Pair

VAS - Value-Added Service

VC - Virtual Circuit

VDSL - Very High-Speed Digital Subscriber Line

VoIP - Voice over Internet Protocol (IP)

W-CDMA - Wideband Code Division Multiple Access

WDM - Wavelength Division Multiplexing

WDM PON - Wavelength Division Multiplexed Passive Optical Network

WiFi - Wireless Fidelity

WiMAX - Worldwide Interoperability for Microwave Access

WLAN - Wireless Local Area Network

WSIS - World Summit on the Information Society

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1 Introduction

1.1 Investment diversity

The telecommunications sector is presently undergoing a dramatic transformation. Technological development and innovation, most recently the growth of the Internet and Internet Protocol (IP) technology, are creating new opportunities for novel markets, relationships, strategies and business models. These developments are cultivating an exceptionally competitive, innovative, complex and dynamic industry.

All market players are affected. Regulators are confronted with the challenge of fostering competition while providing incentives for investment and restructuring regulatory frameworks in an industry beset with regulatory uncertainty. Technological developments have surpassed the demands of the market and consumers are becoming the dictators of product and service developments. Equipment manufacturers and vendors need to ensure openness and interoperability of their systems. Perhaps most importantly, service providers and network operators need to improve the efficiency of their operations and find a competitive advantage in order to survive and succeed.

In light of these developments, operators are re-assessing their existing networks, upgrading to Next-Generation Networks (NGN) and Next-Generation Access (NGA) networks, jointly known as next-generation broadband. The NGN concept refers to an upgrade of the core telecommunications network infrastructure to a converged platform based on packet switching through IP. The IP-based architecture promises the delivery of more innovative services and a reduction in both operational and maintenance costs for operators. For consumers, this means cheaper prices, faster availability of advanced products and services and ubiquitous service access. NGA, on the other hand, refers to the enhancement of the access network to provide greater capacity to end-users, achieved through the use of upgraded access technologies and new topologies. In this way, NGA is emerging as a differentiating asset among operators.

The benefits of NGN and NGA to operators and the society as a whole have been outlined in many next-generation broadband literatures (see Beardsley et al., 2007; BT, 2010a; Kolesar and Levin, 2004; Ofcom, 2006a; Parliamentary Office of

Science and Technology, 2008; Salina and Salina, 2007; Stagg, 2010; van de Velde, 2007). However, despite the numerous advantages, empirical evidence shows that the rate of adoption of the networks has varied around the world. For example, telecommunications operators in Russia (such as JSC Sakhatelecom) and Africa (such as Gateway Communications) have made substantial NGN commitments while operators in the United States (USA) and South Korea (Verizon and KT respectively) have undertaken large-scale fibre access deployments. More generally, operators based in Asian markets are leading the world in the deployment of NGA (Vanier, 2010; Budde, 2010a). At a micro level, the decisions made by operators with regard to NGN and NGA deployments have also been mixed. The USA, for example, has adopted a regulatory forbearance strategy in the roll-out of NGA while France has chosen to enforce cost-oriented duct access (Caio, 2008).

These and similar deployment decisions worldwide indicate that the development of NGN and NGA is influenced by market conditions, an observation that has, in turn, motivated the research embarked upon in this thesis. Vergara et al. (2008) and Ofcom (2007), among other researchers, substantiate this importance of market factors to the next-generation broadband investment decision. However, while there is empirical evidence of the variances in next-generation broadband deployment, an identification of the specific market factors and their causal links to the investment decisions is deficient in next-generation broadband literature. By investigating the market-investment interplay from an empirical perspective, this research intends to understand the underlying causes of the investment diversity outlined above and hence address the existing gap in the literature.

1.2 Objectives of the research

Through an assessment of the activities within selected next-generation broadband markets, this study aims *to provide a comparative analysis of the supply-side development of next-generation broadband*.

The scope of the research is demarcated in several ways. Firstly, a key attribute of the study is its empirical focus. The study is based on data collected from market players involved in the deployment of next-generation broadband networks. Although theoretical relationships between market factors and the investment decisions can be established, two concerns exist with this approach. The first is that pragmatic factors can be overlooked, as their implications may only emerge in actual deployments. The second concern is that, given that next-generation broadband is a recent development, the determination of a theoretical link between market factors and NGN and NGA development is likely to be based on first-generation or current-generation broadband theory. As there are key differences between previous/current generation and next-generation broadband, this approach is neither apt nor adequate.

It is acknowledged, however, that, although the practical approach mitigates the risks and addresses the inadequacies of a theoretical study, the vigorously transient nature of the next-generation broadband industry can impose temporal constraints on the results of this research. A time lapse between data collection and publication is inevitable, during which time the next-generation broadband markets under study can undergo numerous changes. Consequently, the findings are likely to be bound to a window of time. In order to reduce this temporal impact and extend the longevity of the results, the methodology ensures that a holistic view and more fundamental relationships are examined through causal mapping. Such a modeling technique provides an abstract view of the market developments and relationships and removes, to some degree, the temporal element. Nonetheless, it is a caveat of this research that the results of the study be valued within the market context at the time of the data collection and analysis (2008-2010).

A second defining aspect of the scope of the study is its 'supply-side' focus. This choice is linked to the fact that the primary decision-makers in the development of next-generation broadband are network operators, policymakers and other investors.

Emerging from a more critical review of the discussion presented in Section 1.1, the overarching research question is articulated as '*how do market factors influence the development of next-generation broadband?*' Two aspects of this question define the boundary of the study. Firstly, 'development' can entail a variety of elements - the decision to invest, migration strategies, regulatory frameworks and investment models, to name but a few. By considering the availability of literature related to the different aspects of development and the time constraints of this study, the research was confined to development in the context of the decision to invest and technological choice. In the rest of the thesis, references to ‘development’ and ‘investment’ are associated with these two specific decisions. To complement these considerations, the implications of market factors on market players’ perceptions of next-generation broadband and their benefits are also explored. Secondly, the investigation specified by ‘how do’ includes identifying the market factors that influence the development choices and determining the causal relationships between these factors and the decisions made, as explained in Section 1.1.

Finally, although the research can be conducted and analyzed from an organizational perspective, the aim of the study is to investigate the influence of market factors on the investment decisions from a more holistic view. Therefore, individual stakeholders’ and organizational perspectives are examined as part of the more general decision reflected in the market to which they belong. Market factors are considered to be aspects of the immediate telecommunications broadband market, such as competition and competitors, regulation, technological infrastructure and consumers, as well as geographic and demographic attributes.

By answering the main research question within the scope defined above, this study provides a significant contribution to the field of next-generation broadband telecommunications. The study fills a research gap. The findings highlight the empirical perspective of the influential market factors and their links to the development of next-generation broadband that was lacking in the literature. On a practical level, the study provides an insightful understanding of the market factors that encourage, discourage or influence in a conditional way the decision to invest in next-generation broadband and the technology choices that are made. The study identifies generic relationships and lessons learnt that could be passed on to aid network operators and policymakers in their investment dilemma, hence contributing to the acceleration of next-generation broadband development.

1.3 Structure of the thesis

The remaining chapters in this thesis provide greater detail on the background of the study and explain how the research questions were answered and the research objective met. Figure 1-1 illustrates the arrangement of and links between the chapters.

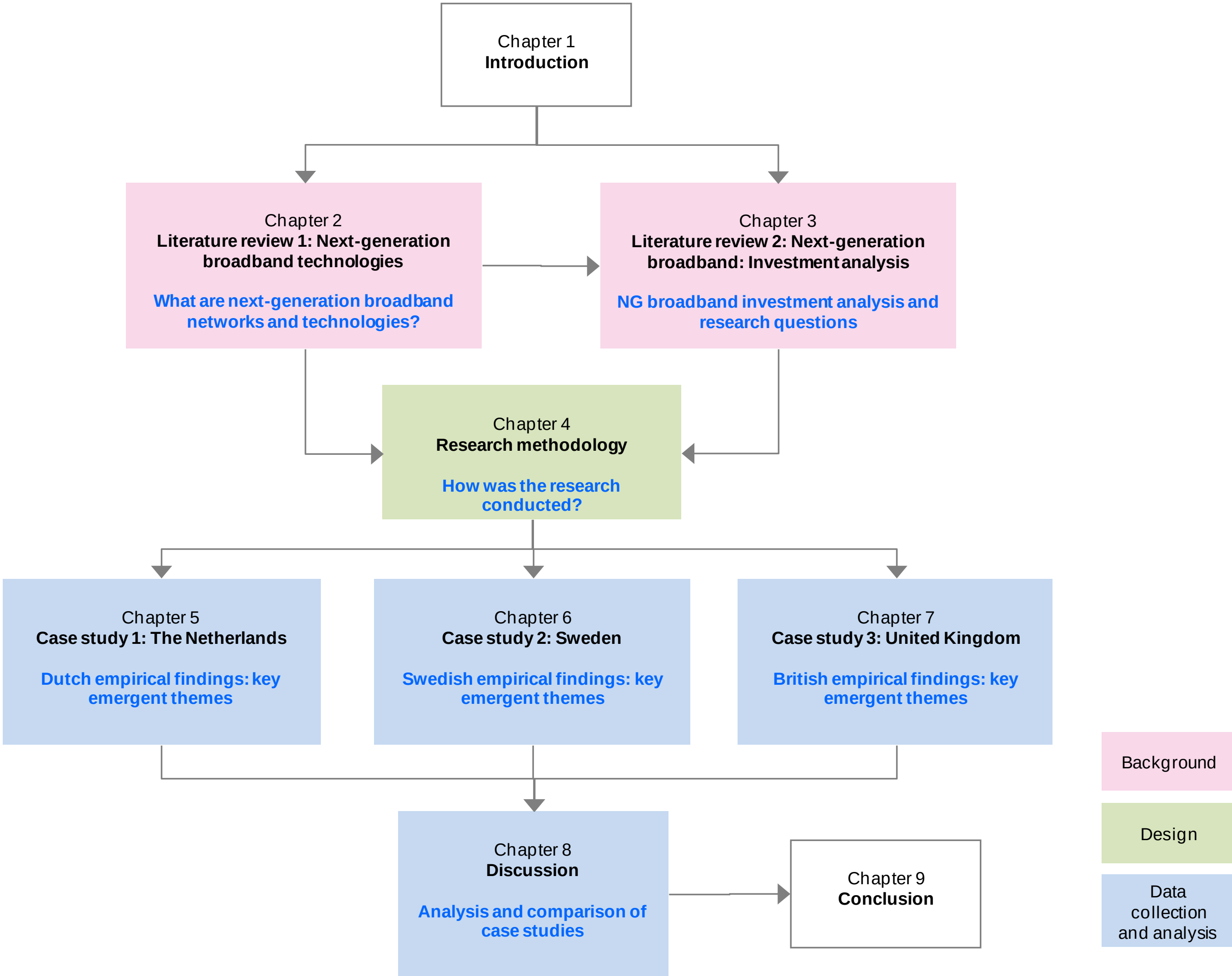

Figure 1-1: Structure of the thesis

Chapters 2 and 3 present the literature review for the study, examining the technical and investment aspects of next-generation broadband networks respectively. Chapter 2 first defines next-generation broadband before proceeding to an assessment of the network technologies. This is necessary not only to understand the differences between next-generation and current-generation broadband networks but also to grasp the investment considerations that are associated with the various technology options.

Chapter 3 shifts the focus of the literature review to an economic one. The chapter explores the relationship between investment decisions and market conditions as presented in existing literature. The information was primarily used, in combination with Chapter 2, to justify the current research. Based on this, the key outputs of Chapter 3 are the research questions and their linkages to one another.

A systematic approach to conducting the research, based on philosophical research paradigms, is necessary in order to produce robust results that can be justified and validated. With this in mind, Chapter 4 develops a conceptual framework for the study, describes the underlying philosophical paradigm and beliefs of the current researcher and their implications on the research design. Data collection and data analysis choices and decisions are also described and explained. In this chapter, screenshots and coding/mapping examples are used to explain how data was analyzed and conclusions drawn.

Chapters 5 to 8 are based on primary data collection and data analysis, complemented by secondary (documented) data, and represent the bulk of the thesis and research. Chapters 5 to 7 describe the three cases studies – The Netherlands, Sweden and the UK respectively. An overview of the respective broadband market at the start of the chapter for each country provides insight into the existing market conditions, thereby laying the foundation for the ensuing market/investment analysis. The status of next-generation broadband in the respective market is then described. An analysis of the data collected from interviews subsequently links these two – the market conditions and the investment in next-generation broadband networks. The results from the analysis are presented on a research question basis in the form of cognitive maps and highlight the salient findings of the interview data for the case under study.

By juxtaposing the findings of Chapters 5 to 7, a comparative assessment of the cases can be undertaken, as is done in Chapter 8. An examination of the answers to the research questions from Chapters 5 to 7 reveals several similarities and differences among the markets from which causal relationships are established and causal maps developed. A combined, high-level model of the causal relationships is also produced and used to highlight, from a more general perspective, the interaction of the market factors in the development of next-generation broadband. Based on the interplay between markets and investment revealed in this chapter, the potential for transferability or sharing of lessons learnt across the three markets is evaluated.

The final chapter of the thesis, Chapter 9, summarizes the context of the research, the key findings and contributions to knowledge, limitations and further work to be undertaken.

2 Next-generation broadband technologies

2.1 Introduction

The dynamics of the telecommunications sector brings with each change more advanced, more efficient and more user-friendly services and applications. From the network operator's perspective, this characterizes the continuous evolution of network architectures and technologies. The new wave of communication in the form of next-generation broadband networks exhibits no difference to this long-standing trend, possessing all the above-mentioned characteristics. NGN and NGA are presenting strong indications that not only will their services and applications be more diverse, more advanced and cheaper, but also that their underlying architectures will be a significant enhancement to those that exist today. Of great significance are the technologies that will be employed within these networks as, even with an improved architecture, such technologies underpin the performance of the network.

The potential 'next-generation technologies' are, in fact, upgrades of technologies that exist today. Having evolved over the past few decades, these technologies have undergone rapid advancements and exhibit tremendous potential in delivering the services and high performance promised by next-generation broadband networks. Each of these technologies possesses unique advantages but also exhibit foreseeable challenges, a comprehensive analysis of which can distinguish one over another as a preferred deployment choice. Operators, therefore, are faced with a technological dilemma in their NGN and NGA decisions.

With these insights, it is the aim of this chapter to focus on the technical features of next-generation broadband networks. The discussion is initiated in Section 2.2, which provides a formal definition of next-generation broadband networks. Section 2.3 describes the functional architecture of next-generation networks, paying particular attention to the improvements over existing networks. Section 2.4 and Section 2.5 discuss core and access technologies respectively. Section 2.6 ends the chapter with a synopsis of the discussions presented throughout.

2.2 What are next-generation networks?

Since discussions about next-generation broadband have been initiated, several industry organizations and working groups[1] have been active in guiding the standardization of and the evolution to these networks. Several descriptions of next-generation broadband networks have been cited within these discussions. Potts (2002, p3), for example, declares that "NGN are intended to be faster, able to support more services, able to support services in a more integrated way, able to support multiple levels of quality of service (QoS), and simpler/cheaper to operate/maintain/manage" as compared to traditional provider networks. The ETSI NGN Starter Group says that "NGN is a concept for defining and deploying networks which, due to their formal separation into different layers and planes and use of open interfaces, offer service providers and operators a platform which can evolve in a step-by-step manner to create, deploy and manage innovate services" (ACIF, 2003, p2).

The most widely used definition of NGN, however, has been proposed by the ITU, who says that "Next Generation Networks (NGN) is a packet-based network able to provide Telecommunication Services to users and able to make use of multiple broadband, QoS-enabled transport technologies and in which service-related functions are independent of the underlying transport-related technologies. It enables unfettered access for users to networks and to competing service providers and services of their choice. It supports generalized mobility which will allow consistent and ubiquitous provision of services to users" (ITU, 2004a, p2). Based on these and other definitions, there is consensus on a technical level that NGN is an Internet Protocol-based network architecture in which service and network layers are decoupled, providing a unified platform over which any service and multiple levels of QoS can be ubiquitously delivered at any time, anywhere to any user, fixed or mobile (see also ITU 2004; Tselikas et al., 2007).

However, many authors also refer to next-generation networks more widely as a 'concept' (EICTA, 2008; ERG, 2008; EURESCOM, 2001; OECD, 2007; Reichl

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[1] Some of working groups for next-generation broadband include the ITU Focus Group on NGN (FGNGN), ITU Study Group 13, the NGN Global Standard Initiative (NGN GSI), ETSI, 3GPP, TMF and OMA.

[2] Several other standardization bodies have also developed functional NGN architecture. For example,

and Ruhle, 2008b). In this context, OECD (2007) suggests that the ‘concept’ is used most commonly to refer to the generation of networks that follow the present-day circuit-switched and mobile networks, while Skouby and Tadayoni (2007, p4) state that it is “a broad concept encompassing the whole development of new network technologies, new access infrastructures and even new services.” This idea of a ‘concept’ hints at the development of both core and access networks.

Reports such as EICTA (2008) and Ofcom (2008) agree that NGN can be defined in this way – as core NGN and access NGN, or NGA. A core NGN refers to “a single, converged fixed network capable of carrying voice, video and data over the same physical network, with IP-MPLS (multi-protocol label switching) as an emerging protocol of choice and all traffic (voice, video and data) carried over IP” (ETP, 2006, p6). NGA is defined generically as “broadband access services capable of delivering sustained bandwidths significantly in excess of those currently widely available using existing local access infrastructures and technologies” (Ofcom, 2006b, p10). This implies downstream data rates in excess of 20 Mbps (Walker et al., 2008).

This idea of core NGN and NGA networks is adopted in this thesis. NGN is considered to be IP-based broadband networks characterized by the delivery of voice, video and data services over a single platform, in which service-related functions are independent of transport technologies and which can provide ubiquitous service and multiple levels of QoS to end-users. NGA is viewed as defined in the preceding paragraph by Ofcom (2006b). The technical features of these networks are described in the following section.

2.3 Functional architecture and features

The definition of NGN provided in Section 2.2 summarizes the key attributes of the network. This section will explore the architectural foundation and features of NGN, explaining the underlying structure and how it facilitates its defining capabilities. Although the discussions focus on the core network, its relation to the access network is described at the end of the section.

The functional architecture of NGN was proposed by the ITU[2]. Specifications for this architecture now exist in ITU Recommendations Y.2011 and Y.2012 as Release 1. This architecture is illustrated in Figure 2-1.

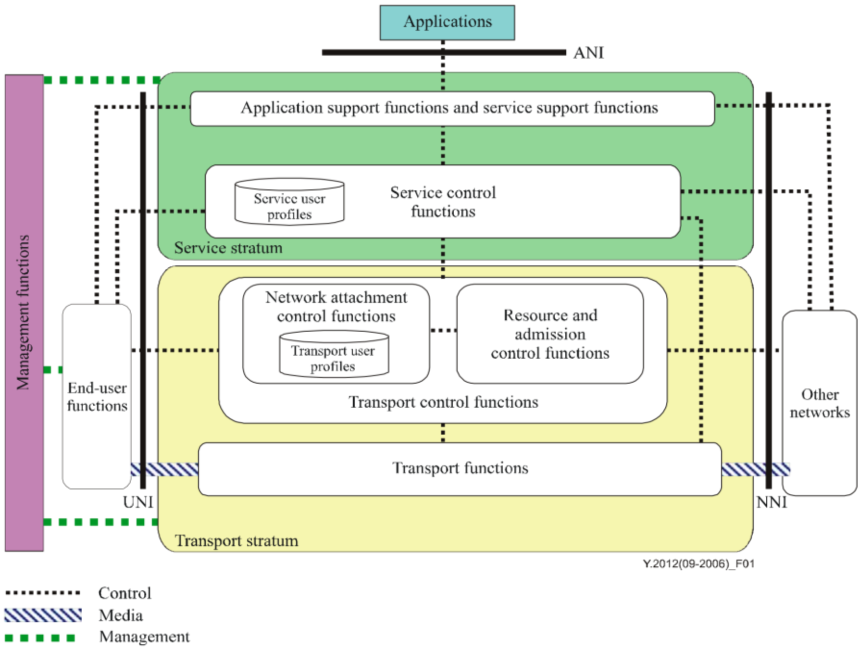

Figure 2-1: ITU NGN functional architecture
Source: ITU, 2004b

A key feature of the NGN is its packet-based operation. Since any type of traffic can be transported over the network in the form of packets, NGN represents a converged or integrated network (OECD, 2004; OECD, 2007). Therefore, issues that exist in the Public Switched Telephone Network (PSTN) with the delivery of services over different networks are resolved in the NGN architecture. In addition, because of the packet-based transfer, the available capacity is utilized more efficiently as dedicated links are not required for individual communication sessions, as with the PSTN.

Perhaps the most significant characteristic of the NGN functional architecture is the separation of services and transport-related functions. As Figure 2-1 illustrates, transport functions are contained within the transport stratum (which represents the

[2] Several other standardization bodies have also developed functional NGN architecture. For example, 3GPP has established an IMS architecture and ETSI an R1 TISPAN architecture. However, the ITU's model forms the basis of each of these and is the most widely used. Therefore, only this architecture will be discussed in this chapter.

core of the NGN) and service-related functions within a separate service stratum. This uncoupling of services and transport enables applications and transport technologies to be offered independently of each other, as applications can be defined directly at the service level and transported over any platform (OECD, 2007).

As a result of this separation between service and transport, services and applications can be easily incorporated within the network. This is achieved via open interfaces. A critical component, open interfaces allow service providers, third party programmers and end-users to incorporate and deliver applications without the intervention of network operators. Therefore, issues of delayed, unavailable or unequal access are mitigated if not completely removed. In addition, the separation of the service control functions from the transport functions allows carriers to select the best transport elements separately from the best control software (Telcordia, 2008). Finally, services and technologies can be independently modified. This open architecture of NGN, therefore, paves the way for the seamless introduction of new services, increased competition and innovation. In turn, a deregulated market can emerge.

The ITU (2004b) claims that any transport technology can be deployed within the transport layer. Therefore, Connection-Oriented Circuit-Switched (CO-CS), Connection-Oriented Packet-Switched (CO-PS) or Connectionless Packet-Switched (CLPS) technologies can be implemented. However, IP is cited as the most suitable technology for use as it can deliver NGN services as well as support legacy ones (ITU, 2004b).

As previously explained, the NGN architecture is characterized by network interfaces, shown in Figure 2-1 and Figure 2-2. An important feature of NGN is its ability to interwork with legacy devices and networks via these open interfaces (ITU, 2006). NGN can, for example, interconnect with the PSTN. NGN achieves this by the inclusion of a PSTN/ISDN (Integrated Services Data Network) emulation service component within the service layer, as shown in Figure 2-3 by the blue circle, and by the use of border gateways. The PSTN/ISDN component supports legacy devices that are connected to an IP network via a gateway. It provides PSTN/ISDN service capabilities in a seamless manner by mimicking the service over the IP network

(ITU, 2006), making the user oblivious to the lack of a physical connection to the PSTN/ISDN. Border gateways are used to interconnect legacy networks at both the service and transport layers and may include (media) transcoding and adaptation operations for successful interconnection (ITU, 2006).

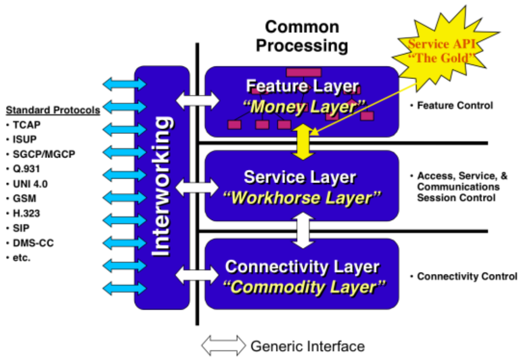

Figure 2-2: The layered architecture of NGN control
Source: Telcordia, 2008

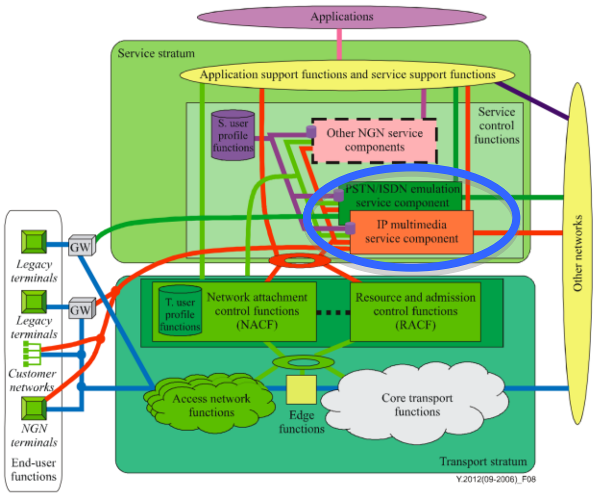

Figure 2-3: NGN functional components
ITU, 2006

NGN also facilitates the convergence of fixed and mobile services. This is achieved by the use of the IP Multimedia Subsystem (IMS), shown in Figure 2-3 as part of the service layer. According to ETSI (2006), IMS is an open systems architecture that enables a mix of services (voice, video and data - multimedia) over IP-based networks using any access technology - fixed or mobile.

Figure 2-4 provides an overall picture of this application. With this facility, end-users can have access anywhere at any time over any type of network, without knowing that there might have been a change in the type of access network, for example. In conjunction with functions within the control layers, the implementation of IP based global roaming, and the use of location-aware communications and enhanced devices, NGN can achieve generalized mobility and ubiquitous service (ITU, 2004; OECD, 2004; OECD, 2007).

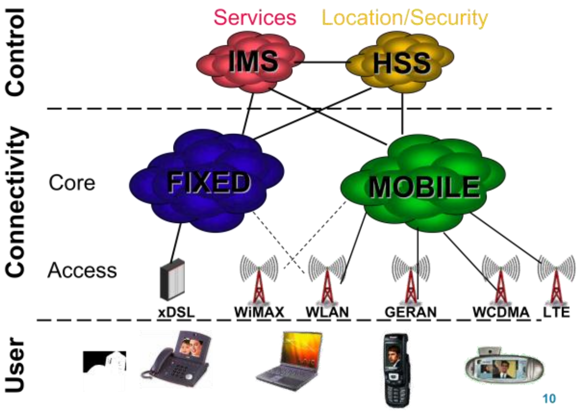

Figure 2-4: The application of IMS within NGN
Source: ETSI, 2006

Finally, by utilizing upgraded technologies and protocols, NGN facilitates secure, broadband capabilities and end-to-end QoS provisions. For example, both IPv6 and MPLS can be integrated within the network, providing the benefits as discussed in Section 2.4.1 and Section 2.4.2 respectively. The application of these technologies within NGN will be described in more detail in Section 2.4.

The overall architecture can be segmented into core and access networks. ITU (2006) indicates that the core network is that part that provides the telecommunications services or multimedia services to the end-user, sharing its functions among different access networks. The access network is the segment that connects the end-user to the core network, thus providing transport services directly to the user (ITU, 2006). This configuration of core and access networks is illustrated in Figure 2-5 that follows.

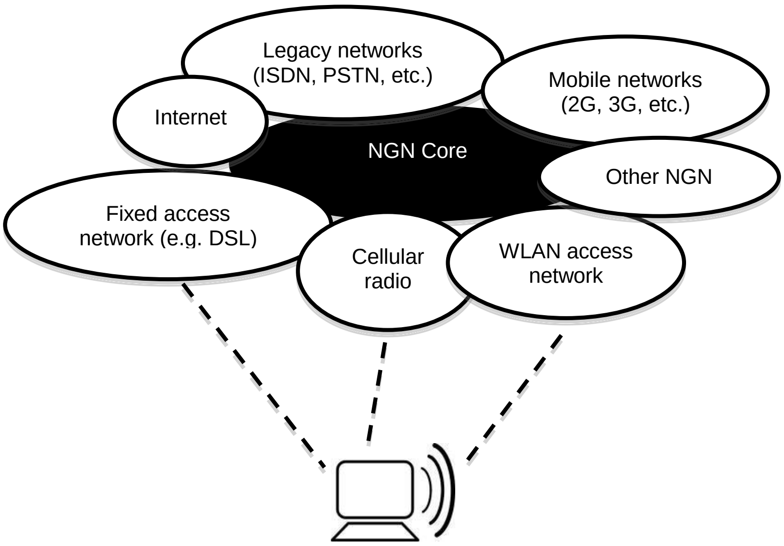

Figure 2-5: NGN core and access networks
Source: Adapted from ITU, 2006

The NGN architecture, from the discussions presented above, clearly exhibits significant improvements to the telecommunications networks that exist today. The transition to packet-based communication using IP opens many avenues for new applications and services with QoS guarantees. The decoupling of the transport and service layers and the existence of open interfaces encourage sustainable competition and innovation, as third party providers can easily deliver their applications with no quality and service discrimination. By incorporating IMS, fixed-mobile convergence (FMC) and generalized mobility can be effectively realized. In conjunction with next-generation broadband access capabilities, such ubiquitous access to services will greatly enhance the experience for consumers. As such, the NGN functional architecture demonstrates significant potential for meeting the growing demands of the current telecommunications industry.

2.4 Next-generation core technologies

Core NGN technologies are those that are deployed within the NGN transport layer to produce a single, packet-based network that enables the transport and delivery of any type of traffic. While the ITU Recommendation Y.2011 defines the NGN transport layer as being able to support “any and all types of network technologies” (ITU, 2004b, p6), they declare that IP is the preferred technology for core NGN deployment. However, in order to guarantee QoS, ITU (2007a) proclaim the use of MPLS together with IP within the core. In addition to IP and MPLS, the NGN backbone employs a high-capacity network. Typically, an optical fibre network is deployed to facilitate the high capacity requirement and to achieve a reliable and robust foundation. These three technologies are discussed in the following sub-sections.

2.4.1 Internet Protocol

IP was developed by the Internet Engineering Task Force (IETF) in 1981 (IETF, 1981). Developed and deployed as IP version 4 (IPv4), this protocol facilitates the delivery of data, in the form of datagrams[3], over interconnected networks or internets that utilize packet-switching technology (IETF, 1981). As such, it has been most widely implemented within the Internet and exists as a network layer protocol in the TCP/IP (Transmission Control Protocol/Internet Protocol) protocol suite, the basic Internet reference model (Figure 2-6) (Cisco, 2002; IETF, 1981).

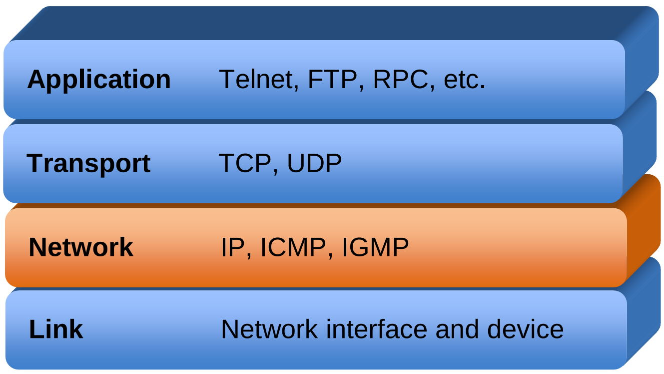

Figure 2-6: The TCP/IP protocol stack

The underlying packet-switching technology of IP allows a single message to be segmented into several packets and transported through the network individually. Thus, each packet can traverse a different route from its source to its destination, requiring no dedicated link between the sender and receiver for a given

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[3] A datagram, according to the IETF, is a "self-contained, independent entity of data carrying sufficient information to be routed from the source to the destination computer without reliance on earlier exchanges between this source and destination computer and the transporting network" (IETF, 1994). IP is, therefore, described as a connectionless (Cisco, 2002) or stateless (IETF, 1981) protocol.

communication session. Unlike the PSTN that implements circuit-switching and requires a single, devoted physical link for each message transfer, resources within a packet-switched network can be shared. For example, packets that belong to different messages can be routed on the same link once the link is available. With circuit-switching, even if the link is free at a given point in time no other message than the one for which it was established can be transmitted along it. As a result of this dynamic packet transfer and the use of datagrams, addressing is a key role for IP, whereby address information must be included within each individual datagram. The address information is used by each router to forward the packet to its next destination.

In late 1990, work began on an enhanced version of IPv4 (IETF, 1995). This new protocol, IPv6 or IP next generation (IPng), adopts the same basic functionality of IPv4 but improves on some of the critical shortcomings of its predecessor linked to addressing, security and QoS, for example (Hinden, 2005; IETF, 1995).

In summary, being a network layer protocol, IP is responsible for routing a message through an interconnected network by packaging the message into a datagram, addressing and transmitting it to the next layer within the protocol stack (Cisco, 2002). IP, however, was not designed perform error control or retransmissions, sequencing, QoS checks, end-to-end reliability or flow control on packets (IETF, 1981). Finally, because of the packet-based nature of IP communication, network resources can be shared, providing a major advantage of this type of communication – greater efficiency and flexibility.

2.4.2 Multi-Protocol Label Switching

MPLS is a standard developed by the IETF to increase the efficacy of packet routing through large networks that utilize a connectionless protocol. While it is most widely used with IP, it is a multi-protocol technique, as its name suggests. It can also be implemented with Asynchronous Transfer Mode (ATM), for example (IEC, 2008a). As a result of the benefits it can bring to an IP-based core network, MPLS is considered to be a key technology for discussion in this chapter.

The functionality of MPLS is based on its ability to add routing information to IP packets and to build virtual circuits (VCs) called Labeled Switched Paths (LSPs) across a packet-based network (Sheldon, 2001). The added information, in the form of a Layer 2 label, contains an index that exists within a forwarding table. This table specifies the path for the packet (its 'next hops') through the network. The label, therefore, effectively indicates the pre-established LSP over which the packet must traverse. Thus, the packet is scrutinized once on entry to the MPLS-based network where its LSP is determined and automatically switched at each successive router, which are now no longer required to perform next-hop or routing calculations (Sheldon, 2001). Figure 2-7 depicts the operation of MPLS.

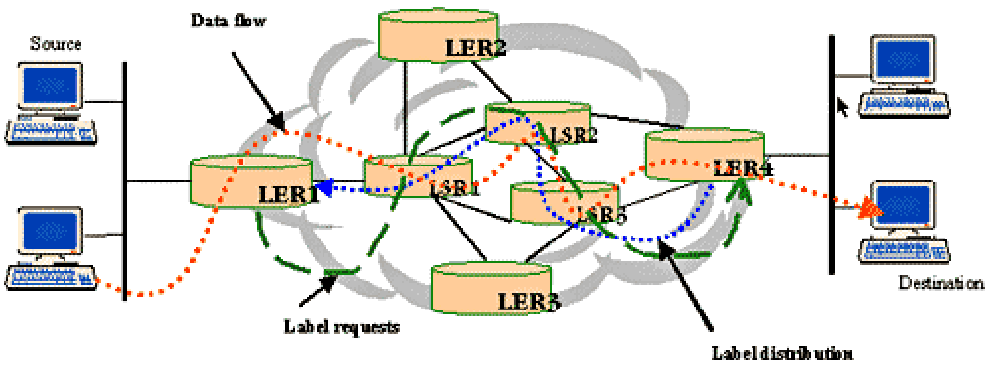

Figure 2-7: MPLS operation
Source: IEC, 2008a

In addition to having a single point of examination, when the packet is labeled the hardware with which the packet interfaces can be coded or programmed to ensure certain levels of bandwidth, delay and congestion control and guarantees (IEC, 2008a). These parameters can then be monitored by the hardware throughout the packet's network life cycle. Alternatively, the packet route can be set manually, whereby network engineers pre-define the path based on traffic type, for example.

In general, MPLS facilitates the delivery of the quality of service that is required with real-time applications, voice and video. It provides traffic engineering capabilities and therefore allows data or packets to be prioritized based on QoS or even the type of customers to which they are associated (premium customers, for example, can have their data transported on a higher capacity link). By amalgamating Layer 2 switching and Layer 3 routing capabilities, MPLS allows advanced scalability in its switching mechanism (IEC, 2008a). These features overcome the limitations imposed by the use of IP on its own to deliver high quality information over a large network.

2.4.3 Optical core networks

Advancements in optical fibre technology coupled with the growing demand for increased capacity in telecommunications networks have led to the development of optical networks. Alcatel and IEC (1998) define optical networks as "high-capacity telecommunication networks based on optical technologies and components that provide routing, grooming and restoration at the wavelength level as well as wavelength-based services." In essence, these networks implement an optical layer within the core transport network (Alcatel and IEC, 1998), with fibre being used as the transmission medium.

In its conventional deployment, optical networks have conformed to the Synchronous Optical Network (SONET) standard. Stallings (2003) and Bellamy (2000) define SONET as an optical transmission interface used to connect fibre systems. The ITU later developed an international version of the standard known as Synchronous Digital Hierarchy (SDH). The primary aims of SONET (or SDH) are to define and standardize a multiplexing format (to exploit the high capacities of fibre cables) and to develop an optical signal specification so that equipment from different manufacturers can be interconnected (Bellamy, 2000)[4]. Table 2-1 indicates the data rates achieved by multiplexing optical signals using the SONET standard.

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[4] SONET/SDH was developed to address many more issues but the ones discussed in this chapter are those that are relevant to this study. A more detailed list of issues can be found in Bellamy (2000).

Optical signal	SONET signal	ITU designation	Data rate (Mbps)
OC-1	STS-1		51.84
OC-3	STS-3	STM-1	155.52
OC-12	STS-12	STM-4	622.08
OC-24	STS-24	STM-8	1244.16
OC-48	STS-48	STM-16	2488.32
OC-96	STS-96	STM-32	4976.64
OC-192	STS-192	STM-64	9953.28

Table 2-1: SONET standards
Source: Bellamy, 2000

However, optical core networks are more commonly adopting a Wavelength Division Multiplexing (WDM) mechanism as it provides greater efficiency and higher capacities. Nortel (2003) defines WDM as a "technology used to expand fibre optic bandwidth by enabling signals from different sources to independently travel together on a single optical fibre", as Figure 2-8 depicts.

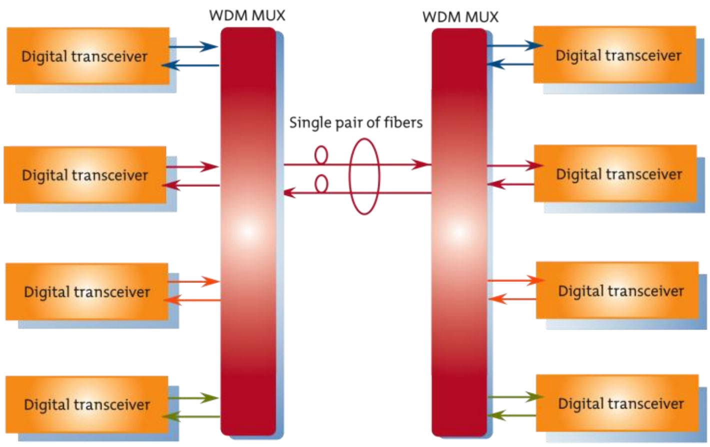

Figure 2-8: WDM
Source: Nortel, 2003

WDM operates on the principle that optical signals can be transported on different wavelengths of light within the fibre cable (Nortel, 2003). By transmitting optical signals on different light wavelengths, or channels, each channel appears to be transmitted along its own optical fibre. In addition, in digital WDM, the different channels are multiplexed and demultiplexed individually at the transmitter and receiver respectively, enabling different digital formats (such as SONET and ATM) with differing bit rates to be transmitted along the same fibre (Nortel, 2003). This is illustrated in Figure 2-9. The advantage is reduced costs that result from eliminating the need to convert data into special digital formats for transmission.

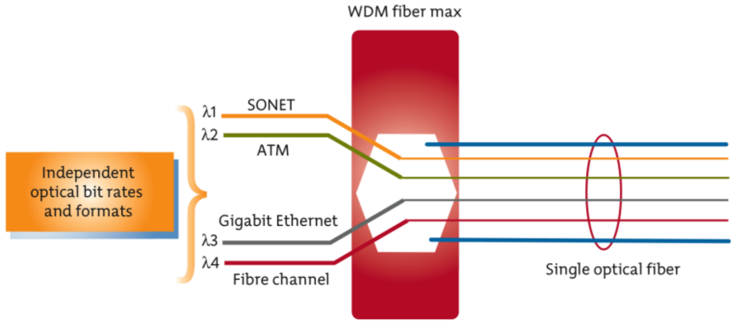

Figure 2-9: Bit rate and protocol independent fibre optical access with WDM
Source: Nortel, 2003

Dense WDM (DWDM) is a form of WDM that enables even more optical signals to be transmitted on a single optical fibre cable. The underlying principle of DWDM is that narrow channel spacing is utilized, allowing more channels to fit within a given bandwidth. DWDM systems typically implement channel spacings of 200 GHz, 100 GHz, 50 Hz or less (Nortel, 2003) and can achieve core network capacities up to many hundreds of gigabits per second (THUS, 2008). For example, the IEC (2008b) has indicated that some DWDM terminals can transmit up to 80 wavelengths of OC–48, resulting in 200 Gbps, or up to 40 wavelengths of OC–192, enabling 400 Gbps.

Optical amplifiers are a key component in realizing this property of DWDM networks. The optical amplifiers allow signals to be boosted without the need to convert them to electrical form (IEC, 2008b), enabling signals to travel longer distances. Optical amplifiers can boost up to 100 wavelengths of light (IEC, 2008b). As these discussions show, optical core networks exhibit many desirable properties that are well suited to the increasing demands on capacity and multiservice delivery that are characteristic of today's telecommunications industry.

2.5 Next-generation access technologies

In light of Ofcom's (2006b) definition, NGA can be achieved by a variety of access technologies – digital subscriber line (DSL), cable, optical fibre, wireless or mobile technologies - or a combination of these as required. This section describes the technologies and their deployment options.

2.5.1 Digital Subscriber Line

Cisco (1999) defines DSL technology as a "modem technology that uses existing twisted-pair telephone lines to transport high-bandwidth data, such as multimedia and voice, to service subscribers". In essence, DSL is a technology that achieves a greater capacity over traditional copper lines by using the extra bandwidth within the lines that the Plain Old Telephone Service (POTS) does not use. In doing so, it can deliver both voice and data traffic over the copper lines at broadband speeds.

DSL exploits the capability of copper to handle up to several million Hertz and to transmit digital signals. By transmitting data in a digital format, DSL increases the capacity on the copper line over which service providers can transfer information. Alternatively, DSL can allow both voice and data to be transmitted at the same time, with voice being sent over low frequencies (0-3,400 Hz) and data occupying the higher frequencies. Either way, the data rates that can be realized are significantly increased, as Table 2-2 indicates.

DSL technology	Speeds		Connection type
	Upstream	Downstream	
ADSL	64 kbps to 1.54 kbps	256 kbps to 9 Mbps	Asymmetric
ADSL Lite/G.lite	512 kbps	Up to 1.5 Mbps	Asymmetric
ADSL2+	3 Mbps	24 Mbps	Asymmetric
R-ADSL	Same as ADSL but can be varied as required	Same as ADSL but can be varied as required	Asymmetric
IDSL	Up to 144 kbps	Up to 144 kbps	
SDSL	1.5 Mbps	1.5 Mbps	Symmetric
HDSL	1.544 Mbps or 2.048 Mbps	1.544 Mbps or 2.048 Mbps	Symmetric
VDSL	1.5 to 2.3 Mbps	13 to 52 Mbps	Both
VDSL2	Up to 100 Mbps	Up to 100 Mbps	Both

Table 2-2: Properties of DSL technologies

A suite of DSL technologies has evolved over the years, also shown in Table 2-2. Variations to these DSL flavours also exist. Despite the variety, all DSL technologies can deliver dedicated and point-to-point configurations and are designed for use over copper wires (Cisco, 2008a). Their differences exist primarily in respect of their speed capabilities and the type of connection they realize (that is, asymmetric or symmetric). Although the more advanced DSL technologies offer higher speeds, this is only possible over shorter lengths of copper. Furthermore, the actual speeds vary with the length of the copper wire over which the technology is employed. The values in Table 2-2 are, therefore, only indicative.

DSL can be used in several configurations within the next-generation access network. For example, asymmetric DSL (ADSL) or ADSL2+ can be used over existing copper lines from the local exchange to the subscriber premises, as they are the DSL technologies with the furthest coverage in terms of distance. As mentioned earlier, the performance of the DSL network is greatly dependent on the length of the local loop. As an indication, Point Topic in BSG (2008) observes that, based on the lengths of the local loops installed in the UK, 40% of users will have faster access with ADSL2+ than they can with ADSL, but less than 10% will receive next-generation access (that is, greater than 20 Mbps) and only with ADSL2+. Figure 2-10 highlights this result.

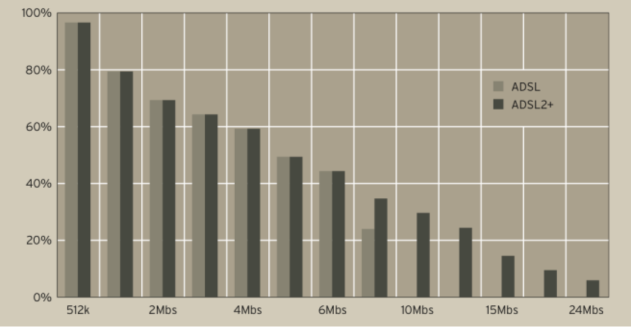

Figure 2-10: Availability of ADSL and ADSL2+ in the UK
Source: BSG, 2008

DSL and Optical Fibre

DSL can also be used in hybrid deployments with optical fibre. As discussed in the following section, fibre topologies such as fibre-to-the-building (FTTB), fibre-to-the-curb (FTTCurb) and fibre-to-the-node (FTTN) require a final connection from its point of termination to the end-user. Once more, the use of DSL in any of these scenarios is largely dependent on the distance to be covered. For example, since FTTB requires a short run of cable to the end-user, very high-speed DSL, VDSL2, can be used. VDSL2 facilitates speeds up to 100 Mbps over a distance of less than 500m and 50Mbps at 1km (ITU, 2007a). This surpasses the NGA data rate requirement and can, therefore, adequately deliver interactive, high-capacity, multimedia services such as IP television (IPTV).

Both FTTCurb and FTTN can be implemented with VDSL as their complementary technology. This DSL variant enables speeds of 12 Mbps up to a distance of 1500m, 26 Mbps up to 1000m and 52 Mbps up to 300m (BSG, 2008). Therefore, VDSL over a copper line 1000m or less in length will deliver next-generation broadband access. Alternatively, nodes can be located closer to the end-user, but the associated cost may hinder operators from doing so.

The considerations in deploying a hybrid fibre access network with DSL, other than distance, are costs and infrastructure or space availability. In the first instance, the longer the fibre run, the greater the cost of deployment but the better the performance of the overall access network as losses, for example, decrease. Secondly, the use of DSL requires dedicated equipment to be installed. Therefore, new equipment and space may be required within the building (in FTTB), at the curb location (in FTTCurb) or within the cabinet (in FTTN).

2.5.2 Optical fibre

As Section 2.4.3 highlighted, with the increasing desire for faster data transmission, telecommunications engineers have broadened their focus from traditional copper lines to exploiting the characteristics of optical fibre. Optical fibre cables are glass or plastic cables that transmit information through their cores in the form of light pulses. With core diameters of 8-10μm (single-mode fibres) and 50-62.5μm (multimode fibres) and claddings of 125μm and 245μm (IEC, 2008c), these cables not only provide greater data transmission speeds but increase the convenience of installation, as smaller ducts and housing are required. Due to their ability to transmit data in the form of light pulses rather than electrical signals (as is done along a copper wire), optical fibres impose lower attenuation on their signals over long distances (up to 100km or 60 miles without amplifiers) (IEC, 2008c), and achieve transmission speeds of 100 Mbps or more (Parliamentary Office of Science and Technology, 2008).

With these technical advantages, optical fibre is one of the most potential candidates for a next-generation access network implementation. Various access topologies can be realized. For example, fibre can be installed on its own (100 % fibre in the access network) or as a hybrid solution with copper, coaxial cable, wireless or mobile technologies. While fibre has been used within core telecommunication networks in previous times, this use of fibre in the access network is a fairly new development. The various topologies for fibre access deployment are now discussed.

Pure optical fibre topologies

Pure optical fibre deployments use fibre from the local exchange to the end-user and are an attractive option for NGA because of the high speeds achievable and the robust nature of the optical cable. BSG (2008) deems it the "ultimate next generation broadband solution." Two possibilities exist, each of which is discussed below.

Point-to-point (PTP) fibre-to-the-home (FTTH)

Figure 2-11 illustrates the first of the pure fibre topologies, a PTP FTTH arrangement. This configuration serves each customer with a direct fibre link from the local exchange to the customer's home (Kunigonis, 2008) so there is no capacity sharing among customers.

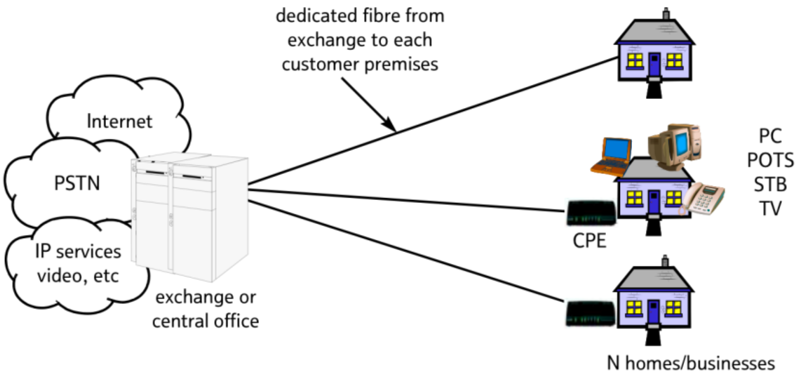

Figure 2-11: PTP FTTH deployment
Source: IEC, 2008c

As PTP FTTH utilizes a direct fibre link to each customer, the potential for the maximum capacity capabilities of fibre (that is, unrestricted capacity) to be realized exists. In practice, however, a limit is imposed by the transmitters that are used within the Optical Line Terminal (OLT)[5], providing capacities between 10 and 100 Mbps (Kunigonis, 2008). In addition to PTP FTTH being the simplest network to design and implement, it is the most flexible and future-proof fibre access deployment option (BSG, 2008).

The costs associated with the deployment of PTP FTTH networks, however, are discouraging, unless deployment is within a densely populated area or an area that is newly being developed (BSG, 2008). Research by Enders Analysis cited by BSG (2008) reveals that the cost of deploying PTP FTTH, for example, to 90% of UK households is approximately €14 billion, or €1000 per household (incremental cost). When compared to the incremental cost per household using ADSL2+, as shown in Table 2-3, the option of PTP FTTH becomes an economically unreasonable one.

Technology	Incremental cost per household in UK (€)	Cost to deploy to 90% households in UK (€)
ADSL2+	60	
FTTC	300	
FTTH	1000	14 bn

Table 2-3: Deployment costs for fibre and DSL
Source: BSG, 2008

FTTH Passive Optical Network (PON)

The alternative to PTP FTTH for achieving NGA with pure fibre is PON. The BSG (2008) defines a PON as a fibre optic network in which a single strand of fibre is brought from the local exchange to a splitter where it is divided amongst several end-users. Like the PTP FTTH architecture, PONs connect users with fibre all the way to their local exchange. Unlike the PTP FTTH system, however, customers are not allocated a dedicated link but instead share the capacity of the fibre. Figure 2-12, adopted from IEC (2008c), illustrates the configuration of a PON.

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[5] The OLT, which is usually housed in the CO or in a remote terminal, contains the laser transmitters for each user and collects all incoming traffic (voice, video and data) (Kunigonis, 2008).

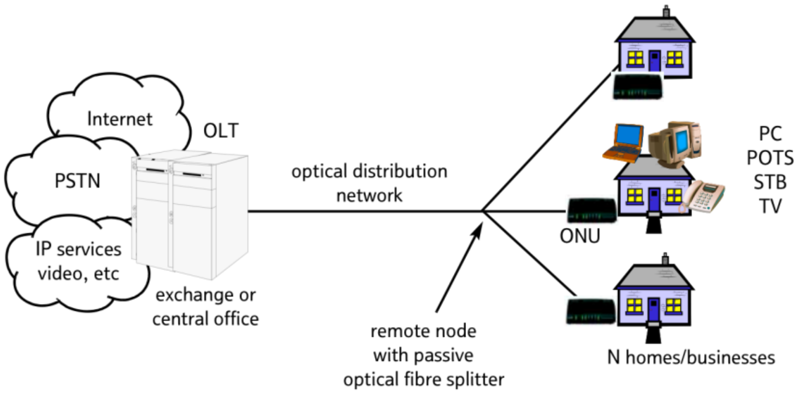

Figure 2-12: PON configuration
Source: IEC, 2008c

In addition to the OLT and Optical Network Unit (ONU)[6] components typical with a PTP FTTH network, the PON comprises a passive optical splitter that can be located anywhere within the access network (Kunigonis, 2008). The optical splitter can divide the fibre strand into 64, 32, 16, 8, 4 or 2 cores (1x64, 1x32, 1x16, 1x8, 1x4, 1x2 splitters respectively), as required (Kunigonis, 2008; ITU, 2007a). Typically, divisions of 16, 32 and 64 are performed.

The technical capabilities of PONs are dependent, in part, on the splitter and multiplexing techniques used. By their very action, splitters introduce losses into the system. Given that the PON uses passive elements, power considerations are significant. Therefore, the level of splitting used must ensure that the power budget is met. Typically, PONs can reach customers up to 20km from the transmitter (Kunigonis, 2008; ITU, 2007a).

Like DSL, variants of PON exist. Two classes of PONs can be identified - Time Division Multiple Access PONs (TDMA PONs) and Wavelength Division Multiplexed PONs (WDM PONs) (Davey et al., 2006). TDMA PONs employ optical splitters that divide the capacity of the fibre in the time domain. Customers have access to all of the capacity but for only a given period of time. ITU Broadband PON (BPON), IEEE Ethernet PON (EPON) and ITU Gigabit PON (GPON) are TDMA PONs. With EPON, up to 16 end-users can be served by a single strand of fibre, sharing a capacity of 1 Gbps (ITU, 2007a). With GPON, up to 128 users can be

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[6] The ONU, located at the subscriber's end, is responsible for converting the signals received from the OLT into a form that the subscriber's devices can utilize. In addition, it sends IP traffic back to the OLT in order to enable web access and voice traffic exchange (Kunigonis, 2008).

served with capacities up to 2.488 Gbps being possible. Other characteristics of the TDMA PONs are summarized in Table 2-4. The data shows that high capacities are achievable in the access network with TDMA PONs, even though capacity is shared among end-users.

	BPON (evolved from ATM PON)	EPON	GPON (evolved from BPON)
Standard	ITU G.983	IEEE 802.3ah	ITU G.984
Bandwidth	Downstream up to 622 Mbps; Upstream 155 Mbps	Up to 1.25 Gbps symmetric; With GePON up to 2.5 Gbps shared capacity	Downstream up to 2.5 Gbps; Upstream 2.5 Gbps
Downstream λ (nm)	1490 and 1550	1550	1490 and 1550
Upstream λ (nm)	1310	1310	1310
Transmission	ATM	Ethernet	ATM, Ethernet, TDM

Table 2-4: Characteristics of TDMA PONs
Source: Adapted from Kunigonis, 2008

Different to TDM PONs, WDM PONs enable capacity sharing on a wavelength basis. The Long-Reach PON (LR-PON) is one such example. This is defined as a PON that uses advanced optical amplifiers and exploits WDM mechanisms to extend the reach of traditional PONs from 10-20 km to at least 100 km (Song et al., 2007). As LR-PON is still fairly new and has not been implemented in NGA networks to date, it will not be further discussed in this thesis.

Hybrid optical fibre topologies

Fibre-to-the-Building

FTTB takes the optical fibre from the local exchange into the building that is being served. Each user within the building is then connected via another access technology, as shown in Figure 2-13. In this deployment, the fibre is terminated by a remote terminal (RT) located in a communications or utility room within the building. Various access technologies can be used to serve users within the building. For example, an Ethernet LAN (Local Area Network) or DSL can be used. With the former, capacities of 10 or 100 Mbps can be achieved (Kunigonis, 2008). If DSL is used over copper lines, up to 100 Mbps can be realized. Typical FTTB capacities are currently in the range of 10 Mbps (Kunigonis, 2008).

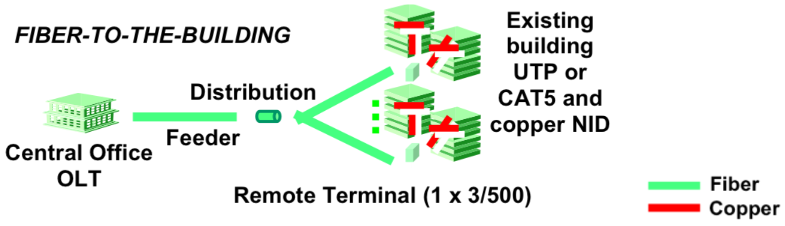

Figure 2-13: FTTB configuration
Source: Kunigonis, 2008

Fibre-to-the-Curb

Figure 2-14 highlights a typical FTTCurb deployment. FTTCurb uses fibre from the local exchange to a curb located near a group of customers to be served. For example, the curb can be near a group of houses or buildings. Thus, the fibre terminates further away from the subscriber than in FTTB. The typical distance with FTTCurb is 500 to 1,000 feet from the end-user (Kunigonis, 2008). Again, the fibre run terminates at an RT that is housed at the curb. This configuration is usually used to serve eight to twelve customers (Kunigonis, 2008).

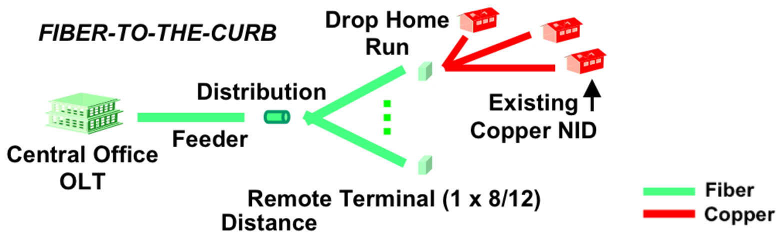

Figure 2-14: FTTCurb configuration
Source: Kunigonis, 2008

Fibre-to-the-Node or Fibre-to-the Cabinet (FTTC)

As suggested by its name, FTTN or FTTC deploys fibre from the local exchange to the telecommunications cabinet within a neighbourhood, usually up to 5,000 feet from the end-user. This mode generally serves consumers in the range of 300-500 in number (Kunigonis, 2008). This is the hybrid option that deploys fibre furthest away from the end-user (Figure 2-15).

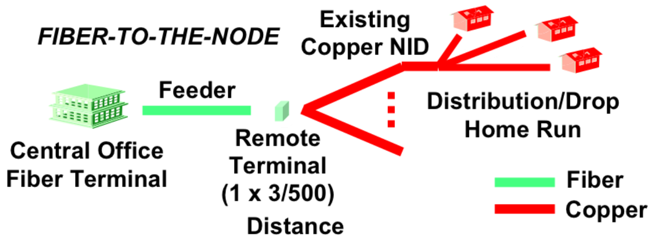

Figure 2-15: FTTN configuration
Source: Kunigonis, 2008

In FTTB, FTTCurb and FTTN, copper lines, cable TV, wireless or mobile access is implemented from the point of fibre termination to the end-user. Generally, if existing copper lines are utilized, they are enhanced by DSL technology. However, because of their degradation in performance as distance increases, it is essential that the type of DSL used be suitable for the distance to be covered, as explained in Section 2.5.1. For example, VDSL2 is recommended for use with FTTB or FTTCurb (ITU, 2007a), but will not perform well in FTTN networks where the distance between the fibre termination and the end-user is greater. Therefore, the performance of these hybrid networks as experienced by the user is dependent on the technology deployed to their location.

Optical fibre and wireless

The combination of optical fibre and a wireless technology can also deliver next-generation access. In this configuration of NGA, the subscriber's service will be determined by the performance of the wireless technology, which can be Wireless Fidelity (WiFi) or Worldwide Interoperability for Microwave Access (WiMAX), discussed later on. WiFi offers a maximum of 54 Mbps and WiMAX has a 40 Mbps capability. For short distances between the optical fibre termination point and the end-users, WiFi can be used. Thus, this is suitable for use with FTTB. WiMAX can be used with FTTCurb or FTTN, depending on the distance of the curb or cabinet.

2.5.3 Cable

Coaxial cable has traditionally been deployed by cable television operators to provide television services to end-users. This communication link is now being exploited, in combination with optical fibre, to provide broadband access to voice services (ITU, 2007a). The combination, hybrid fibre coax (HFC), enables bidirectional high-speed data access to subscribers (Cisco, 2008b). In this deployment, optical fibre is used for transmission from the head-end or central office of the cable TV operator to an optical node (IEC, 2008d). Coaxial cable is used to complete the transmission from the optical node to the end-user. Figure 2-16 shows the configuration.

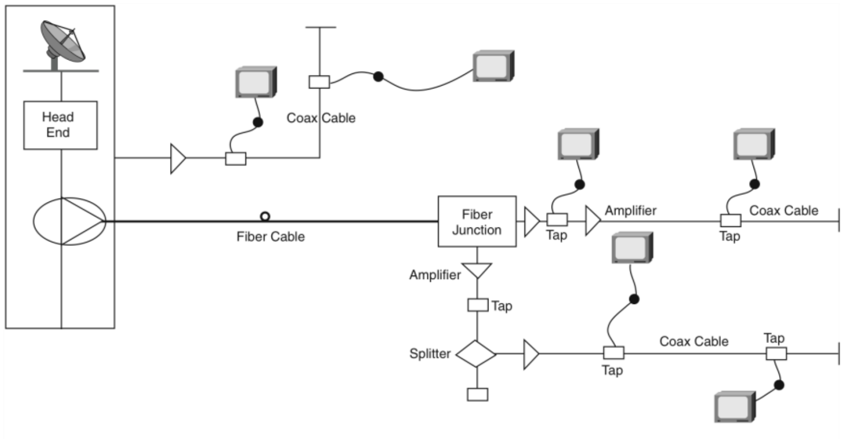

Figure 2-16: The configuration of a HFC network
Source: Cisco, 2008c

In a cable TV network, a cable modem termination system (CMTS) is used to perform the conversion of digital signals to and from radio-frequency signals for multiple subscribers (CableLabs, 2008). In order to achieve the multi-service transmission of voice, video and data in a HFC network, cable modems based on the Data Over Cable Service Interface Specifications (DOCSIS) are required (CableLabs, 2008). In addition, PacketCable architecture is implemented. This is a broadband architecture that supports the transmission of voice, video and data from users using several cable networks (Cable Television Laboratories, 2005). Figure 2-17 shows both the PacketCable segment and how the HFC network is configured with DOCSIS.

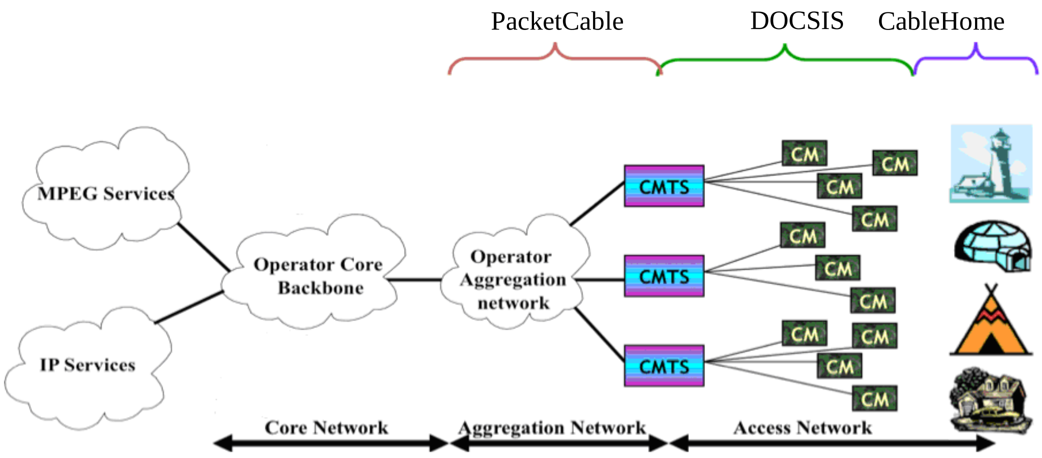

Figure 2-17: Cable architecture
Source: CableLabs, 2005

DOCSIS 2.0 can facilitate 20-50 Mbps downstream and up to 30 Mbps upstream (BSG, 2008). Its upgrade, DOCSIS 3.0 provides hundreds of megabytes and even gigabits per second data rates for cable operators (CableLabs, 2008). However, these speeds are limited by the number of users sharing the link. The combination of optical fibre and coaxial cable in an HFC network allows the benefits of both types of transmission links to be adopted.

2.5.4 Wireless

Over the past few years, the growth of wireless technologies, in general, has been significant, and they continue to promise greater and faster advancements in years to come. Their deployment within the next-generation access network represents a viable option in terms of both speed and geographical reach. In this section, the technical capabilities of fixed broadband wireless access solutions will be described. WiFi and WiMAX are considered.

WiFi

WiFi is a standard developed by the Institute of Electrical and Electronics Engineers (IEEE) in 1999 and comprises wireless specifications in the 802.11 series. These specifications were developed for Wireless LAN (WLAN) connectivity for fixed, portable and moving stations (IEEE, 2005). They define an air interface between a wireless client and a base station or access point, or even another wireless client

(IEEE, 2008). Table 2-5 summarizes the different protocols within the 802.11 suite and their technical capabilities, showing also the improvements in each version. For example, 802.11d is an improvement over 802.11b by specifying another frequency band within which the protocol can operate. 802.11i introduces security within the 802.11 protocols by implementing Advanced Encryption Standard (AES) (Dornan, 2002). An important point to note is that a higher operating frequency facilitates a higher data rate.

	Speed	Indoor range (feet)	Outdoor range (feet)	Frequency (GHz)
802.11a	54 Mbps	27-75	150	5
802.11b	11 Mbps	100-150	300-500	2.4
802.11c	[Mac bridging]			
802.11d	[International roaming]			
802.11e	[Quality of service]			
802.11f	[Roaming]			
802.11g	54 Mbps	100-150	300	2.4
802.11i	[Enhanced security]			
802.11m	[Management support]			
802.11n	Speeds > 108 Mbps			2.4
802.11p	[Wireless for vehicles]			
802.11r	[Fast roaming]			
802.11s	[Mesh networking]			

Table 2-5: Technical properties of WiFi standards

WiFi operates by allowing many users to simultaneously access a single Internet connection using radio waves. The network comprises an antenna and router, and a WiFi card within an enabled device. The ‘owner’ of the WiFi network locates a router within the premises and an antenna is used to broadcast the signal over a geographic range. Any WiFi-enabled device within this range, referred to as a ‘hotspot’, can access the WiFi network, thus obtaining Internet connectivity. Thus, the hotspot represents the Internet access point within the WiFi network. A WiFi-enabled device is one that houses a WiFi card, such as a laptop or personal digital assistant (PDA). Via the card, an IP address is assigned to the device, enabling communication on the Internet. Being a short-range protocol, WiFi only provides coverage over approximately 300-500 feet, but has the advantage of using unlicensed spectrum.

WiMAX

WiMAX, like WiFi, was developed by the IEEE and corresponds to the 802.16 specification. This standard, also known as WirelessMAN (Metropolitan Access Network), was developed for longer-range wireless applications than WiFi. According to WiMAX Forum (2008), WiMAX is "a standards-based technology enabling the delivery of last-mile wireless broadband access as an alternative to cable and DSL."

The WiMAX 802.16 standard includes two components - 802.16-2004 and 802.16e-2005. 802.16-2004 was the first to be marketed and refers to fixed broadband wireless access. 802.16e-2005, the more recent standard, improves on its predecessor by supporting mobility and is, therefore, referred to as mobile broadband wireless access or mobile WiMAX. In this section, reference to WiMAX corresponds to the fixed subset. Mobile WiMAX is dealt with in Section 2.5.5. The 802.16-2004 standard provides support for both fixed[7] and nomadic[8] access, as well as line-of-sight (LOS) and NLOS situations (WiMAX Forum, 2005). It can extend to a range up to 3-10 km in cell radius will an achievable speed of 40 Mbps (WiMAX Forum, 2008). Theoretically, however, the cell radius can be as large as 50km (Light Reading, 2005). In addition, it implements orthogonal frequency division multiplexing (OFDM) with 256 carriers (WiMAX Forum, 2005). Unlike WiFi, WiMAX uses both unlicensed and licensed spectrum. While WiMAX can use any spectrum under 66 GHz (10 GHz to 66 GHz), typical allocations are 2.3 GHz, 2.5 GHz and 3.5 GHz (assigned by the WiMAX Forum) and 5 GHz in the unlicensed spectrum band.

Figure 2-18 depicts a typical WiMAX network that adopts a point-to-multipoint topology and comprises several base stations, with antennae. These base

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[7] The WiMAX Forum defines fixed access as that in which the user device is assumed to be fixed in a single geographic location for the duration of the network subscription (WiMAX Forum, 2005).

[8] The WiMAX Forum defines nomadic access as that in which the user device is assumed to be fixed in a geographic location at least as long as the network data service session is in operation (WiMAX Forum, 2005).

stations are connected to the Internet, either directly or via other base stations which, in turn, have Internet connectivity. Other external devices, or client devices, then connect wirelessly to these base stations.

Figure 2-18 also illustrates the support of mesh networks by WiMAX. Mesh networks allow a device with WiMAX capability to relay signals to another device with WiMAX capability. At some point, however, these must connect to a WiMAX base station to obtain Internet access.

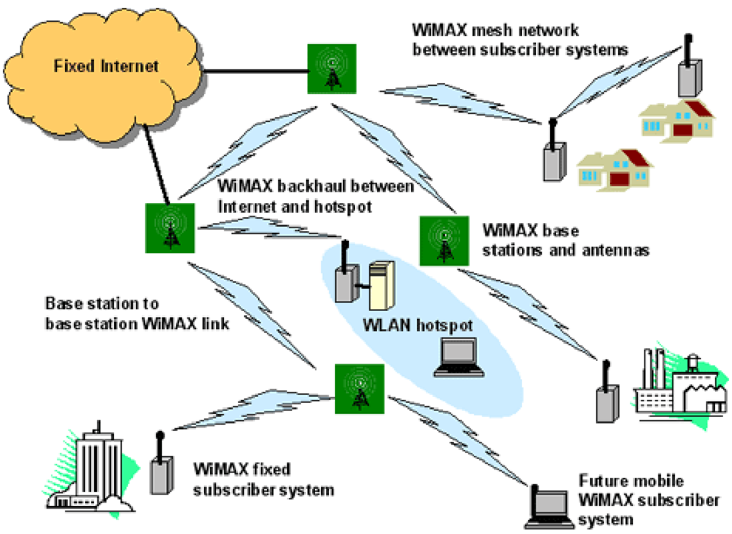

Figure 2-18: Typical WiMAX network
Source: Light Reading, 2005

With NGA and NGN, WiFi and WiMAX can provide complementary services to other technologies, such as 3G mobile, in order to achieve and maintain seamless connectivity. A device can switch between a WiFi network and a 3G network, depending on coverage availability and quality. This application is implemented, for example, with the use of iPhones and iPads. Although wireless access technologies offer, in general, lower capacities than most of the wired technologies, they are comparable and in some instances more advanced than the DSL suite, as Table 2-2 indicates.

2.5.5 Mobile

The developments experienced within the mobile telecommunications domain over the last few years have been remarkable. At the end of November 2011, for example, mobile technologies are expected to boast 6 billion subscriptions (GSM World, 2011a), compared to just over 3 billion at the end of 2008 (GSM World, 2008), less than three years before. In addition, mobile telephony has surpassed fixed telephony in the number of subscribers in many countries.

The trend of the rapid growth and advancement of mobile technologies has made this group of technologies a competitive next-generation access solution. In particular, the High-Speed Packet Access (HSPA) enhancements to Universal Mobile Telecommunication System (UMTS), mobile WiMAX and Ultra Mobile Broadband (UMB) exhibit next-generation data speeds and the potential of providing the quality service that NGN applications require. In addition, Long-Term Evolution (LTE) facilitates even higher capacity applications. Though many other technically-apt mobile technologies exist for next-generation access, these four show the greatest potential to date and are, therefore, the focus of the following discussions.

UMTS and its enhancements

UMTS, or Wideband Code Division Multiple Access (W-CDMA), is a 3G mobile technology (ITU, 2007a) developed by the 3$^{rd.}$ Generation Partnership Project (3GPP). Based on W-CDMA radio-access technology, UMTS possess a major benefit of a high spectral efficiency for both voice and data traffic (3G Americas, 2006), maximizing the use of its bandwidth for information transport. In addition, both voice and data can be carried at the same time (3G Americas, 2007). This technology is based on CDMA, a multiple access mechanism that allows many users to share the same frequency resource by use of a unique code assigned to each individual user (CDG, 2008).

In typical CDMA implementations, a 1.25 MHz signal is coded with each user's unique sequence by a multiplication process (Jelvin, 2001). W-CDMA makes use of a wider signal band than traditional CDMA, a 5 MHz wide radio signal. In addition, the data rate of the code, or the chip rate, is increased from 1.22 to 3.84 Mcps (Jelvin, 2001). As a result, W-CDMA can achieve a higher data rate with the available bandwidth, higher QoS and greater spectral efficiency. With W-CDMA, UMTS can achieve a maximum (refer to Table 2-6) theoretical downlink data rate slightly higher than 2 Mbps per mobile user (IEC, 2008e). Figure 2-19 shows the improvement in data rate performance of UMTS over 2G, 2.5G and 2.75G mobile technologies.

	Data rate	Maximum speed (km/h)
Macro cell	144 kbps (rural)	500
Micro cell	384 kbps (suburban)	120
Pico cell	2.048 Mbps	10

Table 2-6: Data rates achievable with UMTS
Nuntius, 2011

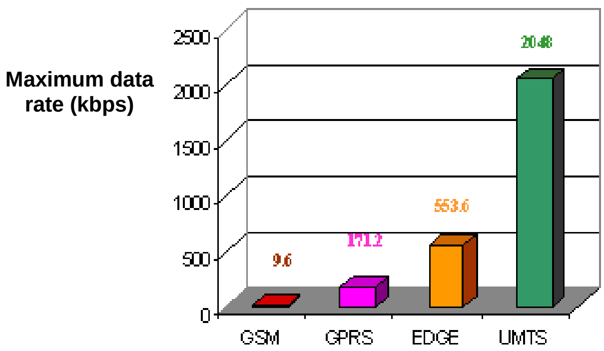

Figure 2-19: Comparison of UMTS with its predecessors
Source: IEC, 2008c

HSPA

HSPA refers to the evolutionary enhancements from W-CDMA to UMTS towards 4G, illustrated in Figure 2-20, improving on spectrum efficiency and, consequently, data rate (3G Americas, 2006; 4G Americas, 2009a; 3GPP, 2011). Improvements in UMTS through HSPA are achieved by using new modulation techniques (16QAM), reduced radio frame lengths and new functions within radio networks, such as re-transmissions (3GPP, 2011). Generally, references to HSPA include High-Speed Downlink Packet Access (HSDPA or 3GPP Release 5) and High-Speed Uplink Packet Access (HSUPA or 3GPP Release 6) (Parkvall, 2008).

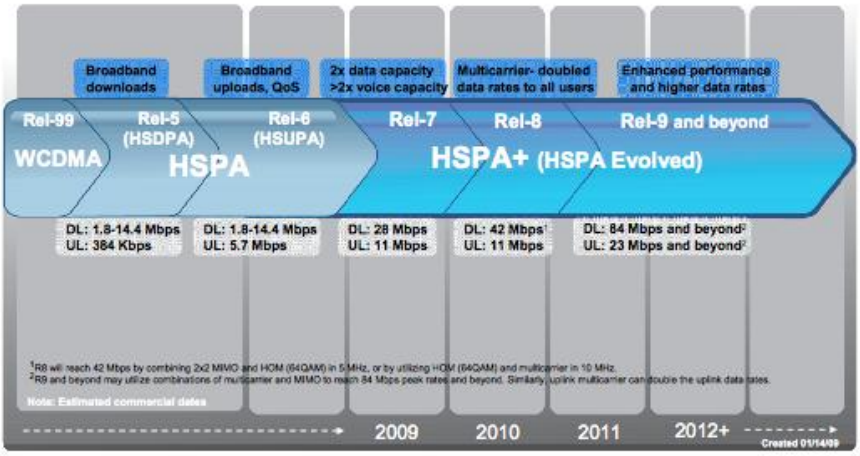

Figure 2-20: The evolution of HSPA
Source: Qualcomm, 2009

Commercially available since 2005, HSDPA initially increased download speeds up to 3.5 times those achievable by UMTS to 550 to 800 kbps (4G Americas, 2009b). Later versions improved the upper threshold to 14.4 Mbps (Mobile Burn, 2009). Throughput and latency are also improved, the latter being reduced to 100ms. The capabilities of HSDPA are possible through adaptive modulation and coding, hybrid automatic repeat request (HARQ) and fast scheduling techniques (4G Americas, 2009b). Launched two years after HSDPA, HSUPA addresses uplink speeds, as its name implies (3GPP, 2011). Users can experience data rates of up to 5.8 Mbps, up from the 384 kbps available with HSDPA, with throughput and latencies of 50 ms (4G Americas, 2009c). HSUPA achieves this by using an enhanced dedicated physical channel (E-DCH), lower transmission intervals, fast scheduling and HARQ (4G Americas, 2009c).

HSPA+

Figure 2-20 shows the HSPA evolution from Release 5 and highlights HSPA versions beyond Release 6. These are referred to as HSPA+ or Evolved HSPA. The first commercial HSPA+ networks were launched in early 2009 (4G Americas, 2009d). Among other benefits, HSPA+ improves further on the downlink and uplink speeds of HSDPA and HSUPA with newer releases achieving data rates of greater than 84 Mbps and 23 Mbps respectively. Advanced antenna techniques, such as Multiple Input Multiple Output (MIMO), and modulation techniques, such as 16

QAM (Quadrature Amplitude Modulation) on the uplink and 64 QAM on the downlink, contribute to realizing the technical enhancements of HSPA+ (3GPP, 2011; Qualcomm, 2009).

LTE

Beyond HSPA+ and closer to the 4G boundary is LTE. The development of LTE was initiated in 2004 but its specification was only completed and released in 2009 (4G Americas, 2009e). The aim of LTE is to provide a high performance, global standardized radio-access technology (4G Americas, 2009e). Using MIMO, Orthogonal Frequency Division Multiple Access (OFDMA) and Single Carrier FDMA (SC-FDMA), LTE provides download speeds of up to 326 Mbps within a 20 MHz bandwidth, upload speeds of up to 86.4 Mbps with a 20 MHz bandwidth, scalable bandwidth up to 20 MHz and lower latencies (up to 10ms) (GSM World, 2011b; 4G Americas, 2009e). LTE also conforms to a full IP network architecture and supports packet-based voice traffic (4G Americas, 2009e).

Mobile WiMAX

The first implementation of WiMAX, the IEEE 802.16-2004 standard, was developed to provide fixed, wireless, nomadic, broadband access to end-users. In 2005, the IEEE defined an upgraded standard, 802.16e-2005, the aim of which is to extend the functionality of 802.16-2004 to include support for mobile subscribers moving at vehicular speeds (IEEE, 2005) greater than 120 km/h (WiMAX Forum, 2005). Aligned with this level of mobility, this enhanced version of the protocol provides handoffs between base stations or sectors and roaming capabilities (IEEE, 2005). In addition, it is listed to operate in licensed frequency bands lower than 6 GHz (IEEE, 2005) and to provide non line-of-sight (NLOS) communication.

Both fixed and mobile WiMAX possess the same basic architectural attributes but the technical features of mobile WiMAX are modified to provide mobility. The underlying mechanism of mobile WiMAX is the multiple access technology, Scalable OFDMA (SOFDMA) (WiMAX Forum, 2005). Based on OFDMA, SOFDMA increases the spectral efficiency of channels (WiMAX Forum, 2005), thereby reducing overall costs and providing an affordable solution in areas that are not heavily populated.

The new WiMAX standard also incorporates the support for Adaptive Antenna System (AAS) and MIMO technologies. Adaptive antennae are those that contain specialized signal processing techniques that allow them to focus directly to a transmitter or receiver, that is, to be spatially selective (FCC, 2001). In this way, interference among mobile devices can be reduced and power can be conserved. In turn, the coverage range, reliability and data rate can be increased. Mobile WiMAX delivers peak downlink data rates of up to 46 Mbps per sector and maximum uplink rates of up to 14 Mbps (in a 10 MHz channel) (Intel, 2007). With the combined effort of multiple antennae, a greater level of traffic can be carried with mobile WiMAX (Intel, 2007).

UMB

The UMB specification was developed by 3GPP2 and released in September 2007 (3GPP2, 2007). 3GPP2 declared UMB to be a “major breakthrough in next generation mobile broadband services” (3GPP2, 2007). More specifically, UMB was deemed the “world’s first IP-based mobile broadband standard” to declare peak download rates of 288 Mbps in 20 MHz bandwidth (3GPP2, 2007). UMB builds on the foundation of its preceding CDMA technologies, implementing OFDMA instead of OFDM as before, MIMO and Space Division Multiple Access (SDMA) (3GPP2, 2007). In addition, it makes use of advanced control and signaling techniques, and Radio Resource Management (RRM). These allow UMB to deliver high voice and data capacities. For example, its Voice over IP (VoIP) offering is a maximum of one thousand sessions within one sector and 20 MHz bandwidth (CDG, 2008). For data, mobility speeds of up to 300 km/h can be handled (3GPP2, 2007). Finally, in addition to providing coverage over a greater area (Wide Area Network areas), UMB can also operate within the 2500 MHz band (CDG, 2008). The potential for this new technology in NGA, therefore, is great.

2.6 Conclusion

The telecommunications industry is a dynamic industry whose direction is influenced by its key players - network operators and service providers, regulators, equipment vendors and consumers. Today, demands by consumers for higher capacity services and the need for increased competitive advantage by operators and service providers are transforming this industry. The traditionally segmented voice, video and data networks no longer suffice as they incur high maintenance costs and cannot offer multi-service and broadband delivery with the level of QoS that is required for effective innovation and competition. In an attempt to merge the three distinct traffic types onto a single network, operators are shifting to an IP-based, QoS enabled, high-speed converged network in the form of NGN.

Though various perceptions of next-generation broadband networks exist, there is some acknowledgement that both the core and access network components can be upgraded. NGN is viewed as an upgrade of the core infrastructure to produce a single, converged fixed network capable of carrying voice, video and data over IP and MPLS. NGA is defined more vaguely as broadband access services capable of delivering sustained capacities significantly in excess of those currently widely available using existing local access infrastructures and technologies, typically greater than 20 Mbps.

Although the next-generation network concept is new to the telecommunications sector, the networks are based on the technologies that have conventionally been deployed within the PSTN, Internet and cable networks. The quest for suitable technologies, however, has brought great innovation to the telecommunications sector. Many of these existing technologies are being enhanced or converged in order to develop the optimum solution for advanced broadband service. From this review, it can be seen that this is certainly achievable. For example, the NGN core can be realized using a combination of IP and MPLS transmission over an optical-based backbone network. With the advances in WDM technology that now exists, this can offer a scalable-capacity network with high resilience and reliability.

There are many options, too, for NGA. Advances in DSL technology, such as VDSL2, optical fibre, HFC, wireless and mobile solutions can all facilitate next-generation broadband access data rates and quality. Even within these options, several deployment configurations exist. Fibre networks, for instance, can be configured in various hybrid architectures, using DSL for very high data rates. Alternatively, optical fibre can be laid directly to the customer for a robust and reliable network. Yet still, access can be shifted to a wireless option with WiMAX being a promising solution, especially for otherwise un-served areas. Significant NGA potential has also been seen in both early mobile technologies, such as mobile WiMAX and UMB, and more recent advancements such as HSPA, HSPA+ and LTE. Figure 2-21 provides a comparison of some of these technologies based on mobility, speed and cost, suggesting that there are technical trade-offs in selecting one over another.

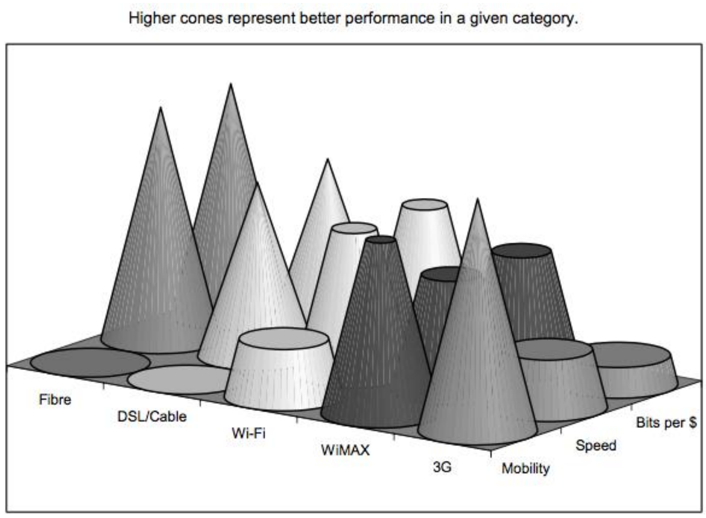

Figure 2-21: Comparative performance of access technologies
Source: OECD, 2006

Given the various alternatives, it is clear that a dilemma for technological choice exists in next-generation broadband. The answer lies with a consideration of both technical and economic factors, which, in general, are crucial to the deployment of a given technology within a particular environment. In order for all stakeholders involved to realize the benefits of NGN and NGA, these factors must be carefully examined. However, as the following chapter will show, the development of next-generation broadband networks is also influenced by a variety of other market factors.

3 Next-generation broadband: Investment analysis

3.1 Introduction

As illustrated in Chapter 2, the technical benefits and technological choices for the deployment of next-generation broadband networks are many. The current chapter shows that the economic implications are similarly numerous and complex, the combined influence of which raises investment issues for network operators and other stakeholders. Investment issues are seen to be linked to market factors and market conditions. The main purpose of this current chapter is to examine and evaluate existing research on next-generation broadband in this context of investment and market factors.

The chapter first provides insight into the impact of next-generation broadband development, in Section 3.2. This discussion highlights the issues and factors linked to investment. The investment decision is examined more closely in Section 3.3. The main investment issues are summarized before an assessment of existing research on the relationship between market factors and investment is presented. Section 3.4 highlights the limitations of the existing material and discusses the consequent emergence of the research questions addressed in this study. A summary of the findings of the literature review is presented in the closing section, Section 3.5. In its entirety, this chapter provides the theoretical basis for the research examined in this thesis.

3.2 Implications of next-generation broadband

As the emergence of next-generation broadband is the most recent and, perhaps, one of the most powerful technological advancements within the telecommunications industry, its implications have been widely studied. The literature shows that the impact of next-generation broadband is most dominant in consumer services and in the technical, regulatory, socio-economic and commercial aspects of a market. This section summarizes the key findings, by researchers, within these five dimensions and is used to introduce the main investment issues. NGN and NGA are individually discussed where relevant.

3.2.1 End-user services

Much of the literature on the development of next-generation broadband examine the benefits related to end-user services. ITU (2007a) predicts trends of increasing demand by consumers for advanced telecommunications services such as VoIP and IPTV and the associated growth of triple- and quadruple-play services such as FMC. Many of these applications have already been facilitated to an extent by the adoption of broadband and the Internet. Television services such as IPTV and high-definition television (HDTV) have been key drivers for fibre investment in markets such as Japan and China (ITU, 2007a). As these trends persist, revenues from traditional voice-only services continue to decline and, coupled with the advanced capabilities of NGN, services and applications are expected to shift from being voice-based to encompassing a range of content such as mobile IPTV (ITU, 2007a).

As a result of the enhanced speed capabilities of NGA, one market argument for its deployment is the introduction of new and innovative services. NGA will enable other high definition and interactive services, gaming being one such example (Burpee and Shumate, 1994; Crimi, 2008; ITU, 2007a; Methley, 2006). Salina and Salina (2007) stress the realization of distributed virtual realities such as e-education, virtual corporate, home hospital and store environments, services that are also mentioned by Crimi (2008) and Falch and Henten (2010). Salina and Salina (2007) also identify home networking as a key next-generation broadband application. The Said Business School/Cisco annual ‘broadband quality score’ contains vague categories of services possible with NGA - telepresence, video networking and large file sharing. Faster broadband is also expected to enhance the services of content-rich websites such as iPlayer and YouTube. BSG (2010) suggests that downloads and uploads will be richer. In general, migration to broadband multimedia and information intensive services can be expected and, as Marine (2007) observes, the end-user will be exposed to the concept of Intelligent Networks (INs) and ubiquitous service acquisition (Crimi, 2008).

Harker (1996) and Salina and Salina (2007) observe that, with the move to next-generation broadband, the market will be driven by consumers and their needs rather than by technology. Services, therefore, will become a differentiating factor among network operators and service providers. Consequently, operators and service providers will not only need to be aware of what consumers demand but will also need to be more innovate in their service delivery (Harker, 1996; Sato, 2007). Cawley and Preston (2007) also attest to the shift in importance of innovation to services and applications in future broadband networks. As such, the provision of value-added services (VAS) becomes an important requirement for providers (ITU, 2007a). van de Velde (2007) identifies the media pilot, personal contact pages and multichannel media, among others, as some of the VAS that can be realized with NGN.

Though Ezell et al. (2009) and others advocate the need for the speeds achievable with NGA and the development of new services, other literature and discussions question this. Firstly, there is no evidence that high-speed services have been facilitated by optical fibre deployments to date. Like others, BIS expects advances in healthcare and education services, higher speeds and more capable services which, in turn, will yield a range of new and innovative applications and increases in employment. However, they admit that there is yet no empirical evidence of such benefits (Department for Business, Innovation and Skills, 2010).

This argument by BIS is supported by observing what consumers have been using fibre broadband for. A detailed, albeit old, research report based on the Swedish market shows that residential customers are interested in information services while commercial customers are interested in communication services (Aronsson et al., 2003). Howell and Grimes (2010) state that recent fibre deployments have driven greater use of the Internet for gaming and entertainment, but no new speed-reliant applications have emerged. Among business consumers, UK case studies on the The Hawk Creative Business site and the York Science Park, University of York explain that services such as VoIP, data backup solution and virtual private networks have been common uses of fibre networks. Clients of British Telecom's (BT's) Business Total Broadband Fibre reveal that the benefits to them have been high upload speeds for videos, increased productivity and lower energy bills (BT, 2010b; York Data Services, 2010a; York Data Services, 2010b). However, none of these indicate the availability of new services for consumers. Instead, the real drivers of service innovation utilizing fibre and NGA are, as yet, unknown (BSG, 2010).

Some argue that the deployment of fibre and the availability of capacity expected with NGA will bring services and demand (see Burpee and Shumate, 1994; Ferreira et al., 2002). However, Lau et al. (2005, p350) explain that this same “over-estimation of audience demand” for applications via the Internet contributed to the “dot-com” collapse in the US in 2001, when many investments in hopeful fibre networks were “under-utilized”. This resulted in a displacement in the economy of the telecommunications and IT industries in the US (Lau et al., 2005). Lau et al. (2005) specifically cite broadband as having failed to meet expectations (from Baldwin et al., 1996; Grant and Meadows, 2004; Lin and Atkin, 2002). Along similar lines of argument, Fijnvandraat and Bouwman (2008) explain that the demand for fibre is unpredictable as trends in the adoption and diffusion of technology are random (Vermaas, 2007) and that benefits to consumers and society do not always occur where the investment is made (Expertgroep Breedband, 2002).

3.2.2 Technical implications

Despite the architectural advantages linked to NGN, early literature on next-generation broadband explains that NGN deployment is not without its share of technical challenges. While Kuhn (2005) discusses challenges with network architectures and platforms, others have more widely identified issues of migration, interoperability, QoS, security, interconnection, numbering and the provision of emergency services as main concerns (Griffiths, 2007; Marine, 2007; Unger, 2005; VeriSign, 2008). With regard to QoS, for instance, the Internet has been designed to deliver ‘best effort’ service, in which QoS is not guaranteed. While this is acceptable for data traffic, voice and other real-time applications are intolerant to significant and varied delays and poor quality (Rogerson, 2007). Therefore, the IP core in NGN has to be designed to provide QoS guarantees. Chaudhary (2009) identifies similar network requirements with regard to latency and jitter performance.

In terms of interconnection, Marine (2007) highlights the requirement to not only connect IP-based networks to each other and to legacy networks, but also to allow consumers to access their service profile on their home network from any other network, to access services from their own network rather than from the visited network, and to access the services of third-party providers. While Griffiths (2007) asserts that interconnection is not technically difficult, this author declares that quality may be reduced if traffic traverses several gateways and that defining the technical standards necessary for interconnection, in the first place, is challenging. Unger (2005), however, questions where access and interconnection will be provided on the networks. Verma (2007) also mentions the requirement of line powering for all IP clients as a technical issue.

The interconnection of different types of networks also requires a new approach to numbering. As a result of the nomadic nature of the services capable with NGN, one suggestion is that numbers are allocated to users rather than to devices (Griffiths, 2007). The nomadic nature of NGN, however, makes it difficult to implement emergency calling within these networks (ITU, 2007a). Emergency calling requires location information to be easily and automatically available but the absence of a connection to a physical location with the use of IP makes this currently impossible.

In the NGA domain, the technical benefits are expected to be plentiful but, although speed is cited as a key advantage, the magnitude of the speed benefit is linked to the technology deployed. Following from the discussion in Chapter 2, a range of technologies can be used in the next-generation access network, presenting another dilemma for investors.

While it is widely accepted that optical fibre is the future-proof technology, practical deployment factors such as cost and terrain are deterrents to the deployment of this technology. Recent arguments are centred on the fact that the service benefits of fibre can be delivered by other broadband technologies. For example, Burpee and Shumatee (2002) explain that developments in copper-based technologies enhance the capability of copper to adequately deliver high-speed services. This potential of copper is supported by a Corning White Paper of 2005, which explains that increases in capacity needs are putting pressure on existing technologies, but variants of DSL (e.g. ADSL 2+ and VDSL) can deliver the required capacities for VoD and HDTV, for example (Corning, 2005). This is evident in the UK, for example, where television services delivered over DSL have been satisfactory to consumers in terms of quality and service (Ofcom, 2009a). Kenny and Kenny (2010) argue that cable networks, too, can deliver the capacities required with high definition on-demand television. With a focus outside of urban areas in Sweden, Ovum also shows that there is no clear evidence that fibre can bring benefits that other technologies cannot (Davies, 2009).

Kenny and Kenny (2010) further argue against the urgent need for fibre by explaining that the incremental benefits of fibre over other, current, broadband technologies may be minimal and should be understood before service benefits are attributed to this technology. By providing a detailed review on these and similar literature, Ragoobar et al. (2011a) agree that the urgency for fibre is unwarranted. These observations question the justification for the significant investment that is required with fibre deployments, adding to the technology predicament for operators and other investors.

3.2.3 Regulatory considerations

The regulatory dimension of next-generation broadband has, to date, been a principal area of discussion within next-generation telecommunications literature. Lee and Knight (2005) provide a possible explanation for this - that the separation of the service and transport layers in NGN affects regulation more than any other aspect of NGN development and deployment. However, new regulatory issues are raised with both NGN and NGA. Dodd et al. (2009), among others, highlight this difference between current-generation and next-generation regulation. By examining the specific case of the bill-and-keep approach, Dodd et. al (2009) reason that existing regulation is unlikely to be suitable and suggest new models for interconnection charging. From a more general perspective, it is believed that the use of historical regulation can discourage investment, competition and innovation in the new telecommunications sector (Kahn, 2007). Rather, regulatory frameworks need to be reviewed to address the issues emerging with the introduction of next-generation broadband.

A key objective of regulation is to foster competition, innovation and investment (Kirsch and Von Hirschhausen, 2008). Prapinmongkolkarn (2007), Sato (2007) and ITU (2007a) confirm that this is essential with NGA, and several others show that without regulatory intervention there is an ambiguous link between NGA investment and competition (see OECD, 2007; Reichl and Ruhle, 2008a; Reichl and

Ruhle, 2008b). Reichl and Ruhle (2008b, p35), for example, conclude in their discussion of a business model analysis, that “NGN should lead to more competition” but that this will not happen without intervention. On a technical level, regulation of NGA is challenged by interconnection, access, technological neutrality and the balance between ex ante and ex post competition policy (Cohen, 2007; Ku et al., 2007; Marcus, 2006; Reding, 2006a; Reichl and Ruhle, 2008b).

In terms of NGN, reports by Kirsch and Von Hirschhausen (2008), Marcus and Elixmann (2008) and Reichl and Ruhle (2008a) affirm that the transition to an IP-based core and the convergence of services contribute significantly to the regulatory mêlée. Cohen (2007), Waverman (2007), Au (2006), Kelly (2008a), Wey et al. (2006) and others identify a combination of network neutrality, licensing, spectrum and universal service/access as other sources of regulatory concern with NGN deployment.

Despite similar regulatory issues and aims across markets, Marcus and Elixmann (2008) show, from an analysis of regulatory regimes adopted by regulators in five countries - USA, UK, Germany, Japan and the Netherlands - that regulatory frameworks for next-generation broadband networks are bound to differ. They find that market conditions and traditions, network deployment options (that is, whether upgrades are made to the access or core network, or both) and the relationship between government and incumbents influence the regulatory tactics adopted. This reasoning of different regulatory frameworks is resonated by Alleman and Rappoport (2007) and Amendola and Pupillo (2008), who suggest a more micro-based distinction at the regional level.

Notwithstanding the extensive work done in determining the regulatory issues that arise with NGN and NGA deployment and analyzing, hypothetically, what the most appropriate regulatory approach might be, there is mutual agreement among researchers that there is not yet any conclusive evidence regarding its impact within the industry. Many conclude that further empirical work is required to effectively assess NGN and NGA regulation (Cohen, 2007; Kirsch von Hirschhausen, 2008; Marcus and Elixmann, 2008; Reichl and Ruhle, 2008a). Some say it is still too early to determine effective regulation for NGN and NGA and that regulation is a work in progress, such that only when next-generation broadband has matured somewhat can regulatory requirements be properly assessed (Cohen, 2007; Preissl and Whalley, 2008).

3.2.4 Socio-economic impact

The socio-economic impact of next-generation broadband has been most widely discussed by economists (for example, Alleman and Rappoport, 2007; Cave et al., 2006; Waverman, 2007) and economic development organizations such as the OECD and ITU. There is general consensus from this literature that NGN and NGA can ultimately enhance social relationships and economic growth, but it is also believed that factors such as regulation can affect these benefits. Consequently, the socio-economic impact can be different across varying environments and economies (Cave et al., 2006).

The literature exposes two primary sources of economic benefits of next-generation broadband, namely, the ‘single-network, multiple-services’ topology and the underlying IP technology. A single network that delivers all types of traffic and a range of services and applications reduces capital expenditure (CapEx) and operational costs (operational expenditure - OpEx) (Beardsley et al., 2007), resulting in direct cost savings to consumers (Lie, 2007). In a study of the European telecommunications market, Cave et al. (2006) suggest that because of the IP-based nature of these networks, a higher capacity at lower total costs compared to traditional networks is realized. This results in a lower unit cost of NGN (Cave et al., 2006; Kurth in Marcus, 2005).

Simpson (cited in OECD 2007) and Lee and Knight (2005) also explain that the technological convergence facilitated by IP encourages competition among disparate market players, creating new business opportunities and an innovative environment. In addition, Cave et al. (2006) suggests that the greater dependence on software in NGN will enable operators and third-party developers to develop their own applications and services, reducing both cost and time-to-market. These results, in turn, will provide new services and enhanced competitiveness in the telecommunications sector. Increased competition introduces lower prices (OECD, 2008), higher quality goods, a more diverse range of services and increased infrastructure investment (ITU, 2007a; Reding, 2006b).

Hwang (cited in OECD, 2007) also believes that next-generation broadband is crucial to achieving a ubiquitous society. Simpson (cited in OECD 2007) envisions that greater and more widespread access to information and public services will result, generating greater productivity and increased economic growth. ITU (2007a) supports this claim and declares that next-generation broadband is a tool for realizing an information society and the objectives of the World Summit on the Information Society (WSIS) (Al Morshid, 2007). Thus, according to ITU (2007a), next-generation broadband will connect citizens, create and sustain new businesses in rural and urban communities and facilitate Information and Communications Technology (ICT) access. ICT development, in turn, is a driver of economic growth (Eggleston et al., 2002; Hameed, 2008; Marcus, 2007). ITU (2007a) expects, therefore, that poverty among citizens will be reduced, that these citizens will become part of the global information economy and that general socio-economic development will result.

ITU (2007a) also believes that NGN and NGA can act as the foundation upon which other sectors can benefit. For example, they suggest that NGA can realize e-government and e-health public services. Reynolds and Samuels (2004) partially echo this sentiment by declaring that ‘targeted’ investment in telecommunications can enhance the efficiency of other sectors such as health and education. Farnsworth et al. (2007) explain that, even at their time of writing, IP networks were facilitating virtual classrooms, thereby accommodating distance learners, life-long learners and others.

Despite the optimism by these authors, many economic studies report that the deployment of next-generation broadband, particularly NGA, is accompanied by concerns of the future of the digital divide (APT, 2006; ITU, 2007a; Xavier, 2006a; Xavier, 2006b). NGN and NGA are expected to promote ICT availability, access and usage (Lie, 2007) and, according to Hernandez and Leza (2007), to be a major driver in narrowing the digital divide. However, as recognized by ITU (2007a), NGA requires significant capital investment, “sums that would go begging in the developing world” (ITU, 2007a, p1). In addition, trends of technology adoption, infrastructure deployment and market conditions can influence NGN and NGA deployment strategies for countries, resulting in possibly different approaches and hence varying opportunities and benefits across nations. Furthermore, Hernandez and Leza (2007), Xavier (2006b) and Ofcom (2008a) acknowledge that NGA migration is most likely to occur first in densely populated areas, presenting the possibility of a widened digital divide within a country or region. Hernandez and Leza (2007) cite Argentina, Bangladesh, Brazil, Bulgaria, the Cayman Islands, Pakistan, Venezuela and Vietnam as countries that embarked on fibre deployments in heavily populated areas. Lie (2007), too, supports this possibility of an uneven distribution of benefits from NGA deployment.

Other opinions on the impact of next-generation broadband on the digital divide are varied. The Broadband Stakeholder Group (BSG), for example, reports that, with the deployment of NGA, an inevitable gap between different geographic areas in the UK will be created in the short to medium term, with uncertainty as to how long such a gap will exist (Kelly, 2008b). BSG (2008) suggests three possible options for rural regions - a significant increase in the take-up of services, demand- and supply-side interventions from the public sector and the use of wireless and satellite technologies. While some have agreed with these potential solutions (see Cohen, 2007; ITU, 2007a; Reynolds and Samuels, 2004), Hernandez and Leza (2007) argue from a technical perspective that developing countries/regions can actually migrate faster and more easily to next-generation broadband because of less established core infrastructure and by leapfrogging technologies in the access network.

However, many uncertainties still exist. Two facts emerging from the literature review question these opinions and the success of wireless technologies as recommended by the BSG (2008), ITU (2007a) and Reynolds and Samuels (2004). Firstly, there is consensus that "technology alone is not the solution" (ITU, 2007a, p2) and regulators and policy-makers play a crucial role in the realization of NGN benefits (Al Morshid, 2007; Au, 2006; Beardsley et al., 2007; Hernandez and Leza, 2007; Waverman, 2007). More specifically, for the socio-economic benefits to be realized, policies that promote innovation and investment must be adopted and enforced (Fransman, 2007; Prapinmongkolkarn 2007; Sato, 2007; Waverman, 2007). Moreover, ITU (2007a) expects that regulatory frameworks are likely to vary between developed and developing markets because of different pricing mechanisms, market structures and technology (broadband) penetration. Therefore, it is essential for industry players and regulators to recognize that regulatory measures cannot be "cut and pasted" (ITU, 2007a, p2) and that the resolution is not a "one size fits all" (Ofcom, 2006c; Phillips, 2007).

Secondly, the proposals put forward by the BSG (2008), ITU (2007a) and Reynolds and Samuels (2004) for developing countries to exploit wireless broadband technologies in the last mile, while theoretically viable and logical, lack evidence of practical efficiency and success. Although the deployments of wireless technologies within the PSTN world have been analyzed from a technical perspective (see, for example, Reynolds and Samuels, 2004), their socio-economic impact has not.

3.2.5 Commercial issues

The development of next-generation access infrastructure promises to deliver enhanced efficiencies to operators, more competitive telecommunications sectors and general economic growth (Alleman and Rappoport, 2007; Cave et al., 2006; ITU, 2007a; Waverman, 2007). For many operators, however, issues surrounding the incentives for infrastructure roll-out are significant. At the heart is the struggle to justify the business case for investment in light of the high capital costs associated with NGA deployment and the uncertain returns for operators in many environments.

Both the FTTH Council Europe (2007) and Ericsson (2010) explain that the high investment costs are attributed to the civil work (passive infrastructure) associated with NGA deployment, which Noam (2010, p6) remarks "do not follow Moore's law at all". Civil works contribute 70% to 80% to the total cost of deployment (Caio, 2008; Elixmann et al., 2008; Ericsson, 2010; Walker et al., 2008). In Ireland, civil works and material to deliver NGA (FTTH) to half of the population are estimated at €2 billion, with a further €450 million required to serve the remaining population (Yardley, 2009). In Germany, nation-wide FTTC and FTTH deployments are estimated at €41 billion and €118 billion respectively (Telecompaper, 2010). For Australia, FTTx deployment can go up to €6,100 billion (Telecompaper, 2010). In the UK, nationwide NGA coverage ranges from £5 billion to £30 billion, depending on the combination of technologies used (Analysys Mason, 2008). For a country with a population of 60 million, Lewin (2008) quotes an investment in excess of €25 billion for migrating from copper to FTTP or FTTN access.

The business case for infrastructure investment of such magnitudes is difficult to justify solely on the basis of the cost savings expected (Lewin, 2008). Unlike the case with current-generation broadband, the costs for NGA roll-out are not sunk and operators, therefore, need upfront incentives to invest (Cave, 2010). As Cave and Hatta (2009) discuss, the transition to NGA becomes viable for an operator only under certain financial conditions that take into account the revenues accrued from the investment. For a monopoly operator, for example, the total additional costs of the new technology must be less than the sum of the variable cost of the old technology and the incremental market revenues gained by the new technology. In a competitive market, the threshold value is increased by the sum of the revenue gained from competitors and the revenue protected from competitors as a result of the investment. Noam (2010) also explains that the challenge to source funding for investment is more so for incumbents than for new entrants, as the former are generally overwhelmed by universal service (and other) obligations and, sometimes, debt.

Linked to this financial uncertainty is what Ruhle and Reichl (2009, p34) refer to as "demand uncertainty". In a market where consumer demand for high-speed broadband is not apparent, Ruhle and Reichl (2009) argue that it is difficult for operators to predict the demand for products and services that do not yet exist. Thus, potential market revenues are, again, debatable.

In addition to the impact of consumer demand, the revenues realized by operators are affected by regulation. Caio (2008) explains that regulatory policies affect, for example, wholesale agreements, interconnection tariffs and advertising. All of these are revenue streams for NGA. Therefore, as mentioned in Section 3.2.3, the investment predicament for regulated or potentially regulated firms who must share the benefits of their investment with new entrants is further complicated by this regulatory dimension (Ruhle and Reichl, 2009). This relationship between investment and regulation is also alluded to in Vareda (2010), Huigen and Cave (2008), Christodoulou and Vlahos (2001) and others, including a detailed literature review in Cambini and Jiang (2009). In essence, unless potential returns and revenues are compensatory for investment costs, thereby making a positive and sustainable business case, there is a major obstacle for private-sector investment in NGA infrastructure (Ruhle and Reichl, 2009).

3.3 The investment decision

While the potentials for end-user services and technical advantages of NGN and NGA may drive investment in next-generation broadband, it is clear from the preceding discussion that many investment concerns remain. Moreover, as some of the quoted studies infer, the implications of next-generation broadband can be influenced by market conditions on a wider level. Thus, not all countries and market players will be affected in the same way. Furthermore, market conditions will determine the priorities for stakeholders, thereby influencing how investment is shaped and how it develops (Rogerson, 2007). From the previous discussion, for example, a difference in investment patterns is expected between developed and developing economies due to dissimilarities in market and economic factors, technology and infrastructure trends and regulatory considerations (ITU, 2007a).

With this in mind, this section further explores the links between markets and investment in the literature. As an introduction, Section 3.3.1 summarizes the key investment issues for operators based on the discussion in Section 3.2. Section 3.3.2 reviews the opinions of researchers on the link between markets and the decision to invest in next-generation broadband.

3.3.1 Key investment issues

In markets where the full potential of the investment can be realized, the benefits of NGN and NGA are likely to be many. However, many markets and market players are faced with one or a combination of the investment issues described in Section 3.2. Based on the literature discussions, perhaps the most heavily weighted of these concerns are the socio-economic and commercial impacts.

Undoubtedly, there is concern about how next-generation broadband can be funded, reasonable returns realized and the potential for a digital divide minimized. As a result, network operators are wary of being caught in the migration to next-generation infrastructure. In addition, the question of duplicate NGA networks and, consequently, the means by which competition can be sustained, is significant. In turn, regulators are confronted with the challenge of establishing a framework that can balance investment and competition. Technologies, too, are posing a dilemma. With a variety of possible solutions, questions surrounding the 'best' NGA technology and topology are commonplace. Finally, some industry members and researchers are beginning to query the need for the speed benefits linked to NGA and particularly to fibre, questioning, in turn, the need for NGA at all.

Several measures to address the commercial investment obstacles have been proposed. In some markets, various co-investment strategies are adopted to share the investment costs – joint ventures (The Netherlands), the exploitation of third party infrastructure (utility companies in France) and the endorsement of open access models, for example (Caio, 2008; Cave and Hatta, 2009; Sadowski et al., 2010; TeleGeography, 2010a; TeleGeography, 2010b). However, where market failure in encouraging investment is inevitable as a result of weaker incentives, policymakers – regulators and governments – have acknowledged that some form of intervention is necessary (see Caio, 2008).

Although private-sector investment is economically the most favoured option (Ruhle and Reichl, 2009), public intervention is deemed necessary where market forces, such as competition, fail to encourage NGA roll-out (Wright, 2010). However, Gómez-Barroso and Pérez-Martínez (2005) declare that no definite conclusions can be made regarding the procedures, generalization and success of state aid while Cave and Martin (2010) explain that establishing the priorities for public investment is, in practice, a political decision. Recent research has extended the intervention debate into the sphere of the relationship between public and private actors. Some have proposed and discussed public-private partnership (PPP) models (see Falch and Henten, 2010; Given, 2010; Nucciarelli et al., 2010), others have identified the benefits of PPPs (see EC, 2009; Fredebeul-Krein and Knoben, 2010) while others have examined the issues associated with the PPP model (Araújo and Sutherland, 2010, for example). As Gómez-Barroso and Feijóo (2010, p494) explain, few general rules can be established but "there is no single recipe for fruitful public-private collaboration."

Overall, the dilemma presented for next-generation broadband investment is significant, complex and, in many ways, affected by market conditions. As a result, it is clear that an understanding of this interplay between market factors and the investment decision is crucial to the successful development of next-generation broadband. Section 3.3.2 that follows extends this current discussion of investment issues by describing the studies that examine this relationship between markets and investment.

3.3.2 The influence of market factors

ITU (2007a), Marcus and Elixmann (2008), Ofcom (2008a), Cave et al. (2006), Alleman and Rappoport (2007) and others have suggested a link between market factors and investment in next-generation broadband, albeit from different perspectives. This section presents the theory on this relationship in more detail. Two classifications of market influences are presented – regulation and, more generally, a mix of other market factors.

Regulatory influence

The most widely discussed influential market factor in the literature is arguably regulation. Three aspects of regulatory influence - general policy, access pricing and geographical regulation - can be identified. Each is now discussed in turn.

General regulation and policy impact

As Aron and Crandall (2008) explain by using US and OECD examples, investment in next-generation broadband only commenced when a favourable regulatory regime, removing unbundling obligations, was announced. These authors adopt the stance that poor policy judgements deter investment in next-generation broadband. Cave and Hatta (2009) also acknowledge the significant role of regulation in encouraging next-generation broadband investment. They explain that fibre NGN requires a hefty investment, for which regulatory certainty is necessary in order to achieve.

From the incumbent perspective, Frieden (2009, 2010) agree with the negative relationship between regulation and investment incentives, though no details, apart from the lack of certainty, are provided. Ruhle and Reichl (2009) also highlight regulation as a ‘cornerstone’ of the NGA investment decision for incumbents, delving a bit further into the relationships that exist. For example, they explain that if fibre exists as a monopoly network, the access network will continue to be a bottleneck, requiring regulation and, consequently, lowering the willingness of the incumbent to invest.

By exploring the relationship at a micro level, Bauer (2010) identifies an ‘investment calculus’ which regulation and public policy affect, thereby affecting the investment decision. The investment calculus takes into consideration the market factors influencing the investment decision for investors and innovators, such as the expanded (strategic) net present value (ENPV), cash flows, costs of service provision and competitive intensity, to name a few. Bauer (2010) explains that, for example, unbundling obligations limit the profits that a network operator can realize, thereby reducing the ENPV and the incentive to invest. On the other hand, unbundling lowers the entry costs for alternative or new entrants, thereby encouraging complementary investment of these competitors.

This notion of access obligations, as discussed by Bauer (2010), has emerged as a key factor in the discussion of the regulatory impact on investment. Frieden (2009, 2010) indicate that operators just do not want to provide interconnection and access to their competitors. Bourreau et al. (2010a) examine the relationship between access obligations and investment more thoroughly through discussion of the ‘ladder of investment’ (LOI) approach. Cave (2010) explains that while the LOI approach can be applied to NGA, several considerations linked to access obligations must be taken into account. Cave (2010) highlights, like Bauer (2010), that access regulation can discourage investment in infrastructure, in turn encouraging the development of service-based competition. Consequently, investment in fibre can be hindered.

Access pricing and interconnection

Access pricing has also been commonly identified as a primary influential factor in the next-generation broadband investment decision. This topic has been examined from many perspectives, with de Bijl and Peitz (2010) considering the link between PSTN pricing and IP-based NGN entry and Vareda (2010) investigating the motives for the investment. The former show that a high PSTN access price deters entry in the VoIP market and underinvestment by the incumbent discourages investment by a new entrant, as the take-up of services is expected to be low. On the other hand, Vareda (2010) shows that a high access price encourages investment with the aim of quality-upgrading but reduces the incentive to invest for cost-reduction outcomes.

In another study, comparing the US and Europe, Chang et al. (2003) find that low access prices encourage the deployment of new technology by incumbent local exchange carriers (ILECs), based on US data. In Europe, the findings are similar albeit limited due to the recent timestamp of the data. Other studies investigate the relationship between the access pricing aspect of a market and investment but are based on old technologies and the implication on the emergence of NGN and NGA are uncertain (see, for example, Cave, 2003; Cave and Vogelsang, 2003).

From a more generic perspective, Nitsche and Wiethaus (2009) analyze the influence of different types of access regulations on investment, showing that a fully distributed cost (FDC) approach or a regulatory holiday has the most positive effect. However, using a ‘real option’ approach, Gavosto et al. (2007) explain that the impact of a regulatory holiday is only positive in the initial period of investment, when uncertainties are still prevalent. This, therefore, suggests that there is a temporal aspect to understanding how regulation affects investment. However, a concern with Gavosto et al.’s (2007) study is that it is based on actual data for a new entrant but predications and estimations for an established operator. Cambini and Jiang (2009) provide a more detailed literature review of the link between regulation and investment, but conclude that more research needs to be conducted, as the findings across the literature are heterogeneous.

Regulation, geography and investment

A growing body of literature links geographic conditions to the regulation of NGA and, hence, to investment. For example, Amendola and Pupillo (2008) discuss the need for regulation to be based on geographically segmented regions beyond the national level as a result of the different competitive and geographical situations that exist across a country. In this way, investment within all geographic segments can be encouraged. Cave and Hatta (2009) distinguish between competitive, non-competitive and non-commercial geographic areas for regulatory solutions, suggesting a relationship between the geographic nature of the region, regulation and, consequently, investment in next-generation broadband. Nitsche and Wiethaus (2009) also allude to a link between geographical characteristics and investment in their analysis of investment incentives – that as remoteness increases and population density decreases, the investment cost becomes higher and the incentive to invest falls.

Other market factors

Apart from regulation, several other market factors with a link to investment in next-generation broadband have been identified in the literature. However, these were limited and are, therefore, collectively discussed in this single sub-section.

On a general level, Ruhle and Reichl (2009) identify two categories of market obstacles in next-generation broadband investment. They define the first category, market uncertainty, as being both supply- and demand-related. Where there is little or no demand from consumers for high-speed broadband services, Ruhle and Reichl (2009) explain that it is a challenge for operators to predict that demand and, consequently, the motivation to invest is curbed. Regulatory uncertainty, as other researchers have clearly shown, also hampers investment, as regulated firms are dis-incentivized to invest because of access-sharing obligations.

In examining the means by which regulators and policies can encourage investment in NGA, Huigen and Cave (2008) also identify several links between market conditions and investment. In the Asian markets, government policy interventions were instrumental. For example, government loans were offered to operators who were investing in high-speed networks. In Japan, unbundled local loops led to fierce competition between the incumbent and firms such as Softbank/Yahoo. Consequently, with the aid of government finances, NTT invested heavily in FTTH. According to Huigen and Cave (2008), infrastructure competition can also encourage investment.

Several other studies more explicitly identify a link between market factors and investment. In investigating the potential of competition in infrastructure among fibre networks, Soria and Hernández-Gil (2010) make some inferences about the factors that can encourage such investment. Firstly, they declare that the ownership of infrastructure assets can be a driver. Alternatively, the availability of ducts for lease can also be encouraging. Secondly, Soria and Hernández-Gil (2010) find that the nature of the company (such as their assets, synergies, technologies and performance) can influence if and how they invest.

Soria and Hernández-Gil (2010) also conclude that incumbents are dis-incentivized as a result of asymmetric regulation. For cable operators, however, the shorter delay in accruing profits with cable networks as compared to FTTH networks is an investment driver. Although they confirm these relationships by examining the entry decisions of operators in eleven European countries, Soria and Hernández-Gil's (2010) empirical analysis is limited to the findings and inferences from their initial theoretically-based cost model. Therefore, while other market factors may play a role in influencing investment, these are not considered in their paper.

Also investigating the development of fibre networks, an earlier study by O'Lessker et al. (1993) identifies several factors in the US that may directly or indirectly influence the development of FTTH, spanning a range of technical benefits to demand, cost and regulatory factors. However, as the research was done in the early stages of fibre deployment, its empirical basis is questionable.

Taking a different perspective, Brito et al. (2008) find that the nature of the expected innovation is influential in determining investments. The authors explain that if the innovation is drastic, that is, the quality of the network is much improved, the incumbent operator is motivated to invest, but does not give access to its competitor. However, this analysis is linked solely to incumbents. Ragoobar et al. (2010a) also highlight several influences of market factors on investment through a comparative European study, though this was a preliminary study.

Finally, in Nitsche and Wiethaus' (2009) examination of the impact of access regulation on investment, the authors develop a model that suggests the influence of several other market factors on the investment decision. Firstly, it is acknowledged that investment cost becomes higher as remoteness and population density increases, thereby discouraging the roll-out of infrastructure. Secondly, the authors highlight that the (un)willingness-to-pay of consumers has made the success of NGN yet uncertain, thereby, once more, having an adverse effect on the investment decision.

3.4 Research gap and emerging research questions

The review of existing literature above examines the economic implications of next-generation broadband and discloses that, while numerous benefits can be realized from investment in NGN and NGA, a multiplicity of investment issues continue to exist for potential investors. The review highlights a crucial link between this investment potential and market factors, consequently suggesting that variations in next-generation broadband investment are likely across the world.

While the studies in Section 3.3.2 divulge some of the causative factors towards the diversity in investment, several shortcomings of this literature can be identified. Firstly, it is evident that existing research has focused primarily on the role of regulation, with little attention being paid to other cited influences such as geography and deployment cost. In particular, an explicit and detailed description of the relationship between the market factors and the investment decision are not always provided. Secondly, with the exception of several regulatory-focused studies by Ruhle and Reichl (2009), Marcus and Elixmann (2008), Ragoobar et al. (2010b) and others, there is an evident lack of empirical data upon which the discussions are based. The 'value add' of robust empirically-based analysis is significant as such data serves to identify practicalities that may otherwise be overlooked or obscured. In this way, a more realistic representation of the situation, a more complete insight and useful results related to the phenomenon at hand is provided.

With the aid of the literature reviewed in this and the previous chapter, this thesis addresses the deficiency of empirical data on the market-investment interplay. As several aspects of the next-generation broadband investment decision have been highlighted in the literature, this research adopts an overarching research task of examining how market factors influence the general *development* of next-generation broadband. Five related research questions have been identified, shown in Figure 3-1.

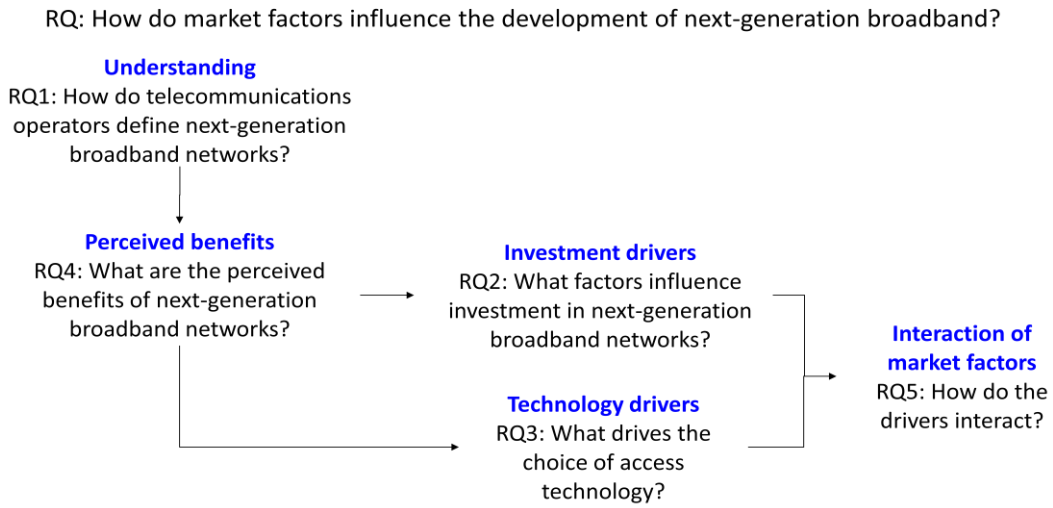

Figure 3-1: Research question framework

Firstly, as the most dominant issue in the literature and a principal aspect of the development of next-generation broadband, the market factors that influence the *decision to invest* in these networks will be examined (RQ2). This includes understanding the chain of relationships between market factors and the investment in next-generation core networks and next-generation access networks. Secondly, as the literature suggests that market conditions are likely to influence the benefits that emerge, the *expected benefits of next-generation broadband* will be explored (RQ4). Thirdly, as Chapter 2 illustrated, the decision to invest in NGA is accompanied by the *choice of access technology*, which also presents a dilemma for network operators. Thus, the factors related to this decision will also be studied (RQ3).

The three research questions that emerged from the literature review were the initial questions for the study. Later activities of the research, namely data collection and data analysis, revealed two additional issues that were subsequently included under the umbrella of research questions. The first is linked to an understanding of next-generation broadband networks. While hinted at in the literature, the differences in interpretations of the next-generation broadband term were emphasized during the interviews. Thus, in order to understand the meaning of next-generation networks in the broadband markets under study and to contextualize the data input to the research, the *definition of next-generation networks* was investigated (RQ1). The second addition emerged during data analysis, during which phase an *interaction* *among the market factors* and various aspects of next-generation broadband development was revealed. Ruhle and Reichl (2009) also hint at this interaction of market factors in their discussion. Being examined as the fifth research question (RQ5), the interaction of market factors was based on the results of the other four research questions. Figure 3-1 shows that the research questions are aligned to five themes.

It is important to mention that, although regulation is a key factor in the investment discussion, its significant influence on investment makes it difficult to include merely as a secondary topic in this thesis. Any extensive research on this subject matter was, therefore, intentionally omitted from the current study. This decision was complemented by the fact that much research already focus on the regulatory aspect of investment.

By empirically examining the research questions identified herein, insight into the incentives for the development of next-generation broadband and the areas of a market that need to be targeted in order to accelerate and successfully deploy NGN and NGA can be determined. In this way, the study not only fills the research gap in existing literature, but also provides a useful guide for policymakers and other investors in their decision to move to next-generation broadband.

3.5 Conclusion

The review presented in this chapter focuses initially on the impact of next-generation broadband networks on telecommunications markets. The review reveals that next-generation broadband has implications within five domains - end-user services and technical, regulatory, socio-economic and commercial areas. Though many benefits are expected with the deployment of next-generation broadband networks, many issues, mainly within the socio-economic and commercial aspects, are also introduced. A key finding within the literature is that market conditions influence how and the extent to which the benefits and issues associated with next-generation broadband are experienced. Consequently, investment in and the development of next-generation broadband have the potential to be diverse around the world.

The literature identifies several major investment issues, such as significant capital and unfavourable regulatory frameworks, which are linked to market conditions and, therefore, contribute to the investment dilemma. Though the existing literature hints at this link between market factors and investment, a close scrutiny of researchers' work in this field reveals that, with the exception of the regulatory perspective, little detail has been reported. As a result, the claims and relationships remain ambiguous. Furthermore, and again with the exception of the regulatory dimension, there is a distinct absence of a timely empirical evidence base. As these findings indicate that extensive work is required in this area, this study undertakes the task of empirically examining how market factors influence the development of next-generation broadband.

By exploring the results of the literature review, several key research questions were identified. Additional research questions were later included in the study based on fieldwork and data analysis. The five research questions and their corresponding themes are listed below:

- RQ1 – Understanding: How do telecommunications operators define next-generation broadband networks?
- RQ2 - Investment drivers: What factors influence investment in next-generation broadband networks?
- RQ3 - Technology drivers: What drives the choice of access technology?
- RQ4 - Perceived benefits: What are the perceived benefits of next-generation broadband networks?
- RQ5 – Interaction: How do the drivers interact?

The deeper understanding of the factors that influence the development of next-generation broadband that will be gained from this research is valuable for policymakers and investors in mapping their own strategies. As explained earlier in this chapter, such an understanding is crucial for the establishment of an appropriate enabling environment and, consequently, the successful realization of next-generation broadband.

4 Research methodology

4.1 Introduction

Collis and Hussey (2003, p55) define research methodology as "the overall approach to the research process, from the theoretical underpinning to the collection and analysis of the data." The methodology can influence the type of data obtained, the analysis of the data and, hence, the results. A successful research project is built upon a well-grounded methodology, the design of which, therefore, is a crucial stage within the research process.

This chapter presents the methodology adopted for this research. Section 4.2 describes the development of a conceptual framework, which was derived from the literature review and research questions and shows the arrangement of and links between the research variables. Section 4.3 describes the overall approach adopted for conducting the study. Section 4.4 discusses the various elements that comprise research methodology design, starting with an understanding of research philosophies and followed by a discussion of the research strategies, that is, the general means by which the research was conducted, and then specific data collection and data analysis methods. An explanation of how these choices were made and the limitations of the choices are presented.

The rest of the chapter focuses on the application of the chosen strategies and techniques, with data collection and fieldwork being described in Section 4.6 and a detailed account of the data analysis being presented in Section 4.7. Section 4.8 concludes with a summary of the methodology adopted. An accompanying compact disc (CD) contains several Appendices that are supplementary to this chapter.

4.2 Conceptual framework

Punch (2005, p151) defines a conceptual framework as one "showing the central concepts of a piece of research, and their conceptual status with respect to each other." The development of such a framework aids the identification of the variables and relationships that are important to the study, and gives an indication of what information should be collected and analyzed (Miles and Huberman, 1994). It focuses the objectives, requirements and organization of the research.

Figure 4-1 presents the conceptual framework developed for this study, and was derived from existing theory on the impact of market factors on the development of next-generation broadband as described in the previous chapter. Chapter 3 showed that services, regulation, technological, socio-economic and commercial aspects of telecommunications markets are affected by the development of next-generation broadband and vice-versa. Therefore, these five dimensions were considered to be the central focus of the conceptual framework, with technology as the starting point.

Several relationships, which can be mapped onto the research questions, can be identified from Figure 4-1. Table 4-1 demonstrates this mapping, which also highlights the application of the conceptual framework to answering the research questions. Although Punch (2005) recommends the use of the conceptual framework in identifying and clarifying research questions, the questions emerging from Figure 4-1 were numerous and at a detailed level and were, therefore, not adopted as formal research questions. Instead, these questions were considered to be more suitable for use during data collection and were used to develop the interview questions.

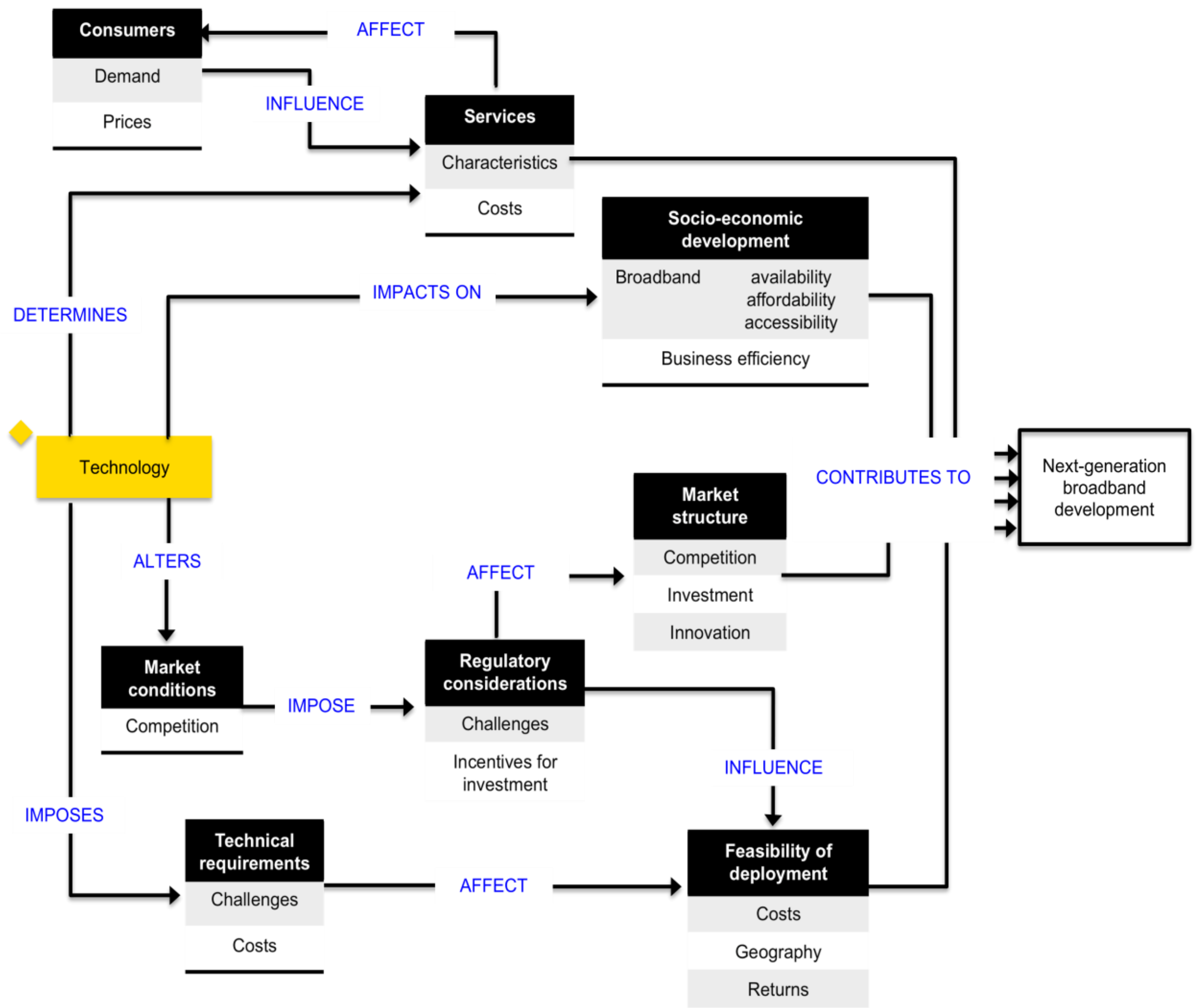

Figure 4-1: Conceptual framework

Research question	Use of conceptual framework
RQ1 How do telecommunications operators define next-generation broadband networks?	NA
RQ2 What factors influence investment in next-generation broadband networks?	What are the technical and economic challenges associated with the deployment of NGN and NGA? What are the regulatory concerns associated with the deployment of NGN and NGA? Does the regulatory framework need to be modified? Is there a demand for NGA services? What broadband services are currently used and how are they used? How is investment in NGN and NGA likely to affect the competitive nature of the operator and the market in general?
RQ3 What drives the choice of access technology?	What are the technical and economic challenges linked to a given technology? What services can be delivered by (new) technology, that is, by NGN and NGA? Can existing technologies deliver the services demanded of consumers? What is the status of technology competition in the market? Can infrastructure competition be sustained with the deployment of NGN and NGA? Does one access technology offer advantages over another – technically, economically and socially? Are there any regulatory concerns associated with the deployment of a given access technology?
RQ4 What are the perceived benefits of next-generation broadband networks?	How/Can competition be sustained with the deployment of NGN and NGA? What (unique) services can NGN and NGA deliver? How do NGN and NGA impact on business and residential consumers? How do NGN and NGA impact on operators? How do NGN and NGA affect availability and use of broadband?
RQ5 How do the drivers interact?	NA

Table 4-1: Application of the conceptual framework to answering the research questions

4.3 Research approach

A research project involves the use of theory. The research approach refers to how the theory is used for the given study (Saunders et al., 2007). The deductive approach, for example, involves developing a theory and hypotheses and testing these in a scientific manner (Saunders et al., 2007). The inductive approach adopts the opposite order – theory is developed from data that is collected, typically from within the setting of the studied subjects, and analyzed (Saunders et al., 2007). Identification of the research approach enables informed research design choices to be made, such as the nature and sources of data and research strategies (Easterby-Smith et al., 2002).

More importantly, the research approach can ensure that constraints of the study are minimized or effectively catered for. For example, lack of theory on the given research topic may mean that hypotheses cannot be developed, thereby making an inductive approach more suitable. Thus, knowledge of the approaches available and an understanding of the differences between them enable a researcher[9] to choose an appropriate approach for the given study.

An inductive approach was chosen for the current study for various reasons. Firstly, as next-generation broadband is a recent development, the available empirically-based material, upon which this study needs to be based, was limited. Therefore, the ability to develop robust hypotheses from the existing literature was a significant challenge. Rather, primary data collection and analysis were necessary in order to draw conclusions and develop theories and insights.

The second justification for an inductive approach lay in the purpose and nature of the study. The study was aimed at understanding and determining the relationship between market factors and various aspects of next-generation broadband development, such as understanding the networks, the investment decision, the benefits and the choice of technology. These concerns were best addressed by understanding the environment within which the decisions were made (the research context) and the stakeholders involved in the decision-making processes. In this way, a better perception of the variables, their link to decisions and why the decisions were made would be gained. Finally, by being open to emergent ideas and not being rigid with a set hypothesis, induction lends to a more flexible approach for investigating the influence of market factors. This is crucial as next-generation telecommunications is a dynamic and novel field and unexpected tangents can occur.

4.4 Research design

Punch (2005) uses the term 'research design' to refer to that aspect of research that connects research questions to data while Robson (2002) explains that the design is

[9] The term 'researcher' as used within this chapter can be vague, referring to either researchers in general or the researcher of this study. To differentiate between the two, the first is referred to as 'a researcher' while the latter is referred to as 'the researcher' or 'this researcher'.

the process that turns a research question into a research project. A research design is based on three elements of inquiry - philosophical assumptions of a researcher, strategies of inquiry and methods for data collection and analysis (Creswell, 2003).

Collis and Hussey (2003) and Saunders et al. (2007) explain that the philosophical assumptions or knowledge claims influence the strategies and methods adopted, and it was important, therefore, that this was first determined. Other factors, such as the nature of the study, also influenced the choice of research strategies and methods. Each of these elements, as applied to this study, is presented in the following sub-sections.

4.4.1 Philosophical underpinnings

Burrell and Morgan (1979, p1) declare that "all social scientists approach their subject via explicit or implicit assumptions about the nature of the social world and the way in which it may be investigated". These philosophical viewpoints of a researcher relate to the development of knowledge and the nature of that knowledge (Saunders et al., 2007). They position a researcher within a *paradigm*, which, in turn, influences the overall research design adopted.

The nature of social science is described by two fundamental assumptions relating to ontology and epistemology. Bryman and Bell (2007) explain that an ontological perspective is based on views about the nature of social entities. Two such views exist. Firstly, social entities can be considered objective entities that have a reality external to social actors. Conversely, they can be considered social constructions built up from the perceptions and actions of social actors. The same authors define epistemology as being concerned with the question of what is, or should be, regarded as acceptable knowledge in a discipline (Bryman and Bell, 2007).

The researcher of this study adopts the subjective or nominalist ontological position, which is reflected in several ways in the context of this study. Firstly, the researcher believes that, in practice, the decisions related to the development of next-generation broadband are influenced by stakeholders' perceptions such as the importance of the networks. This, in turn, is influenced by the environment within which the stakeholders are embedded. Different stakeholders may have different views with regard to priorities and decisions. Thus, the opinions and decisions may vary based on the role of the individual (that is, incumbent operator, alternative operator or regulator, for example) and across different environments. Additionally, the researcher believes that decisions change over time as market conditions change.

The researcher's epistemological position is based on the belief that knowledge can only be acquired from experience, that is, from interactions with social actors. This positions her within the 'sociology of regulation'[10] end of the 'regulation-radical change' dimension (see Figure 4-2). The researcher's epistemological belief is that it is more important to understand, describe and explain the market factors linked to the development of next-generation broadband and to offer recommendations than to focus on the disorder that exists with the aim of imposing change. In the perspective of the sociology of regulation, it is the researcher's inclination to understand and compare the developments under different market conditions, as understanding the harmony can provide insight into how lessons can be shared among countries where necessary. In other words, the principal aim is not to impose change within the different markets, but rather to understand the relationships and to offer and to suggest a change only if necessary. Consequently, considering both ontological and regulation-radical change positions, the researcher adopts the 'interpretive' epistemological stance, as Figure 4-2 illustrates.

An 'Interpretivist' believes that the social world consists of and is constructed through meanings, lending itself to research in which the phenomenon being studied is constructed by the individuals engaged with it (AS Sociology, 2006). The impact of the interpretive paradigm on this study is discussed in Sections 4.4.2 and 4.5.

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[10] 'Sociology of radical change' and 'Sociology of regulation' are two perspectives of the nature of society. The first advocates change while the latter is concerned with explanation. See Burrell and Morgan (1979).

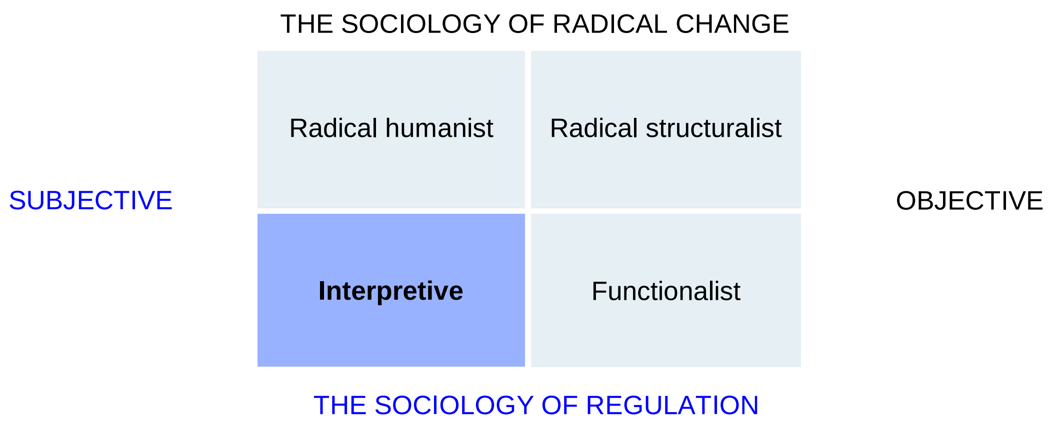

Figure 4-2: Four paradigms for the analysis of social theory
Source: Burrell and Morgan, 1979

4.4.2 Strategies of inquiry

Also referred to as methodologies (Collis and Hussey, 2003; Crotty, 1998), designs (Bryman and Bell, 2007) and research strategies (Punch, 2005; Saunders et al., 2007), strategies of inquiry are defined by Punch (2005, p48) as "the reasoning, or the set of ideas, by which the study intends to proceed in order to answer its research questions." For this study, the case study strategy was chosen. This section outlines the factors that influenced this choice and describes how the case study was designed.

Choosing the research strategy

The strategy of inquiry adopted for research was determined, in part, by the researcher's paradigm (Easterby-Smith et al. 2008). In the particular case of this research, the nature of the study also played a significant role. This section describes the influence of these two factors.

Research philosophy

Collis and Hussey (2003) declare that the research strategy chosen by a researcher should reflect his/her philosophical position. In the literature, several methodologies have been linked to each of the positivistic and phenomenological approach. The latter limits potential strategies to those that are phenomenological, inductive and participatory. Therefore, while case studies, action research, hermeneutics, grounded theory and ethnography can be used, experiments, cross-sectional studies, longitudinal studies and surveys are not primary research techniques used with the interpretive perspective (Collis and Hussey, 2003; Easterby-Smith et al., 2008). They can, however, be used as supplementary methodologies. Nonetheless, Collis and Hussey (2003) and Saunders et al. (2007) admit that, like paradigms, strategies can be moved along a continuum and are not mutually exclusive. Rather, other factors, such as the research topic, contribute to the decision of which strategy, or combination of strategies, to adopt. This list of phenomenological strategies, therefore, only provides a guide for the researcher.

Nature and expectations of the research

Saunders et al. (2007) suggest that research questions and objectives guide the choice of research strategy. This is indeed evident with the current study. A key component of this research was the analysis of next-generation broadband development within their environments, that is, the *context* of the deployment was crucial. As such, inherent in the nature and requirements of the study were the need to conduct the research within different environments and to gain an understanding of these different contexts. A comparison of several countries, which required that each of the chosen countries be studied and analyzed in sufficient detail, was necessary. Finally, based on Robson's (2002) categorization of research projects, this study is defined as an explanatory one. Such a study is aimed at determining the "causal relationships between variables" in order to explain the relationships (Saunders et al., 2007, p134). With the use of practical examples, this study aims to identify the influential market factors, their interaction and the causality of the links. The research strategy adopted for this study must facilitate the investigation of these causal relationships.

The case study strategy satisfied these philosophical and logical considerations. Robson (2002), Morris and Wood (1991) and Yin (2003) advocate the use of case studies in research where context is important and Saunders et al. (2007) say that the case study strategy is most commonly used with explanatory studies. These justifications for case study use are features of the current research.

Several other techniques were also considered for this study. Surveys, for example, would have offered the advantage of reaching a wide audience. However, surveys are generally useful when a testing a hypothesis, such as in a deductive study, and when a standardized set of questions can be asked. In addition, it is difficult to collect qualitative data using a survey strategy as both questions and responses may be limited. While interviews can be used with surveys, these too are generally standard (that is, structured interviews) and do not allow the flexibility of discussion required for the current study.

Both action research and ethnography are context-based research strategies like case studies and were, therefore, also considered. However, an action research strategy focuses on "research in action rather than research about action" (Coghlan and Brannick, 2005; Saunders et al., p140). Furthermore, action research involves making a change within the studied environment; this is not the aim of, and not possible with, the current study. Ethnography imposes similar obligations. In addition, both action research and ethnography are time-dependent while the current research is time-limited. Also, action research and ethnography would have required the researcher to be immersed in the decision-making process, which was not appropriate for this study.

Finally, a grounded theory strategy could have also been adopted. However, grounded theory eliminates the use of a theoretical framework. A framework is important to this study in order to target the participants and to focus the research topic, especially given the time constraints on the research and the potentially wide span of the research topic. In addition, grounded theory partially adopts a deductive approach that is difficult to utilize in this study, as the study is largely based on the practical management decisions made by stakeholders.

Case study design

A case study is "a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence" Robson (2002, p178). It is vital that the case study is well-constructed in order to provide effective answers to the research questions. Miles and Huberman (1994) approach the case study design by considering three major requirements, as follows:

- *case definition* - defining the case and case boundaries or ‘bounding the territory’
- *sampling* - identifying the subjects of data collection or ‘bounding the collection of data’ and
- *instrumentation* - outlining the methods of data collection and recording.

These three tasks are interrelated but, more importantly, the case must be defined before the samples can be identified. This discussion now focuses on these elements of the case study design.

Defining the case

The ‘case’ of case study research refers to the object or phenomenon of interest that a researcher aims to explain or investigate, occurring within a bounded context (Bryman and Bell, 2007; Miles and Huberman, 1994). In addition, a sub-case, known as a ‘unit of analysis’, can exist within a single case. This is considered to be an entity about which data will be collected and analyzed in reference to the variables or events under study and the research question (Collis and Hussey, 2003; Easterby-Simth et al., 2008).

According to Yin (2003), four types of case study designs, based on the number of cases (single or multiple) and the units of analysis (holistic or embedded), can be identified. For this study, multiple cases were inherent, as a comparative assessment of countries was the main objective of the research. Although Yin (2003) argues that multiple cases are valuable when a generalization of results is the target, generalization was not the aim of the current study. Rather, multiple cases were a crucial part of this study in order to comparatively assess the impact of market factors on the development of next-generation broadband, making the variable of market conditions an important one. According to Silverman (2005), multiple cases are best suited for studies in which replication is important, or alternatively, in which contrasting or comparable environments are an essential requirement.

The second design consideration of the case study strategy is the unit of analysis. A holistic case study is one in which the single unit of analysis is considered as a whole. An embedded case study is one in which various segments of the unit of analysis are examined individually. This research takes the form of a holistic case study in which the unit of analysis is the broadband telecommunications market (or a country). The decision to use a holistic approach was taken as the aim of this study is to determine the impact of market factors on the development of next-generation broadband, thereby considering a market as a whole unit. The study is not concerned about the individual decisions made by the various stakeholders, the role of the stakeholders or the individual organizational decisions, but, rather, about the impact of the market conditions on the deployment and investment decisions of the country as a whole.

Sampling

The next stage of case study design, as described by Miles and Huberman (1994), is identifying the samples from which data will be collected. Miles and Huberman (1994) discuss two dimensions in which sampling is required - across cases and within cases. These are described below.

- **Across-case sampling**

Across-case sampling refers to determining the overarching cases. For the current study, a case referred to a next-generation broadband market. Initially, a sampling frame, which is “the list of all those eligible to be included in a sample”, was developed (Easterby-Smith et al., 2008, p332). The sampling frame was based on the research questions and the conceptual framework, along with several criteria that the samples must satisfy (criterion sampling[11]) (Miles and Huberman, 1994). As the research was focused on examining the impact of market factors on the development of next-generation broadband, countries within which these developments were evident were necessary. Secondly, evidence of varying levels of development and investment in next-generation broadband was crucial, so that the impact of market

[11] Criterion sampling is aimed at selecting cases that meet a given criterion (or criteria) (Kuzel, 1992; Patton, 1990).

conditions could have been compared effectively. The final criterion was a constant, or similarities, among the market conditions. In this way, the reasons for the disparities in development and investment could have been properly examined. Based on this and practical considerations, Europe was selected as the target region.

A combination of intensity sampling, criterion sampling and convenience sampling[12] were then used to reduce the sampling frame to the individual countries shown in Table 4-2. Intensity sampling targeted the cases that exhibited the characteristics being studied and provided ‘information-rich’ samples (Kuzel, 1992; Patton, 1990). This was primarily based on an examination of next-generation broadband development, policies, regulations and geography. The final stage of sampling was linked to convenience whereby countries were chosen based on practical considerations such as time, cost and ease of access.

	NGN investment	NGA investment	Access technology	European Union (EU) regulation	Geographically comparative
The Netherlands	◑	◕	cable and fibre	✓	✓
Sweden	◔	◑	fibre	✓	✓
United Kingdom	◕	◔	cable and fibre	✓	✓

Key

◔● Relative level of investment

✓ Market characteristic

Table 4-2: List of final cases

As Table 4-2 shows, The Netherlands, Sweden and the United Kingdom (UK) were chosen as the three case studies. The combination of varied NGN and NGA investment and diverse market conditions among the three countries was evidence that there is some interplay among market factors that influence private sector investment in next-generation broadband. Therefore, the three countries were

[12] Convenience sampling targets cases that “save time, money, and effort, but at the expense of information and credibility.” (Kuzel, 1992; Patton, 1990)

deemed useful for understanding, within a European context, how these factors interact and if and how lessons can be transferred across markets to encourage the development of next-generation broadband. As such, they were considered to be valuable in achieving the objectives of the study.

- **Within-case sampling**

Within-case sampling refers to the selection of informants within each of the cases defined for the study. Informants were chosen based on the research questions. This was done using quota selection, in which the major subgroups of informants for each research question/theme were identified from theory (Goetz and Lecompte, 1984). This relation is shown in Table 4-3. However, the number of participants selected was not random as Goetz and Lecompte (1984) define of quota selection. Instead, quota of participants was based on the participants' level of involvement and exposure to the development of next-generation broadband, in both technical and managerial capacities. It is important to note, however, that the initial samples were subject to iterative variation as the fieldwork was conducted. For example, information obtained from one party led to questions that involved a group of participants or an individual not initially considered (Miles and Huberman, 1994). In addition, practical issues such as participant availability, access and willingness to participate influenced the list of participants.

Research question	Major groups of informants
RQ1 How do telecommunications operators define next-generation broadband networks?	Incumbent and alternative network operators, service providers
RQ2 What factors influence investment in next-generation broadband networks?	Incumbent and alternative network operators, service providers, regulators, researchers
RQ3 What drives the choice of access technology?	Incumbent and alternative network operators, service providers, regulators, equipment vendors, researchers
RQ4 What are the perceived benefits of next-generation broadband networks?	Incumbent and alternative network operators, service providers, regulators, equipment vendors, researchers
RQ5 How do the drivers interact?	All groups of informants and also based on the findings of the study

Table 4-3: Major groups of informants

Instrumentation

Miles and Huberman (1994) view instrumentation as a conceptual design decision that indicates how data will be collected and recorded. In the particular application of a case study strategy, Yin (2003) incorporates instrumentation as part of a larger requirement for case study preparation, that is, the development of a case study protocol. The case study protocol is a field guide for the collection of data from a single case (Yin, 2003). For this study, the case study protocol was developed from a combination of the individual case study design components. A major component was the instrument for data collection – semi-structured interviews. This is described in detail in Section 4.5.1. While using such a protocol is recommended for any case study research, it is essential for multiple-case studies (Yin, 2003). By ensuring that issues are considered and addressed beforehand (that is, before the fieldwork), the protocol was a means of increasing the reliability of the current research.

4.5 Research methods

Creswell (1994) identifies research methods as the third and final contributor to the research approach. Research methods refer to the techniques by which data is collected and/or analyzed (Collis and Hussey, 2003). This section describes the choices for this research. As they are different techniques in their own right, data collection methods and data analysis methods are discussed separately.

4.5.1 Data collection methods

Data collection, as the name implies, refers to the acquisition of data for the research being undertaken. This part of the research design was concerned with how data will be collected (what procedures?) and recorded (what instruments?). The considerations made in choosing the data collection methods and the design of these techniques are now discussed.

Choosing data collection methods

Like the research strategy, the choice of data collection method was influenced by factors such as the researcher's paradigm and the research being undertaken. In this study, the research strategy adopted also impacted on the data collection techniques to some degree. These influences are described below.

Research paradigm

As discussed in Section 4.4.1, the paradigm adopted by a researcher reflects the perspective of how reality exists, the nature of knowledge and how knowledge can be developed. With the interpretive paradigm adopted by this researcher, understanding and considering the perspectives of the participants in a study is the key to producing new knowledge. The research methods adopted by this researcher, therefore, must have facilitated this interaction, involvement and interpretation with/of the subjects. While methods are not strictly located within a single paradigm, Easterby-Smith et al. (1991) identify interviews, observation and diary methods as being suitable within the interpretive paradigm, while questionnaires and surveys are easier to use within a positivistic paradigm. Like research strategies, this list served as an indication of the methods that could be utilized within this study.

Nature and expectations of the research

In examining the objectives of the study, several data collection requirements were identified. Firstly, (primarily) qualitative data was necessary as the factors influencing the investment decision, for example, were subjective (such as regulatory policies). Secondly, several factors of next-generation broadband deployment were being considered in the research. Thus, input from various types of stakeholders involved in the decision-making process and the development of next-generation broadband, such as incumbents and regulators, were required. As a result, a data collection method that was flexible, open and provided an easy means of comparing responses was required. As many individuals were involved, it was important to understand the personal experience of each so that the reasons for the decisions made will be clear.

Among the qualitative-based approaches, Saunders et al. (2007), Collis and Hussey (2003) and Bryman and Bell (2007) suggest that interviews satisfy these requirements. Interviews are data collection methods that ask questions to determine what the interviewees "do, think or feel" (Collis and Hussey, 2003, p167). Saunders et al. (2007) also explain that interviews are one of three principal methods of undertaking explanatory research such as this one.

Case study strategy

The comparative case study strategy adopted for this research also influenced the choice of data collection method. In their treatment of case studies, Yin (2003), Saunders et al. (2007) and others advocate certain data collection methods more apt than others. Yin's (2003) list contains six such techniques, namely documentation, archival records, interviews, direct observations, participant-observation and physical artifacts. While interviews have been endorsed as a primary data collection technique with case studies, Yin (2003) suggests that a single source of evidence is not more beneficial than another. Rather, he explains that his six sources are complementary and several should be used where possible.

Based on the influences of these three factors - the research paradigm, the nature of the research and the use of case studies – interviews, documentation and archival records were chosen as the data collection methods for this study, with interviews being the primary source. It is worth mentioning that questionnaires could have also been used to collect data but the engagement of the researcher, the flexibility of the questions asked and the number and extent of responses would have been constrained. These characteristics of the data collection were important for this study. The design of the data collection methods is discussed in more detail in the subsequent sections.

Design of data collection methods

Corbin and Strauss (2008) stress that, although several factors contribute to the quality of data analysis and the results obtained, the quality of the materials being analyzed is one of the most significant. It is crucial, therefore, that the techniques used for gathering this material, the data collection methods, are well formulated. With this in mind, this section focuses on the design of the interview and documentation methods chosen for this study.

Interviews

An interview design includes the identification of the type of interview, the selection of interviewees, the measures carried out in preparing for the interview and those involved in the actual interviewing process, such as documenting and recording the session. With the exception of the choice of interviewees, which was described in Section 4.4.2, these elements are discussed hereunder.

- **Structure of the interview**

An interview can be regarded as a "purposeful discussion between two or more people" (Kahn and Cannell, 1957, p149) that can follow varying degrees of formality and structure (Saunders et al., 2007). Three types of interviews of varying formalities are identified within research methodology literature, with the semi-structured interview, chosen for this study, lying between the two extremes. The semi-structured interview involves questioning based on a predetermined theme(s) and questions, but is flexible in the questions asked, the order of questions and the nature of responses (that is, the questions are open-ended).

In this study, the semi-structured interview facilitated the versatility required in obtaining information from the wide span of participants of varying backgrounds (Welman et al., 2005). It allowed flexibility of the questioning procedure such that the logic and order of questions were varied according to the context of the interviewee and to the responses provided. The semi-structured interview allowed interaction between the researcher and the interviewees such that an understanding of both the environment and their impact on decisions were grasped. The semi-structured interview also provided the opportunity for the emergence of new sources of data and insights into events otherwise unavailable. These included, for example, deployment strategies or technological failures that were not publicly announced. The semi-structured interview enabled clarification, via probes, of issues or answers that were not blatantly clear (Easterby-Smith et al., 2008; Saunders et al., 2007; Welman et al., 2005). Finally, the interview approach made sensitive information, such as failures related to deployment, easier to discuss. Each of these was vital for the current study.

- **The interview guide**

Semi-structured interviews are guided by a list of predetermined themes and questions, referred to as an interview guide. Welman et al. (2005, p166) provide an expanded interpretation, that an interview guide is "a list of topics and aspects of these topics (note, not specific questions) that have a bearing on the given theme and that the interviewer should raise during the course of the interview…".

For this research, an interview guide was developed for each subgroup of participants as each subgroup has a different role within the next-generation broadband market. Therefore, they were interviewed from different perspectives. The guide was developed from the conceptual framework and the research questions. Although different interview guides were developed for each group of participants, many of the themes overlapped and variations were made even within the same category as interviews were conducted. For example, questions were added to the interviews based on emerging information. The interview guides were the main part of the case study protocol described in Section 4.4.2. An example of an interview guide is included in Appendix II.

- **Recording and documenting interviews**

For this research, interviews were digitally recorded upon permission of the interviewee. Firstly, recording interviews minimized the distraction of note-taking hence allowing the researcher to focus on the interviewee's responses and identify lines of inquiry. Secondly, it allowed repeated plays of the interview and, therefore, the opportunities to pick up and clarify issues that may be have been originally overlooked/misunderstood. Finally, recording allowed the data to be examined by other researchers (Heritage (1984) in Bryman and Bell, 2007). However, a significant drawback of recording the interviews was its potential to make respondents uncomfortable and reserved in their responses, limiting the effectiveness of the interview. This was mitigated by obtaining prior approval from the participants and by allowing the participants to subsequently review and amend the discussion.

In cases where permission was not granted, note-taking using an interview protocol was used (Creswell, 2003). The protocol was an expanded version of the interview guide, incorporating the research themes and questions, probes, the interviewee's answers where possible, the researcher's comments and reflective notes (adapted from Creswell, 2003). Answers to questions and general themes and their relationships emanating from the respondent's discussions were documented. As with the recorded interview, the interview notes were reviewed by the participant shortly after the interviews were conducted. In this way, the data collected at this stage was as accurate a reflection of the participant's opinions as possible.

Documentation and archival records

Yin (2003) differentiates between documentation and archival records, the difference being based on their use. Documentation was primarily used to corroborate data collected from interviews and support the claims made. For example, trends in the use of existing broadband services among consumers were captured from documented sources. In addition, administrative documents and formal studies of the cases, where available, were also utilized to enlighten the study. Archival records were more commonly used to inform the study (Yin, 2003) and played a key role in gathering information about technological deployments and their status and other background information, for example. Statistics regarding the penetration of technologies are generally recorded by regulators, consumer panels and operators, and were, therefore, obtained from these archived records.

4.5.2 Data analysis methods

Data analysis involves "making sense out of text and image data" (Creswell, 2003, p190). This stage of the research process relates the data collected back to the initial research questions and hence leads to the development of the conclusions of the study. Miles and Huberman (1994) consider three operations in analyzing qualitative data that were adopted for this study. These are highlighted below:

- *Data reduction* - selecting, focusing, simplifying, abstracting and transforming field notes and transcripts.
- *Data display* – developing an arranged assembly of the information that allows conclusions to be made and further action to be taken.
- *Conclusion drawing/verification*.

These activities took place simultaneously and throughout both the data collection and data analysis phases. In addition, they together formed an interactive and continuous process, as shown in Figure 4-3. The interaction and iteration ensured that the required data was obtained as far as possible and was focused to answering the research questions, that inconsistencies and uncertainties were clarified and that any findings were soundly drawn.

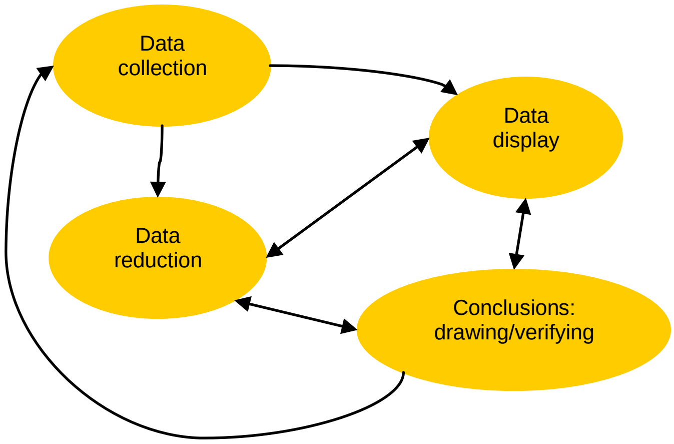

Figure 4-3: Components of data analysis: Interactive model
Source: Miles and Huberman, 1994

In the process of data reduction, NVivo, a Computer Aided Qualitative Data Analysis Software (CAQDAS), was used, primarily because of the large volume of data that was involved in this research and the efficiency with which the analysis given that the research was a time-constrained one. The use of software also provided a simple yet flexible and powerful means of organizing the interview data, observations made during the fieldwork and any other memos and notes written during the research period. This ensured that all data related to the study were kept in an organized manner in one location.

After comparing several packages, such as ATLAS.ti and NVivo, NVivo proved to be the most suitable for this study. NVivo allowed the entry of long code names, which meant that the names could be adequately descriptive for the researcher to remember their applications. In addition, NVivo is widely used in the university, so that access to and support for the software was easily available. Finally, NVivo provided the capability to export files in a format that could be used by Decision Explorer, another software package used in this research. This compatibility between the two was considered to be a key factor in the decision to use NVivo. During the course of the data analysis, several features of NVivo were found to be extremely useful and added to its value, including the ability to review the context of the coding as surrounding words, sentences or paragraphs, and the ability of the software to recognize and ignore duplicated coded entries. Since the interview data were large in volume, these features were particularly valuable.

4.5.3 Limitations and practical constraints

As can be gathered from the preceding discussions, the requirements imposed by both the nature of the study and the researcher's world view were satisfied by the multi-method multiple case study strategy. Although this strategy was carefully chosen, several challenges exist.

The multiple case study approach satisfied the key requirement to analyze several countries and their deployment decisions in detail. However, with an imposed time restriction, the number of countries as well as the detail with which they could have been studied became a challenge. Thus, the use of archival data, careful selection of case countries and prudent time management were key priorities. As previously discussed, however, the selection of countries was already narrowed by the limited deployment of next-generation broadband across the world.

In addition, obtaining access to and cooperation from organizations and broadband stakeholders for data collection was problematic in some instances. The establishment of a relationship with organizations beforehand was helpful in this regard. Access to the target organization was also made easier by exploiting existing affiliations between the target participants and the researcher's University and personal contacts. A third technique - careful selection of case studies, such as those that have readily available information – was also used to mitigate the effects of this difficulty. The same technique was applied to the challenges of language barriers and culture differences. While it would have been useful to learn the native languages, this was not practical in this study. Familiarity with participants was also useful in addressing issues of confidentiality codes.

Another practical challenge with the research methodology was the development of effective questionnaires and interview questions and their analysis.

While not only being time consuming, the development of interview questions that could competently and adequately address the researcher's needs was not straightforward. Pilot interviews significantly assisted in this regard but, unfortunately, no foolproof solution really exists. Rather, the interview process had to be well time-managed and carefully thought through and the interview questions revised as the interviewing process progressed. It can be seen that, although suitable, the multi-method multiple case study approach was not flawless in its application to this research, and that careful planning was required to address difficulties that may have arisen.

4.6 Data collection

This section shifts the focus of the research methodology from its theoretical design to its empirical application. The focus of this section is the data collection stage and describes the preparation that was done for the data collection and the actual fieldwork activities.

4.6.1 Preparing for data collection

In general, the activity of data collection is influenced by the preparatory measures undertaken. For this study, several preparatory requirements were imposed by both the University and the logistics of the data collection activity. Ethical approval for conducting interviews, for example, was required and the distribution of consent forms and information sheets to participants was necessary prior to the interviews. The development of interview material and the performance of test interviews were also key preparatory activities. Details of each of these, including sample documents, can be found in Appendix II. Since pilot interviews have a direct impact on the actual data collection process, a brief discussion of their contribution is presented in the following paragraphs.

A pilot test is a small-scale test of a questionnaire, interview or observation checklist before they are administered (Saunders et al., 2007). Two pilot interviews were conducted for this research. One participant was an ex-employee of an international telecommunications incumbent and a mobile operator. In both companies, the participant held a Senior Legal position. The second participant was a researcher in the telecommunications industry. These participants were chosen because of their experience in the telecommunications industry, their dis-association with the study and for practical reasons, such as availability.

The pilot interviews provided an opportunity to test the interview questions for applicability, answerability and clarity and to estimate the duration of the interview. It also gave the researcher the experience of conducting an interview. One of the key outcomes of the pilot interviews was a realization that the interview discussion can take any direction and that the order of interview questions, as outlined in the interview guide, was not important. However, attention to the flow of the discussion to suitably answer the relevant questions must be paid. A second important result was the need to clarify and re-phrase some of the interview questions. In general, the pilot interviews were useful in preparing the researcher emotionally, mentally and technically for the real interviews and were considered to be vital preparatory measures.

4.6.2 Fieldwork

The fieldwork for this research involved conducting semi-structured interviews with selected key members of the Dutch, Swedish and British telecommunications markets. This section summarizes the work conducted and the experiences in each market.

In The Netherlands, fifteen members of the telecommunications sector were interviewed over a nine-day period. The participants ranged from the incumbent operator, alternative fixed operators and representatives, the regulator, competition authorities, community leaders, consultants and researchers. Participants from the Dutch market were chosen based on their job relevance, recommendations and by their availability and are described in Table 4-4. With the exception of two interviews, one of which was held in a restaurant and the other conducted via telephone, all interviews were held at the participant's location. The Dutch interviews lasted seventy-five minutes, on average. Fourteen interviewees allowed the discussion to be recorded. Notes were taken for the single interview that was not recorded.

Expert	Sub-group	Role
1	Fixed alternative operator	Manager, Network Operations
2	Incumbent	Business consultant, All-IP strategy
3	Consultant	Researcher and Founder
4	Consultant	Senior advisor and Partner
5	Consultant	Partner
6	Regulatory body	Head of Unit Network Sectors and Media
7	Regulatory body	Case Handler
8	Researcher	Founder and local champion
9	Regulatory body	Directorate General for Energy and Telecom
10	Regulatory body	Deputy Director, Department of Markets
11	Regulatory body	Economist and Senior Worker
12	Cable operator association	Director
13	Incumbent	Director, Wholesale and Business Development
14	Researcher	Program Manager of Programs 'Next-generation infrastructures' and 'The future use of the Internet'
15	Incumbent	Director of Regulatory and European Affairs

Table 4-4: The profiles of Dutch participants

Eleven members of the Swedish telecommunications sector were interviewed over a one-week period. The participants included employees of alternative infrastructure providers (such as utility companies), the regulator, fibre project organizations, consultants and researchers. These interviewees were selected based on their job relevance and recommendations. Interviewees are described in Table 4-5. All interviews were held at the participant's location. The Swedish interviews averaged seventy-five minutes in length and all interviewees allowed the interview to be recorded.

Expert	Sub-group	Role
1	Regulator	Consumer Market Division – broadband issues and access to rural areas
2	Researcher	Strategy formulation for large mobile equipment vendor
3	Alternative infrastructure provider	Chief Executive Officer
4	Alternative infrastructure provider	Business strategy development
5	Consultant	Project Manager for home and access network development; Liaison with large mobile equipment vendor
6	Consultant	Senior Advisor for open networks for large mobile equipment vendor; Advisor on business models to municipalities and European Commission
7	Regulator	Competition Department, Economic analysis
8	Consultant	Advisor on fibre deployment for non-profit housing companies
9	Researcher	Professor and Head of the Division of Technology and Society
10	Regulator	Competition Department, Market analysis of network infrastructure access
11	Researcher	Liaison with the Royal Institute of Technology for wireless services and optronics

Table 4-5: The profiles of Swedish participants

In the UK, fifteen key members of the telecommunications sector were interviewed. As a result of the (un)availability of the participants, the interviews were spread over two months. Participants included employees of the incumbent operator, alternative fixed operators, wireless operators, the regulator and researchers. Participants were chosen based on their job relevance and by recommendations from other participants. Practical considerations, such as availability, also influenced who was interviewed. The final participants are described in Table 4-6. Interviews were held, in most cases, at the interviewee's office. In a few cases, phone interviews were conducted. One interview was a 'travelling' interview in which the interviewee provided a tour of the company's sites and operations. The interviews lasted from thirty minutes to three hours, with an average duration of seventy-five minutes. All interviewees allowed the discussion to be recorded.

Expert	Sub-group	Role
1	Incumbent	Director Communications of Wholesale and NGN Communications
2	Wireless operator	Technical and IT services
3	Regulator	Head of Research and Development; Policy activities
4	Incumbent	Strategy and Portfolio
5	Alternative operator	Capacity planning and capacity management
6	Wireless operator	Head of Engineering Delivery
7	Incumbent	Head of Portfolio Projects
8	Incumbent	Regulatory policy and strategy on NGA
9	Incumbent	Head of FTTP Programmme
10	Wireless operator	VP Strategy and Planning
11	Wireless operator	Chief Executive Officer
12	Wireless operator	Marketing Director
13	Researcher/Consultant	Member for England on Communications Consumer Panel; Consultant
14	Alternative operator	Technology Division
15	Alternative operator	Engineering Planning Manager

Table 4-6: The profiles of British participants

4.7 Data analysis

The three stages of the iterative data analysis process shown in Figure 4-3, as used in this study, are described in this section. After providing a description of how data was prepared for analysis, the data reduction process is described in Section 4.7.2, data display in Section 4.7.3 and conclusion drawing in Section 4.7.4.

4.7.1 Data preparation

For this study, data preparation involved transforming the interview data to a format that could be reviewed by the participants in order for the data to be verified. The recorded interviews were stored in mp3 format and, therefore, enabling data analysis to be performed directly on the audio file. However, for several reasons the recorded interviews were transcribed. Firstly, a written report of the interview gave the interviewee the opportunity to review and verify the information, adding, deleting or indicating data segments as confidential as necessary. A review of the interview report before the data was actually used in the research not only made the data more reliable, but also gave the participant a sense of comfort during the actual interview process, thereby facilitating a more open discussion.

Secondly, a written record of the interview made it easier for the researcher to search the material during the analysis process for phrases, keywords or to simply to review the interview at any time. Finally, the transcription process, although time-consuming, enabled the researcher to re-live the interview, particularly at her own pace, so that any information overlooked or misunderstood during the interview could have been identified and clarified. In order to capture the value of the responses, the interviews were transcribed verbatim. Appendix IV contains a sample of a transcribed interview.

4.7.2 Data reduction

Data reduction is the process of selecting, focusing and simplifying the data collected (Miles and Huberman, 1994), ensuring that the scope of the study is maintained and that a focused approach to the research and the analysis is followed. Saunders et al. (2007) refer to this process as 'categorizing' and 'unitizing' the data. The data reduction done for this study, achieved via coding, is described in this section. Both the coding process and the observation made during the coding process are described. More information on how NVivo was used can be found in Appendix III.

NVivo coding

Coding is one of the most common techniques of data reduction and is described by Rossman and Rallis (1998) as the process of organizing the material into chunks before bringing meaning to those chunks. The chunks are labeled such that they can be identified within the context of the research and used to organize and retrieve the data.

Different types of coding are used at different stages of data analysis (Cybernos, 2009). However, because coding was only utilized in this study to reduce and structure the data collected, only two of these classes of coding were adopted, namely open coding and axial coding. Open coding involves identifying and labeling the relevant information in the text while axial coding organizes the individual chunks of labeled data. In NVivo, this was achieved by the construction of *trees*, which is a hierarchical organization of the categories of data (nodes).

Figure 4-4 is a screenshot of NVivo that illustrates how open coding was conducted. The text shown is the transcribed interview imported from Microsoft Word. The coloured stripes on the right show the codes that were used and the range of text that they cover. For example, the text highlighted in yellow is coded by ‘perception of access network’. This coverage of this code is shown as a red stripe on the right side.

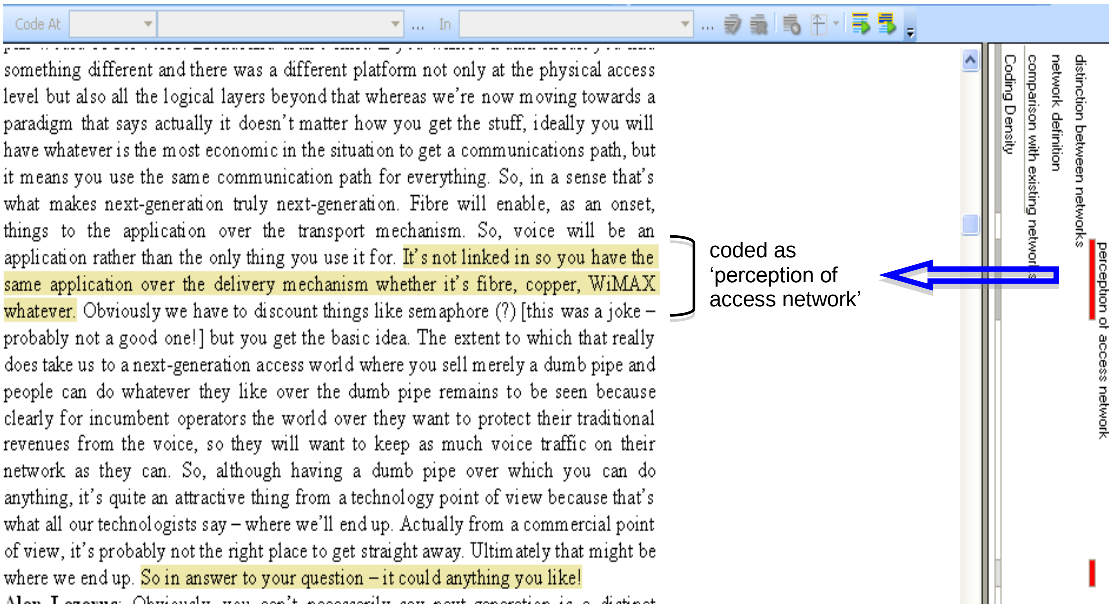

Figure 4-4: A screenshot of NVivo illustrating the coding process

Figure 4-5 shows how this text was positioned within the tree structure, illustrating an example of the axial coding process. Starting with the general category of ‘Network description’, sub-codes of ‘comparison with existing network’ and ‘network definition’ were created. These were further divided as other sub-categories or dimensions emerged. The coded text from Figure 4-4 was added to the ‘perception of access network’ segment of the tree shown in Figure 4-5. Since the entire tree is large, Appendix III shows part of the final structure.

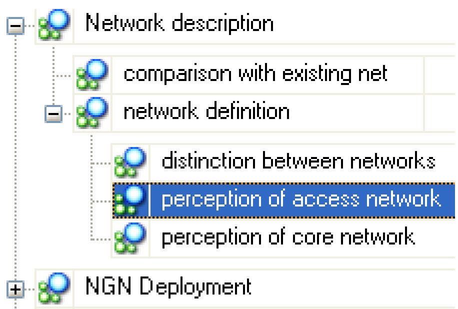

Figure 4-5: A result of axial coding

NVivo analysis

The objective of using NVivo in this project was to store, reduce and organize the large amount of qualitative data collected from the interviews. Although more extensive data analysis was conducted outside of NVivo, the initial stage of analysis was done using this software. Two major analyses were focused on – identifying key topics and making initial, general observations. These were achieved using the node summary reporting capability and by making observations during the coding process.

Following the examples used in Figure 4-4 and Figure 4-5, Figure 4-6 is a snapshot of the node summary report showing the statistics of the node ‘perception of access network’. As Figure 4-6 shows, the report provides a breakdown of all the references made to the node at different levels of detail – number of sources (that is, number of participants), number of references, number of words and number of paragraphs. Nodes with a high frequency can be cited as being commonly discussed and, consequently, important topics among the interviewees.

perception of access network — **Tree Node**

Created On	24/09/2009 14:37	**By**	TR
Modified On	24/09/2009 14:37	**By**	TR
Users	1		
Cases	0		

Type	Sources	References	Words	Paragraphs	Region	Duration	Rows
Total	3	15	663	9			0

Figure 4-6: Snapshot of Node Summary report

The coding process itself also revealed several patterns that were noteworthy at this first level of analysis. Findings such as a distinction between the perception of next-generation networks and next-generation access networks and the link of NGA to fibre technology, for example, were revealed. This process also highlighted the key topics from the discussions. These general findings from the coding analysis were pursued with data displays to produce more concrete conclusions, as explained in Section 4.7.4.

4.7.3 Data displays

Miles and Huberman (1994, p11) identify data display as the second stage of analysis activity and describe a display as "an organized, compressed assembly of information that permits conclusion drawing and action". Displays can take one of two general formats – networks and matrices (Miles and Huberman, 1994). Networks comprise nodes with links between them and are useful when the analysis involves understanding many variables at the same time (Miles and Huberman, 1994). The data display and subsequently the core of the analysis in this research were done using networks.

Miles and Huberman (1994) identify four categories of displays, namely partially ordered, time-oriented, role-ordered and conceptually oriented. Conceptually oriented displays are used to organize the information by concepts or variables, rather than by time or roles as the time- and role-ordered displays do. Since this study was focused on identifying market factors and relationships, the conceptually oriented display was considered to be most suitable for this research. In particular, cognitive and causal mapping were employed based on the nature of the individual research questions and overall research objective, as explained in the following paragraph.

This research was aimed at determining the market factors that influence next-generation broadband development and how these factors impact on the decisions of operators and policy-makers, based on empirical evidence. This required, therefore, a proper reflection and understanding of market players' contribution. Perhaps more importantly, however, was the need to determine and understand the relationships and links among the factors. Cognitive mapping addressed the first requirement while causal mapping was effective in illustrating drivers and their effects. Cognitive mapping identifies "chains of thinking" (Ackermann, 2009) and was performed using Decision Explorer. Causal loop diagrams are useful for examining the wider structure and showing feedback loops that exist among variables (Pidd, 2004). The causal loops were produced in Vensim PLE. Vensim PLE provides a user-friendly interface for producing causal loop maps and was only used for this display purpose.

The mapping process

Decision Explorer was used to create cognitive maps of the interviewees' responses on a research question basis, as illustrated in Figure 4-7. By immediately examining the objectives of the research as they were linked to the research questions, the data analysis process was more focused. The organization of the data in NVivo meant that locating the relevant responses for a given research theme was simplified.

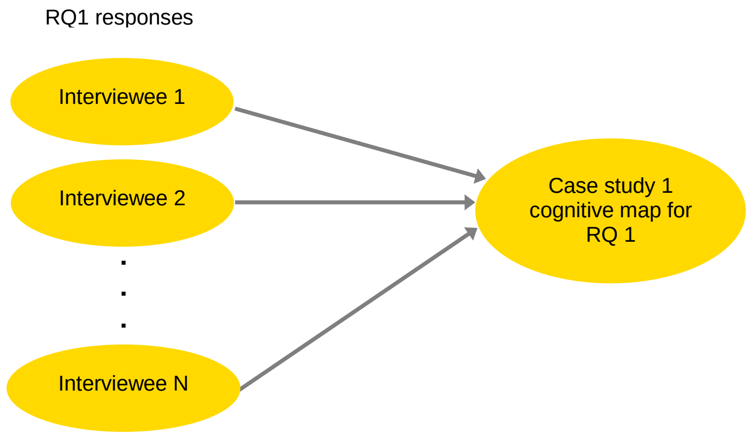

Figure 4-7: Approach to developing cognitive maps in DE

By continuing with the 'perception of access network' example, Figure 4-8 illustrates the mapping process for RQ1 for a single case study. Part of this research question examines the definition of next-generation access networks. The related data is found in NVivo under the 'perception of access network'. As Figure 4-8 shows, the interview text for this node can be directly viewed. The first reference implies that the access network will create in situation in which the application will be delivered over any transport mechanism and, therefore, different access technologies can be used. This chain of relationships is mapped as concept 1, 2 and 4 on the investment map in Figure 4-8. The second reference in NVivo in Figure 4-8 expresses uncertainty in the definition of NGA and is mapped as concept 5 on the cognitive map. Appendix VIII contains a sample of a cognitive map created from the raw interview data and before any analysis was done. The map is not included for its data but rather to illustrate the complexity of the original cognitive maps created from the interviewees' responses.

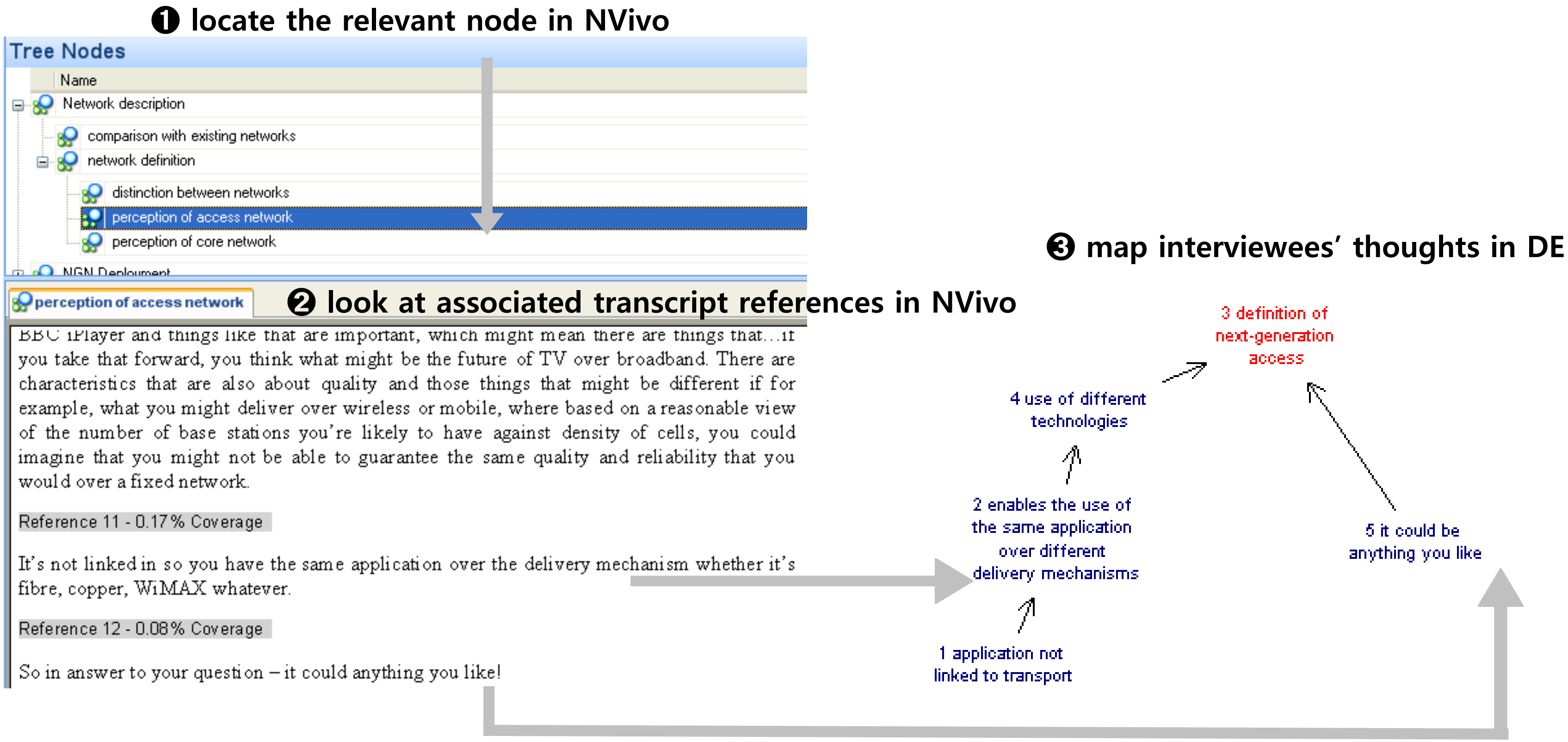

Figure 4-8: Creating cognitive maps - moving from NVivo to Decision Explorer

The findings from the cognitive maps with regard to concepts and their causal relationships were depicted in the form of causal maps. As shown in Figure 4-9, causal maps were produced by combining, on a research question basis, the relationships among market factors that emerged from the examination of the cognitive maps produced for the three case studies. The cognitive and causal maps formed the basis for making observations and drawing conclusions, as discussed in Section 4.7.4.

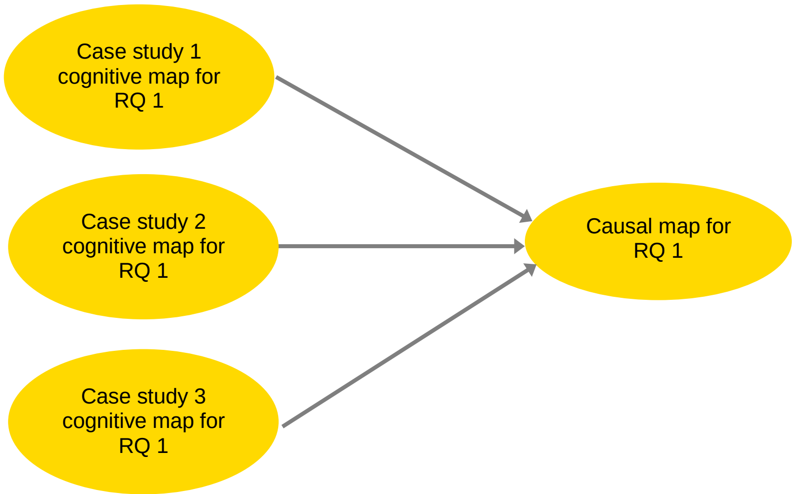

Figure 4-9: Approach for developing causal maps from cognitive maps

Reading Decision Explorer maps

Decision Explorer provides a flexible means of mapping variables and their relationships. In Decision Explorer models, variables are referred to as *concepts* and relationships between them are denoted by arrow links. It is possible to use a range of colors, fonts and text box styles for distinguishing between different types of concepts. The combination of colors, fonts and text box styles for a concept is called the concept *style*. For example, in this research red font is used to identify the core concept or the topic of the research question/map. In a similar way, links can be distinguished by colors and symbols. These attributes form the link style. Figure 4-10 describes the link and concept styles used in the maps in this research and will be useful in reading the maps in Chapters 5 to 7.

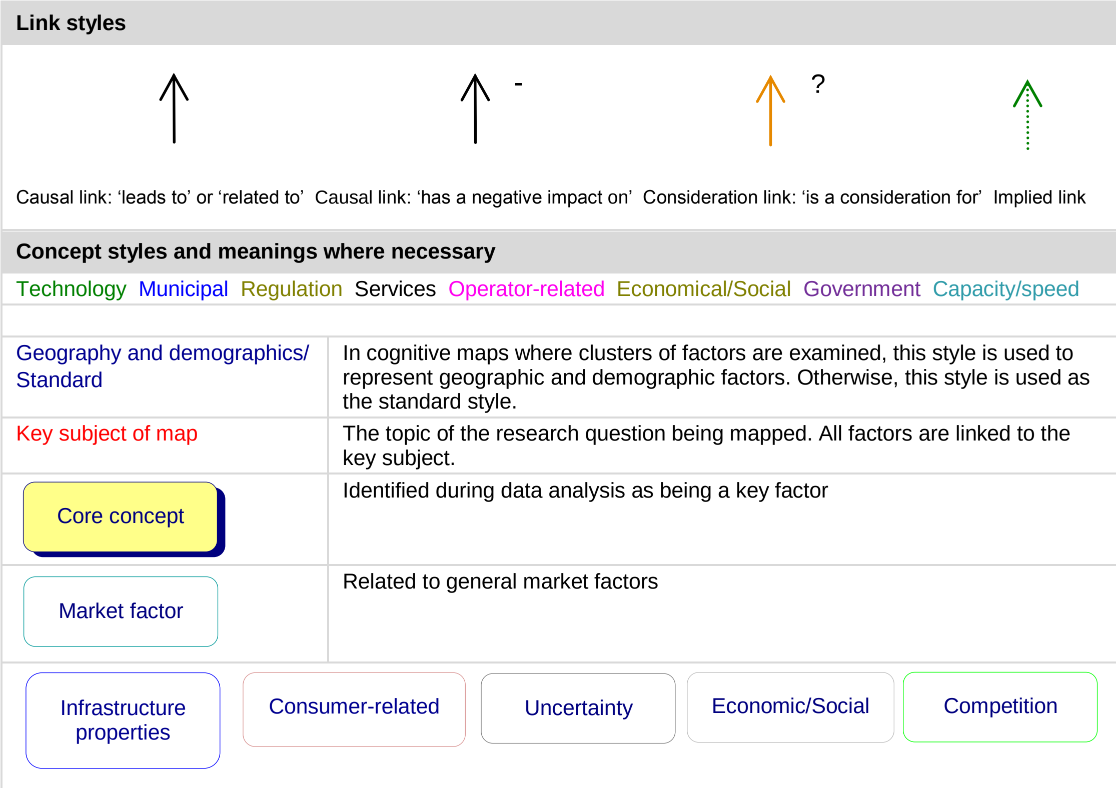

Figure 4-10: Link and concept styles used in data analysis

4.7.4 Conclusion drawing and verification

Conclusion drawing and verification, the third aspect of data analysis, involves 'making sense' of the data collected and verifying the truth and quality of the emerging ideas. Miles and Huberman (1994) identify thirteen tactics for drawing conclusions, seven of which are employed to varying degrees within this research. These are depicted in Figure 4-11. The dashed arrows on the diagram indicate a replication of propositions. In each case study chapter, the main conclusions drawn are indicated throughout the analysis in bold, italic text and summarized at the end of the chapter.

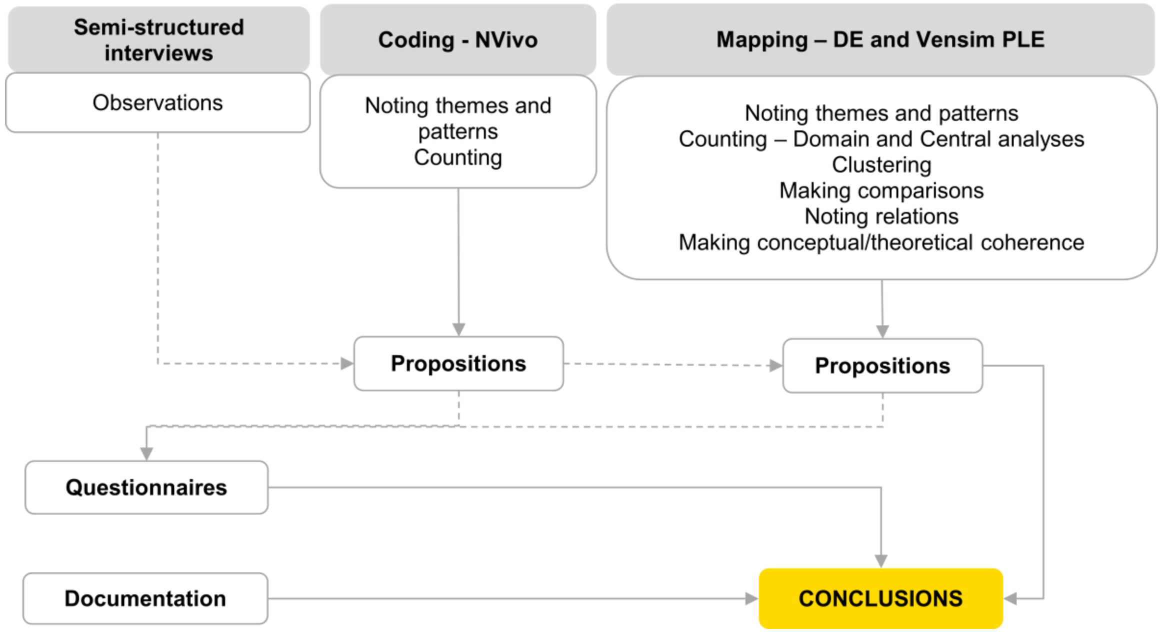

Figure 4-11: The process of drawing conclusions

As Figure 4-11 illustrates, the process of generating meaning from the data began in the interviews. Observations were made during the discussions and these were noted in a starting list. Further conclusions were drawn in the coding and mapping stages. As discussed in Section 4.7.2, themes and patterns emerged during the coding process and these observations were developed as propositions that were subject to further testing as analysis continued. In addition, statistical information was gathered from the Node Summary report (see Section 4.7.2).

In Decision Explorer, patterns were observed based on the type of links that existed between concepts – positive, negative influences or conditional influences. Concepts were also clustered into broader categories to identify and observe the general areas of influence. Comparisons were made, for example, across the findings for different network segments (that is, NGN and NGA). Counting and weighting were used by both the researcher (in checking frequencies of topics) and Decision Explorer tools (Domain and Central analyses)[13] to help identify core concepts.

[13] More information on the Domain and Central analyses of Decision Explorer can be found in Appendix VI.

The observations made and the conclusions drawn from the data using these seven techniques were only part of answering the research questions. Verification was also an integral process, necessary to ensure the validity of the conclusions. In this research, verification was done from the data collection phase until the end of the data analysis. Therefore, both the original data and the conclusions drawn from the data were verified. Table 4-7 shows the verification measure undertaken at each stage of the research. Details on these can be found in Appendix VII.

Stage of research	Verification measure
Data collection	Firsthand data collection Trustworthy interviewer Favourable setting Time alone with interviewee
Data preparation	Feedback from interviewees (review of transcripts)
Data reduction - coding	Second coder
Data display - mapping	Second mapper
Drawing conclusions	Replication across different analysis stages Feedback from interviewees

Table 4-7: Verification measures used in the research

4.8 Conclusion

Research methodology is an important part of a research project. By starting with the research questions emerging from the review of existing literature, this chapter outlined the research design for the current study. Firstly, a conceptual framework was derived from theory. By identifying the key concepts, variables and their relationships within the study, this framework served as a tool for focusing the objectives of the research and for structuring the interview questions.

A major underlying factor in the research design was the philosophical beliefs of the researcher. By considering ontological and epistemological assumptions, the researcher’s philosophical stance was deduced to be interpretive, a worldview which believes in the social construction of reality and the influence of social actors on entities and phenomena. This swayed the choice of research strategies and methods adopted for the study towards those being phenomenological in nature. In addition, the decisions of research strategies and methods were influenced by the nature of the study. For example, the need to understand the context within which next-generation broadband decisions are made and to make comparisons across different market conditions led to the choice of multiple case studies as the research strategy. In addition, a holistic case study was utilized. The cases for the study were chosen by a combination of sampling techniques, including criterion sampling, intensity sampling and convenience sampling, while the participants for the study were chosen by a form of quota selection. The Netherlands, Sweden and the UK were seen to be appropriate for conducting the study at hand.

The choice of data collection methods, too, was influenced by the nature of the study. For example, the requirement to gather the opinions of several stakeholders within each economic market and to understand their behaviour and thinking that underlie these opinions dictated the need for a flexible and open data collection method. Semi-structured interviews were found suitable for this purpose. In addition to interviews, archival records for background, statistical data collection and documentation for data corroboration were used. For the interviews, interview guides were developed and pilot interviews were conducted to ensure that questions were understood, relevant and can be answered. Although digital recording was the primary method of noting interviews, note-taking was done in the single instance in which permission was not granted. In both cases, however, the notes were reviewed by the participant before being used further in the research. Data analysis was conducted in an iterative manner among data reduction, data display, and drawing and verifying conclusions. The qualitative analysis software package, NVivo, was used in the data reduction process while Decision Explorer and Vensim PLE were used for producing data displays.

The design of this research as detailed in this chapter was a key tool in conducting the research. While it is acknowledged that variations were made once fieldwork began, it was essential that a guide for the research be developed before fieldwork commenced. In so doing, objectives, target participants and data collection and analysis approaches were focused, laying the foundations for the project to be a successful one.

5 The Netherlands

5.1 Introduction

This chapter is the first of three that examine the case studies explored in this research. With a focus on The Netherlands, the chapter continues in Section 5.2 with a description of the telecommunications industry. A general overview of the telecommunications sector and then more specific details of the broadband market, both current-generation and next-generation broadband, are presented. This market introduction lays the foundation for the market-investment analysis presented in Section 5.3, in which the key findings of the empirical work are described. The results of the analysis are complemented by relevant interviewee quotes and cognitive maps developed from the interview data. Section 5.4 ends the chapter with a summary of key findings.

5.2 The Dutch telecommunications market

In the discussions presented herein, Section 5.2.1 provides an overview of Dutch telecommunications while Sections 5.2.2 and 5.2.3 describe the Dutch broadband market in general and developments in next-generation broadband respectively. The insight provided in these sub-sections is important to the analysis of the Dutch investment behaviour in both this chapter and Chapter 9.

5.2.1 Overview

Up until 1990, Royal KPN N.V. (KPN) held a monopoly on the installation of telecommunications networks and the provision of telecommunications services in The Netherlands (OECD, 1999). The liberalization of the sector was initiated in 1989 when a decision was taken to freely open the markets for terminal equipment and value added services (OECD, 1999). By July 1997, Dutch telecommunications saw its complete liberalization, open to all forms of competition including voice telephony (OECD, 1999; van As, 1999).

Like many European countries, Dutch telecommunications is regulated by an independent authority – the Independent Post and Telecommunications Authority

(OPTA) – and complies with directives issued by the European Commission. OPTA was established in August 1997 and is responsible for the postal and telecommunications sectors in The Netherlands, including mobile television (OPTA, 2009). OPTA's activities are set out in the Independent Post and Telecommunications Authority Act, the Postal Act and the Telecommunications Act (OPTA, 2009). OPTA works in conjunction with the Ministry of Economic Affairs and the Competition Authority (NMa) (ITU, 2007b). Although the development of telecommunications regulation lies with OPTA, both the Ministry and NMa ensure that the policies enforced promote and maintain competition in the market.

The telecommunications sector in The Netherlands is competitive. At June 2011, several fixed-line operators including KPN, Tele2, UPC, Ziggo and smaller DSL and cable operators, three mobile operators - KPN Mobile, Vodafone and T-Mobile – and a growing number of mobile virtual network operators (MVNOs) (58 at March 2011) including debitel Netherlands and Tele2 were active in the market (OPTA, 2010a, 2010b; Analysys Mason, 2011a; TeleGeography, 2011a).

The country's single incumbent operator, however, maintains the lead position in both the fixed and mobile markets, with 37.5% and 49.4% subscriber market share respectively as at June 2011 (Analysys Mason, 2011a). Previously owned by PTT Nederland, a government-owned monopoly, KPN was privatized in 1994, selling 30% of its shares (OECD, 2009). Today, KPN remains privatized with its majority of shares being owned by Capital Group International Inc. and the Capital Research and Management Company (Analysys Mason 2009; Funding Universe, 2010).

5.2.2 The broadband market

At the end of June 2011, The Netherlands boasted a 43.8% (fixed broadband) line penetration by population (Analysys Mason, 2011b). However, with a penetration of 42.7% at the end of December 2010, a growth of only 1% occurred over the half year. This indicates a possible recent stagnation of fixed broadband growth among the Dutch.

Historically, however, broadband penetration has been high and is partly attributable to the high population density of the country (Analysys Mason, 2009).

With 16,654,979 citizens distributed over 41 526 km^2 of land, broadband access reached 83.4% of households in one form or another in June 2011 (Eurostat, 2011; World Bank, 2010; TeleGeography, 2011a). The most widely penetrated broadband infrastructure is DSL, with 60.5%% of the total fixed broadband connections at the end of June 2011, as Figure 5-1 shows (Analysys Mason, 2011a).

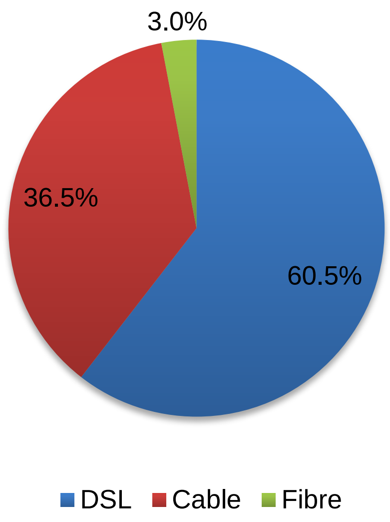

Figure 5-1: Dutch broadband penetration as a percentage of total fixed broadband connections by infrastructure, June, 2011
Source: Analysys Mason, 2011a

However, The Netherlands is also home to a geographically extensive cable network infrastructure, which, as Figure 5-1 indicates, competes with DSL penetration. Broadband access is also increasingly provided by optical fibre. Although relatively new, by June 2011, 768,000 homes had been connected with FTTH, exhibiting a growth of 35% in one year (OPTA, 2011a).

The fixed broadband market is also competitive in terms of operators, as Figure 5-2 illustrates. At June 2011, KPN held a subscriber market share of 37.5% while Ziggo, the dominant cable operator, had a share of 22.9%. UPC, another cable operator, held 12.1% of the total broadband subscribers. The remaining 27.5% was shared among smaller broadband players including Tele2 (7%), Online (4%) and others (16.5%).

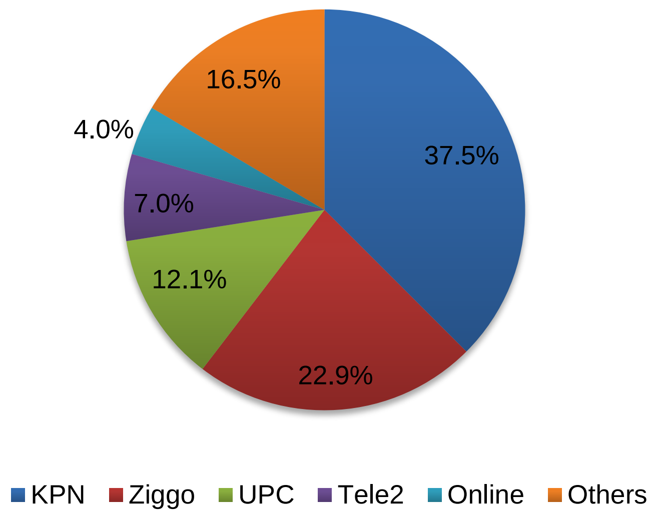

Figure 5-2: Dutch broadband market shares at June 2011
Source: Analysys Mason, 2011a

In the broadband service market, digital television, IPTV and VoIP are emerging and are in increasing demand (Budde, 2010b). At June 2011, 72% of Dutch television consumers had digital television while over the five-year period from 2005 to 2009 VoIP usage per household increased by 45% (KPN, 2009; OPTA, 2010c; OPTA, 2011b). Widely marketed by cable operators, at June 2011 VoIP services accounted for approximately 55% of the fixed connections in The Netherlands (Analysys Mason, 2011b). Orange Netherlands and Tele2/Versatel also offer VoIP services to consumers. As a result of KPN's dependence on its established legacy PSTN and narrowband voice services, VoIP remains a service market in which the incumbent fails to achieve a leading position. Statistics Netherlands (2010) also cites growth in other broadband services such as gaming, music streaming, online banking and e-shopping.

Apart from an increasing inclination towards the use of bandwidth-intensive, high-speed and digital services, The Netherlands has exhibited a shift from a single-service telecommunications market to one that is characterized by service bundling. In 2010, 80% of broadband services were acquired via a bundle (OPTA, 2010d). Moreover, there is a more prominent migration from the take-up of dual play to the take-up of triple play packages. From June 2010 to June 2011, triple-play bundles grew in subscriptions by 17.7%, with fixed triple-play bundles that included television services being particularly popular (OPTA, 2011c).

The mobile broadband market is not as advanced as its fixed counterpart. The success of the fixed networks, the relative high prices of mobile telephony and the increasing popularity of VoIP have stagnated the growth of mobile services among the Dutch. Ultimately, the fixed-mobile substitution effect is not as evident in The Netherlands as it is in other European markets. Recently, however, there has been greater activity in wireless data access and devices such as dongles and 3G smartphones. Such separate mobile broadband connections increased from 0.3 million to 0.6 million from 2009 to 2010 (OPTA, 2010d).

As a result of the high broadband penetration over the years, the rate of growth of broadband subscriptions has slowed over the last few years. However, as this market overview reveals, there continues to be a (growing) demand for and use of broadband services among the Dutch.

5.2.3 Developments in next-generation broadband

The rapid and continuous development of broadband telecommunications in The Netherlands has led to a general forward-looking approach to next-generation broadband. This section outlines the developments that have taken place until the present time and provides a brief insight into the role of the government in the development of the next-generation broadband market.

Investments to date

In 2005, KPN announced its ‘All-IP’ vision of migrating its core and access networks to IP-based networks by 2015, a move that is envisioned to be cheaper, more efficient and future-proof for the incumbent. At December 2009, the upgrade of the backbone was largely complete and at the present time, KPN is upgrading its access network (Gospić, 2009; KPN, 2010). Other Dutch operators appear to have little appetite for NGN upgrade.

The growth of NGA networks, on the other hand, has been significant and rapid among both DSL and cable operators. The Netherlands hosts hundreds of fibre access networks whose deployments were initiated by Reggefibre[14], alternative operators and other parties such as municipalities and housing corporations. As an indication of the progress made in The Netherlands, IDATE (2008) ranked the Dutch market as number one in new fibre connections over the period June 2008 to December 2008. At March 2009, 12 provinces in The Netherlands had fibre access but the distribution of the fibre connections was varied within each province (Stratix, 2009). The major fibre projects have been undertaken in Eindhoven and the provinces of Noord-Holland, Flevoland, Gelderland, Overijssel and Utrecht (Stratix, 2009; Statistics Netherlands, 2010).

The cable operators are upgrading their access networks using DOCSIS 3.0. UPC, for example, launched DOCSIS 3.0 in 2008 while Ziggo started upgrades of its network in 2009 (Stratix, 2009). In addition, some cable operators are rolling out fibre as their NGA infrastructure. In 2006, CAIW and the then Casema (now Ziggo) initiated their deployment of fibre access networks. In 2008, KabelTV Brabant-Gelderland (KBG) committed to FTTH roll-outs and, in 2009, Kabel-Noord also announced planned FTTH investments.

Alongside KPN and cable operators, many of the early NGA networks deployed in The Netherlands were initiatives of local municipalities and housing corporations (Stratix, 2009). In 2006, the Dutch city of Amsterdam launched the Citynet Amsterdam project, one that would deliver FTTH to 370,000 households in Amsterdam (Citynet, 2007). Municipality fibre networks have also been deployed in Eindhoven through the Kenniswijk project and in Leiden (Kramer et al., 2006). Together with the municipalities, several residential communities have lobbied for fibre networks for their residents. The first of these, OnsNet Nuenen, was a huge success and inspired other similar networks both in the local market and on an international level (Rovers, 2009).

A recent development in the Dutch broadband market and of great importance in the next-generation broadband discussion is the 2008 joint venture of KPN with its largest competitor in the fibre access market, Reggeborgh. Reggeborgh is a private

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[14] Reggefibre, as explained later on, is a joint venture established between KPN and a fibre investor, Reggeborgh.

investment company involved in real estate, construction and the roll-out of communications networks (van Rooijen, 2009). The joint venture, Reggefibre, was established to merge Reggeborgh's expertise of rolling out fibre network infrastructure with the benefit of KPN's established customer base. KPN has 41% ownership in the joint venture (KPN, 2009). At the end of 2010, Reggefibre owned over 94% of the fibre optic connections in The Netherlands (OPTA, 2010d).

The role of the Dutch Government

Investment in NGA in The Netherlands has been assisted somewhat by state involvement. Of particular importance is the government contribution of US$155 million for the development of high-speed networks for research (Fiber Utilities Group, 2011). In addition, commitment has been given to the provision of limited funds to municipalities for the development of municipal networks. For example, US$66 million was provided for the Kenniswijk Broadband Demonstration Center. This was an FTTH broadband initiative in Eindhoven that aimed to provide more than 100 consumer services for 14,000 households (Atkinson et al., 2008). A similar scheme was undertaken in the neighboring town of Nuenen in 2004 whereby government monies were used to connect 99% of the households with FTTH. This was, however, a pilot, but at the end of the trial period over 80% of the households registered for a paid service (van der Woude, 2005). FTTH projects have also been initiated by the Amsterdam City Council. These investments by the state have, in turn, provoked fibre investment by the private sector in The Netherlands.

5.3 Analysis

Section 5.2 described the nature of the Dutch telecommunications industry, focusing on developments within the current-generation and next-generation broadband markets. Based on interviews conducted in The Netherlands, this section describes the empirical links between the market conditions and the development of next-generation broadband. The findings are discussed in relation to the research questions.

5.3.1 What are next-generation broadband networks?

The understanding of next-generation networks by the Dutch is linked, in general, to next-generation access and the technologies that are used in the access network to achieve specific service attributes such as high speeds and high-definition quality.

While many Dutch broadband stakeholders define next-generation broadband networks individually in terms of core and access networks, several are yet unable to make a distinction between the two. The reason for this is two-fold. Firstly, the close association of next-generation broadband with NGA means that there is no need to distinguish between the two types of infrastructure:

> "*…although over here when we talk about next-generation networks, we usually zoom in on next-generation access networks…*"

Secondly, the need to have an official definition is not considered to be an important one:

> "*I would consider it [next-generation network] to be the whole network, not only the core. But that's an informal understanding – we don't use the term often as such.*"

> "*Yes. I don't think very deeply on next-generation networks. I just see what the policy discussions are on them and the definitions they use. I'm not very much deeper than that."*

In essence, while participants are aware of the distinction between NGA and NGN, the distinction is not considered to be relevant as a result of the NGA focus within the market. It can, therefore, be deduced that ***NGA is of greater interest to the Dutch than NGN***. Notwithstanding, the following sub-sections pay attention to each of NGA and NGN individually.

Definition of NGN

Figure 5-3 illustrates the definitions of NGN proposed by the Dutch participants[15]. Several general characteristics of NGN can be identified from the clusters shown on the map. From a technology perspective, NGN are variably considered to be IP-, Ethernet- or fibre-based and providing technology-neutral transport [concepts 1010, 1019, 1020, 1023 and 1024].

[15] Since no main definitions were identified by the Dutch, all the responses are discussed, in categories.

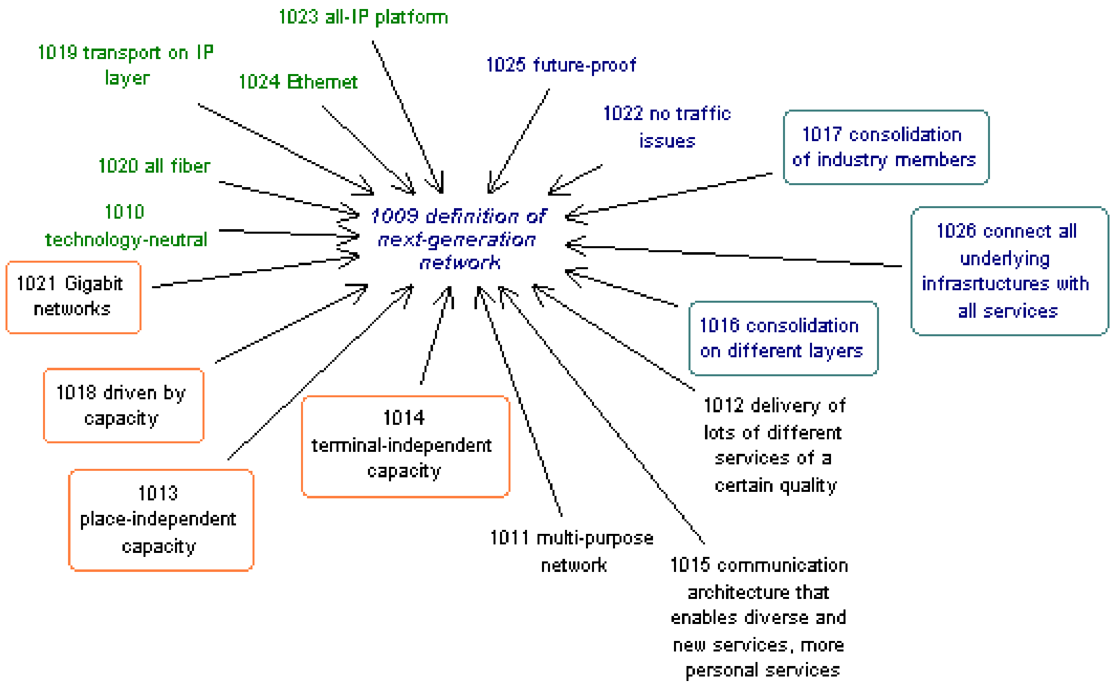

Figure 5-3: Dutch definition of NGN

With regard to capacity, interviewees believe that NGN are high capacity networks that can deliver high speeds independent of location or device [concepts 1013, 1014, 1018 and 1021]. NGN is also considered to be networks that offer a range of services or a multi-purpose platform [concepts 1011, 1012 and 1015]. Others believe that NGN will provide consolidation of platforms, network layers and market players [concepts 1016, 1017 and 1026]. In a more general sense, NGN is envisioned to be networks that are future-proof and which could accommodate any volume of traffic [concepts 1022 and 1025].

However, since the definitions all have an equal weighting, it is evident that there is no agreement with regard to the meaning of NGN. From this, it can be concluded that ***there is no view of NGN of particular importance to the Dutch*** and that ***the market conditions do not influence how NGN are defined***.

Definition of NGA

Despite the focus on network access, the NGA concept itself holds a variety of meanings for the members of the Dutch broadband market, such as capabilities in speed, service delivery and an enhancement over current-generation broadband. However, the “devil is in the detail” and the interview data shows that, in general, there is still uncertainty among the participants in identifying specific network attributes.

The main definitions emerging from the responses are shown in Figure 5-4 and can be seen to link to technology. In the most part, the technological definitions are also linked to speed. For example, NGA is defined as a fibre-only network [concept 1007] because of the opinion that it should be a future-proof network [concept 1001] and because it should deliver at least 10 Mbps symmetrical speeds [concept 1006]. Similarly, wireless networks are not considered to be NGA networks on the basis of their achievable speeds as speeds of greater than 50Mbps and 100Mbps, expected of NGA networks, are not realizable with wireless technologies [concepts 1002 and 1003]. There is, therefore, some indication that data rate is a key element of the Dutch perspective of a NGA network.

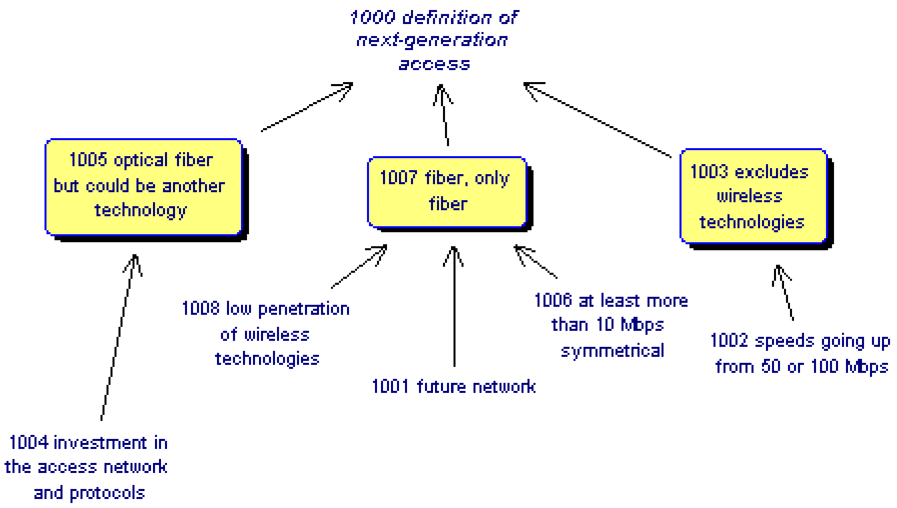

Figure 5-4: Dutch definition of NGA

The low penetration of wireless compared to fixed infrastructure in The Netherlands also influences the opinion that NGA can be only fibre [concepts 1007 and 1008]. More importantly, however, there is little or no consensus as to what the NGA technology is or might be. While 46.7% of the interviewees believe that any technology could be used, as NGA is a general investment in the access network and in access protocols [concepts 1004 and 1005], 33.3% are adamant that only fibre could be considered [concept 1007].

A quarter of the interviewees admit that while other technologies might theoretically be potential NGA technologies, at the present time only optical fibre is relevant and used in practice. It can be concluded from this analysis that the Dutch market considers NGA to be technology-neutral but for practical reasons is focused on optical fibre at the present time. As a result of such uncertainty in a technology-based definition, several interviewees deemed it wiser to define NGA from a service perspective. The following quote is from one such interviewee.

"...But, then you already have the problem, is it fibre-to-the-home, is it fibre-to-the-curb? Probably both. But, what about cable? Cable has fibre in its network. Is that a next-generation network as well? So, when you look at it from the infrastructure perspective, it's hard to make a definition, but when you look at it as broadband, so don't look at technology but rather from a service point of view, it's a network where you can have high bandwidths.

Then you get the distinction, because with fibre-to-the-curb you can have maybe 30 Mbps or 40 Mbps, but with fibre-to-the-home you can have 100 Mbps, but 1 Gbps is also possible and even 10 Gbps."

One interviewee identifies the issue that NGA should be technology-neutral but, because of the existing availability of high-speed copper and cable networks, an upgrade of the access network usually entails the roll-out of fibre. Therefore, NGA becomes a definition based on fibre, so friction between technology-neutral and an explicit definition of a fibre-based network exists, as the following indicates:

"*Well, in fact you see some friction between on the one side you want to talk about fibre optics because you really want to upgrade the networks, but on the other side you want to be technology-neutral, you don't want to say we want to have fibre optics, so that's the friction.*"

For a third of the Dutch interviewees, it is not important to have a tight or rigid definition of NGA, as such a definition is difficult to specify and is likely to change. Two such remarks are quoted below:

"*I think the definition will change all the time. I don't have one at the moment.*"

"*So, it's difficult. For us, it's not so important to have a very tight definition; it's more in general terms an indication of what we're talking about.*"

These responses reveal that there is still uncertainty in establishing a general definition for NGA among the Dutch. However, it is evident that a significant emphasis is placed on technology and its speed capabilities and, therefore, one can conclude that, at the present time, ***technology and speed are key defining factors of NGA in the Dutch market***. In addition, ***although they are open to the use of other technologies, the Dutch presently consider NGN to be based on optical fibre for practical reasons***.

5.3.2 Next-generation broadband investment

Investment in next-generation broadband in The Netherlands is exclusively split between investment in NGN and investment in NGA, as the data analysis reveals that different market factors influence investment in these two network segments. However, the key drivers for next-generation broadband investment are specifically linked to NGA investment. It can be speculated, therefore, that ***the market conditions in The Netherlands are more conducive to NGA deployment than to NGN deployment***, and, consequently, that the Dutch pay particular attention to investment in the access network. Both the NGN and NGA investment decisions are discussed in detail in the following sub-sections.

Investment in next-generation core networks

Figure 5-5 captures the key factors influencing NGN investment in The Netherlands and reveals several noteworthy investment drivers.

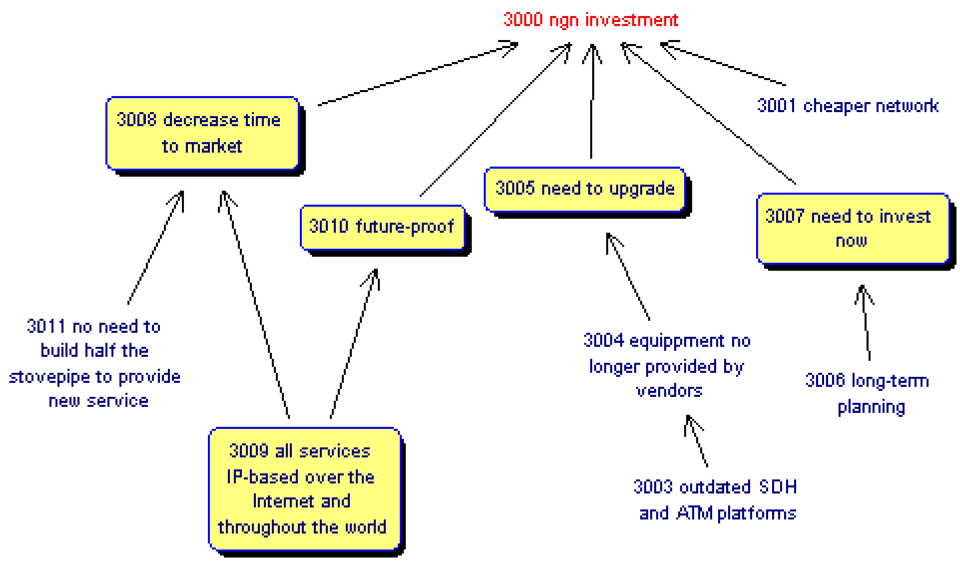

Figure 5-5: Main market factors influencing NGN investment in The Netherlands

Firstly, the map shows that the IP-based nature of the network [concept 3009] reduces the time to develop and deploy services, and hence, the time to market these services [concept 3008]. With NGN, there is no need to build a new network for each new type of service or to attempt to deliver new services over the old platforms [concept 3011], as an interviewee explained:

> "*…it gives you the possibility to decrease your time to market, because when you have a new service, you don't have to build half the stovepipe to provide it but you can just pin it on your platform and it finds its way. It's all over IP, so it decreases your time to market and it's future-proof because all the new services will be IP-based.*"

An IP-based core also ensures that the network is future-proof [concept 3010], as new services can easily be developed and the network easily scaled. As IP becomes more popular, traditional forms of technologies and protocols including ATM and SDH, become obsolete and equipment vendors are gradually ceasing production and support of equipment based on the old technologies [concepts 3003 and 3004]. Thus, network operators need to upgrade their equipment and their network accordingly [concept 3005]:

> "*Yes, it's cheaper and it's future-proof, because you see that all services over the Internet and in the world is going to all-IP. Also, ATM and SDH platforms will get out of service in the future and also the providers of this equipment are just not providing this equipment anymore, because it's outdated.*"

Finally, as a measure of long-term planning, operators consider it necessary to invest now in the new networks [concepts 3006 and 3007]:

> "*That's also with your infrastructure: it's getting old so you have to renew your network to be future-proof again, and that's the idea, and you can't do it from day one to day two. It's a long-term period planning towards 2015, 2018 but you have to start this migration and this planning at this moment.*"

While such identification of the core concepts is important, several other findings were also useful to this study. Firstly, most of the factors influencing investment are linked to the NGN network infrastructure. For example, the IP-based core of NGN, the creation of new platforms and the elimination of the stovepipe structure are the key sources of the benefits identified, that is, the reduced time to market and the future-proofedness of the network. It can be surmised, therefore, that ***the desire for an upgraded network infrastructure is the major motivation for NGN investment in The Netherlands***.

Secondly, the investment drivers are all related to an increase in the network operator's own efficiency, rather than to the wider market or society in general. For example, there is no mention of regulation or competition driving NGN investment. While these factors may be influential, the interviewees do not identify such relationships. It can, therefore, be deduced that ***NGN investment in The Netherlands is supply-driven***.

Investment in next-generation access

Figure 5-6 shows that investment in next-generation access networks in The Netherlands is primarily driven, albeit to varying degrees, by competition effects, commercial/business requirements and consumer trends and demands. Based on the analysis of this data, ***cable infrastructure competition is the greatest driver of NGA investment***.

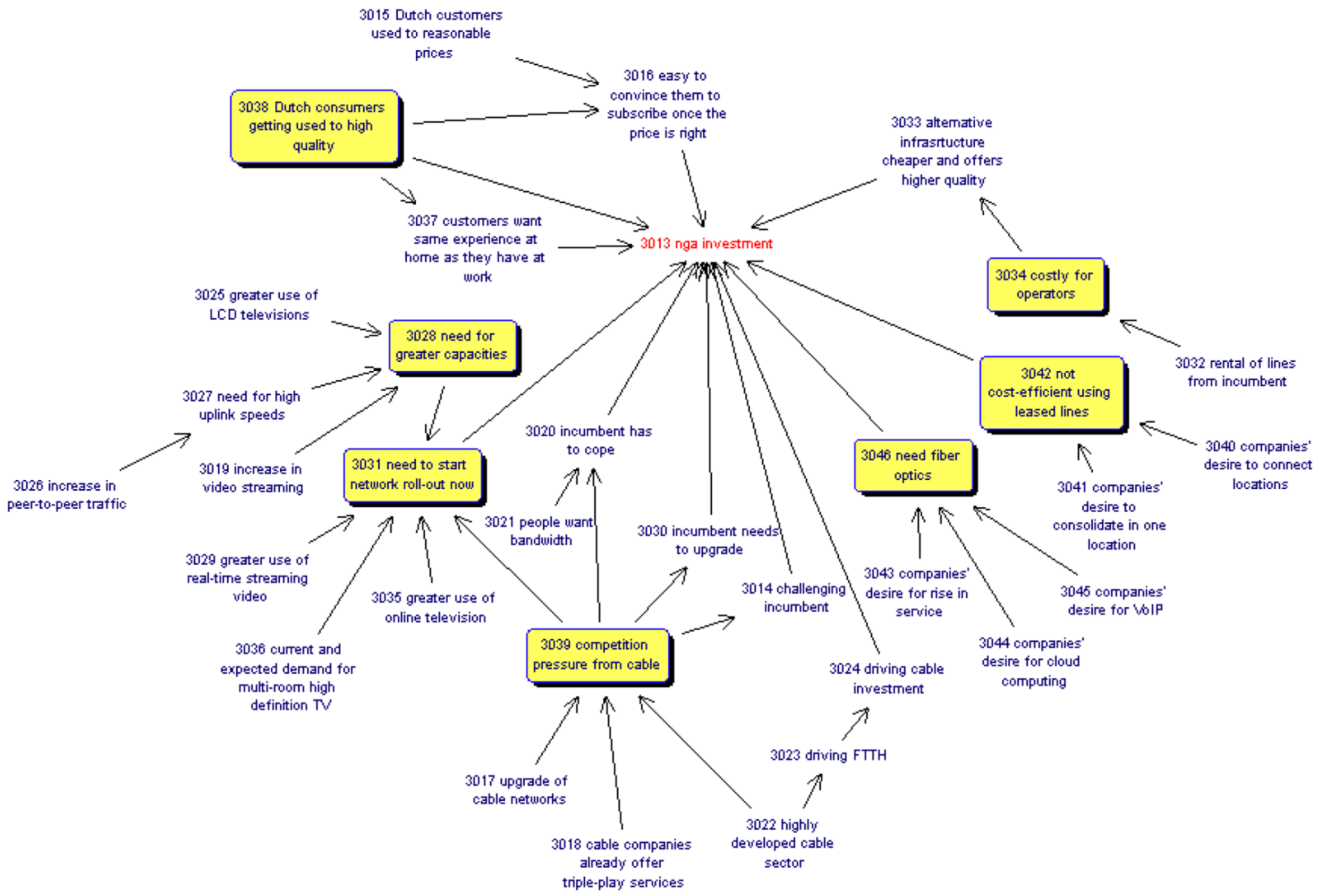

Figure 5-6: Main market factors influencing NGA investment in The Netherlands

The Netherlands has a highly developed national cable network [concept 3022] that spans 98% of the country and over which triple-play services are offered [concept 3018]. Cable operators upgrade these networks using DOCSIS 3.0 [concept 3017]. These three factors have increased the competitive pressure on other operators [concept 3039] and have driven the incumbent, in particular, to upgrade its access network [concepts 3014, 3020 and 3030]. As a result of the increased competitive pressure in the Dutch market, immediate investment in NGA is required so that alternative access infrastructures will be available, in a timely manner, to compete with the cable networks [concept 3031]. Several participants also remarked that operators are investing in optical fibre because others are, as a result of the competition:

> "…*operators are looking at each other and they don't really have the need to invest in optical fibre but they see others do it and they do it also.*"
>
> "*It's a bit strange but that's how it works – not because they think it's the best thing to invest in but because others do it and they can't stay behind.*"

Dutch consumers are also contributing to this perception of an immediate need for access infrastructure investment. With increasing use of and continuous consumer demand for multi-room and online services such as IPTV, operators see an urgent need to invest in NGA [concepts 3019, 3025, 3027, 3029, 3035 and 3036]. Such services also drive the need for greater capacities within the access network [concept 3028] and, again, operators believe that current investment in the access network is vital in order to satisfy these requirements. However, of importance to this study, respondents acknowledge that the need for greater capacities is expected but not evident at the present time:

> ”*What you see is yes, we need it, we will need it, not at this moment yet, but what you see and what the market expectations are, the forecast, is multi-room high-definition television coming up, and you need a lot of bandwidth for that.*”
>
> ”*So, on the one hand, you see we're really convince of the fact that the market will need it, not now but in ten years...*”

Furthermore, although the Dutch participants identify a range of services that can utilize high capacities, there is no indication of a single service that *requires* the high capacities provided by NGA nor of a service that can ensure significant rates of return on the investment, or no “killer application”:

“*…these services are not there yet. We’re delivering a promise.*”

However, particular to the Dutch consumer market is the historic availability of high quality telecommunications service at affordable prices. Presently, consumers are accustomed to a high standard of service and are increasingly expecting the same level of service despite their physical location [concepts 3037 and 3038]. In order to maintain their consumer base, operators find it necessary to upgrade their networks to deliver the expected high quality of service. In addition, because consumers are also more easily convinced to subscribe to a service once the price is affordable, as Vermaas (2007) shows, operators are more easily motivated to commit to the investment in NGA as they are almost guaranteed of take-up [concepts 3015 and 3016]. It is this behaviour of consumers that Dutch operators rely on for a high take-up, rather than a killer application:

“It’s not about the demand, it’s about the price. It’s about the price people are willing to pay for all this.”

As mentioned earlier, business consumers also play a key role in driving Dutch NGA investment. Participants identify a range of business services and applications, such as cloud computing [concept 3044], VoIP [concept 3045] and a general enhancement of services available [concept 3043], that stipulate investment in optical fibre networks by operators [concept 3046]:

“…and for many other businesses, especially the more advanced business and the larger businesses, they have clear images of what they want – they want rise in service, they want cloud-computing, they want Voice over IP, etc. and they need fibre optics to get them there.”

In addition to service-related requirements, business consumers are concerned about the efficiency of their own operations, including the financial demands.

Companies are desirous of integrating their own sub-locations and operations [concepts 3040 and 3041] and require high-capacity connections in order to do so. While leased lines are an option for such a configuration, they are not a cost-effective technique for the company using them [concept 3042]. Operators, too, requiring leased lines from the incumbent operator, are subject to high costs. Cheaper options become available by investing in alternative infrastructure [concepts 3032, 3033 and 3034]:

> "*If you look at companies, then you see a different image. You see companies who do have a want to…for example, take a company with more than one location. They want to connect their locations, they want to have several consolidation in one location, they want to have all their sub-locations connected, but they cannot do it cost-efficiently using leased lines, so they change to fibre optics…"*

This analysis reveals that, whether the demand for services is currently evident or expected in the future, Dutch operators are investing in NGA as they are aware that consumers will subscribe to the services for the right price. As such, it can be deduced that ***services and demand do not drive NGA investment*** but, rather, ***investment in NGA from a service perspective is supply driven***, as one participant describes:

> "*It's supply-driven, of course*".

While Figure 5-6 shows the main factors influencing NGA investment, of great significance to this study was that 96.6% of the relationships between market factors and NGA investment are positive, implying that the majority of influential factors *drive* investment in NGA in The Netherlands. In addition, only 1.7% of the factors – the investment climate and the role of regulation – are conditional factors, implying that the majority of factors are *definite* drivers.

Secondly, the investment climate or, more specifically, ***geographical characteristics and regulation are considered to be facilitators of NGA investment***. With regard to geography, the high population density of The Netherlands is cited by several interviewees as a key aid for network deployment. A high population density makes it easier to achieve a wide coverage and makes it economically feasible to deploy NGA networks. In addition, The Netherlands has soft soil, making it easy and cheaper to dig to install optical fibre cables. Lastly, The Netherlands is a flat and small country, again making the deployment of optical fibre networks a physically easier undertaking:

> "*Because we're many people in a very small country, that's flat and has easy soil, I think, they say. It's very, very cheap compared to other countries to dig up the streets here, and to just, even without a duct, to drop your cable in, and it's the most highly densely populated country in Europe, in the world, maybe, besides Singapore and Hong Kong, so it's just economic.*"

Finally, influences on NGA investment from regulators and the government are evident. In the first instance, although the role of regulation cannot yet be assessed, interviewees describe the two possible effects. One interviewee highlights that strict regulation can actually deter investment in NGA:

> "*but if not and if regulation is then also pretty limiting, then maybe [operator] will say, 'Well, forget about. Maybe we'll do some stuff in certain areas but maybe it's going to very, very slow and very small investment levels.'*"

On the other hand, the right regulatory framework can significantly increase the rate of investment in NGA. With the joint venture of KPN and Reggeborgh, the regulatory influence in The Netherlands becomes more significant. As Reggefibre is a combined effort of the two largest fibre operators in The Netherlands, OPTA has to ensure that competition by alternative operators is maintained. From Reggeborgh's perspective, regulation is new and some adjustment is required, as the company was not regulated prior to the joint agreement.

In the second instance, the Dutch government considers NGA investment to be important for society and, as a result, supported investment by municipalities and local governments. Municipalities, driven by local "champions", are eager to improve their own quality of life, to market their communities to the wider nation and, in general, to profile themselves for both commercial and economic reasons. As such, with the aid of the central government, many local communities in The Netherlands have invested in local optical fibre networks, as described in Section 5.2.3.

5.3.3 The technology dilemma

An examination of interviewees' responses to the factors influencing the choice of technology reveals a segmentation of drivers amongst the various technological options. Market factors are directly linked to specific technologies with no overlap across technologies. This division implies that specific criteria influence the decision to invest in given technologies in the Dutch market. In general, optical fibre, fixed wireless and mobile technologies are highlighted in the discussions. Apart from those factors that dictate the use of a particular technology, several more general considerations for choosing an access network technology are identified by the interviewees. These are discussed below before an examination of the specific technologies is presented.

General considerations for the choice of technology

The main factors influencing the choice of technology are captured in Figure 5-7. In The Netherlands, the status of the fixed network and existing infrastructure, in particular, play a significant role. The fixed network is extensive and has been very successful, resulting in sluggish investment in wireless technologies [concepts 6001]. As the fixed network is well-developed and has a huge penetration, network operators are inclined to continue investing in a fixed technology.

The diagram shows that technical limitations, such as data rates, limit the drive for a pure wireless implementation in the access network [concepts 6014 and 6015]. Participants highlighted that technologies should be used in combination, particularly where a broad coverage is desired and FTTH is too costly to achieve this coverage [concepts 6004, 6005 and 6006]. This indicates that wireless technologies are not a primary choice for NGA deployment. Rather, ***the use of wireless technologies is driven by the geographical characteristics of the region.***

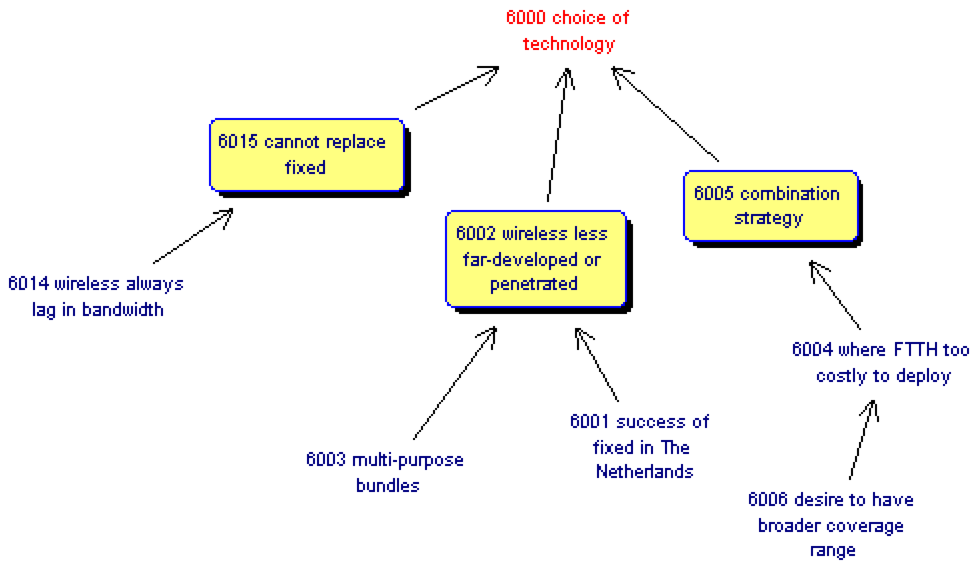

Figure 5-7: General factors influencing technological choice in The Netherlands

In essence, ***the general choice of technology is most greatly influenced by the technical limitations of wireless technologies and*** the advanced status of fixed line networks, that is, ***by the status of existing technology***. ***Geographic conditions, too, are important and,*** for economical and practical reasons, ***operators are open to using a combination strategy*** in regions where the cost of fibre deployment is unjustifiable.

Optical fibre

Figure 5-8 shows the principal factors, along with their relations, as considered in the decision to invest in fibre. The map highlights competition as the key driver for fibre investment. Cable competition is the strongest driver for optical fibre investment [concepts 6065 and 6081], although several operators also opt for fibre as a result of competition from other fibre networks, deployed by local municipalities and other parties, for example [concepts 6055, 6066 and 6068]. As a result of the increase in fibre deployments by public entities, commercial and private organizations initiated fibre investment in an attempt to not be "left behind" [concepts 6068, 6067]:

> "*It's a bit strange but that's how it works – not because they think it's the best thing to invest in but because others do it and they can't stay behind.*"

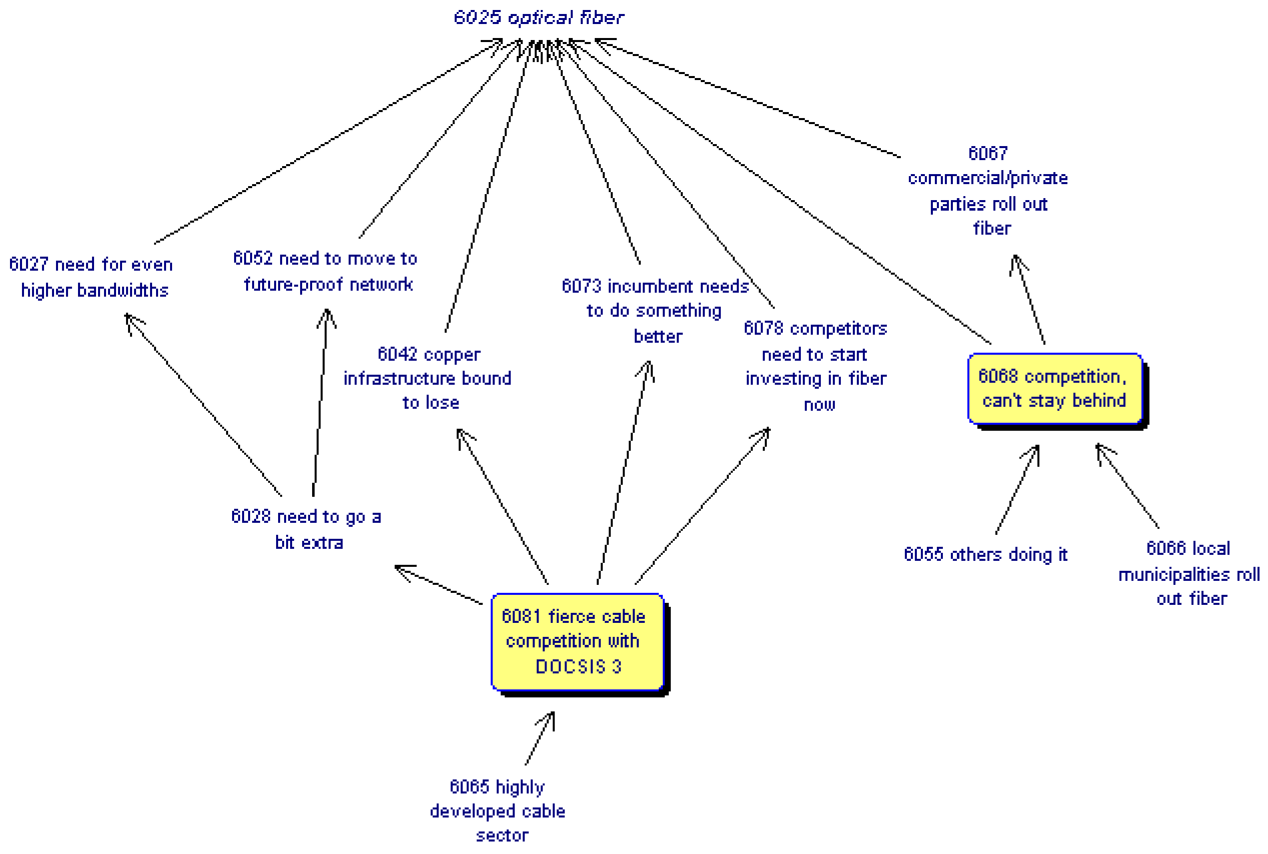

Figure 5-8: Main market factors influencing the use of optical fibre in The Netherlands

In addition to identifying the specific factors that influence optical fibre investment, a key outcome of the analysis is that the optical fibre map contains the greatest number of concepts among all technology maps and, more importantly, all the factors have a positive influence on optical fibre investment. These findings highlight that ***infrastructure competition is the key driver for optical fibre investment in The Netherlands*** and that Dutch operators/investors consider fibre to be the most effective technology for enhancing their competitive advantage.

Wireless/mobile technologies

Figure 5-9 shows the factors influencing the choice of wireless/mobile technologies. Five key factors are identified. Firstly, participants believe that the availability of frequency auctions will enable more frequencies to be claimed and used and, therefore, could encourage the use of wireless technologies [concepts 6073 and 6074]. Auctions are thus considered to be a facilitator for using wireless technologies:

> "*And the other issue is obviously, frequencies are scarce, so getting more and more frequencies there that are not specifically tied to a specific service will make it easier for the mobile or the wireless side to develop in the Netherlands, but there's still a lot of auctions that have to take place. It's the Ministry of Economic Affairs that does that. So, that's also a very influential factor over here.*"

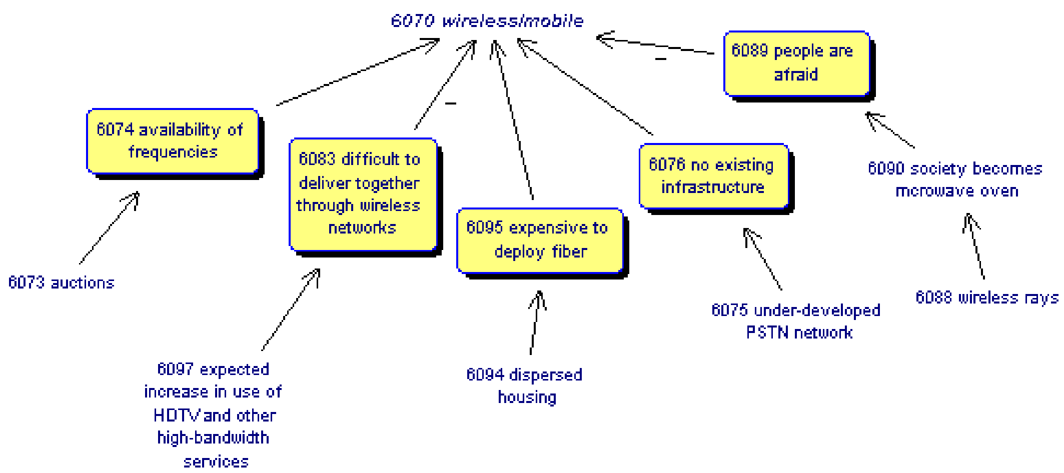

Figure 5-9: Main market factors influencing the use of wireless technologies in The Netherlands

The expected increase in the use of high-definition television and multi-service applications is also a main consideration for the use of wireless technologies [concepts 6097]. One participant explains that the capacity of wireless technologies will be too limited to deliver this combination of services [concept 6083]. Apart from the data rate limitations, another participant expressed concern in the wireless rays associated with wireless technologies, indicating that people are afraid to use the technology [concepts 6088, 6089 and 6090]. For these reasons, wireless technologies are not the preferred choice.

However, participants indicate that in areas in which the PSTN network is not adequately developed and, hence, there is a lack of infrastructure, wireless technologies should be used [concepts 6075 and 6076]. Additionally, in areas with a small housing nucleus or dispersed housing, participants thought it would be expensive to deploy fibre and, as such, recommend the use of wireless technologies [concepts 6094 and 6095]:

> "*So, you can be in a rural area with a small nucleus but you can be in a rural area with more dispersed housing, and especially in the second one then fiber optic will be hardly interesting, because if you have to make all the star network in that one it will be extremely expensive, so maybe in the first one a fiber optic network can be interesting while in the second one I think you will have to deal with wireless technologies.*"

The main observation among these core concepts is that only two of these – no existing infrastructure and the high cost of fibre deployment – *drive* the choice of wireless/mobile technologies. The availability of frequencies is a facilitator for wireless investment while the 'fright' and 'difficulty of delivering multi-services' factors deter investment. It can be concluded that ***the use of wireless technologies is limited by their technical capabilities*** but is valuable in areas where it is geographically challenging to deploy fixed infrastructure.

5.3.4 Perceived benefits of next-generation broadband

The indications of the benefits expected with the deployment of NGN and NGA networks are discussed herein. The findings with regard to NGN and NGA were analyzed separately and are discussed in this order in this section.

Perceived benefits of NGN

The map of the perceived benefits of NGN as informed by the Dutch participants is depicted in Figure 5-10. Although not many responses were obtained for this inquiry, indicating that there is little knowledge or concern about the benefits of NGN among the Dutch interviewees, Figure 5-10 highlights two main benefits, namely the capability to decrease the time to market of services [concept 5005] and the move to an all-IP core [concept 5001]. An all-IP network provides a cheaper, more future-proof infrastructure and facilitates faster service development and delivery times [concept 5002, 5003 and 5005]. The reduction of multiple networks into a single platform also reduces service deployment time [concept 5004]. It is evident that ***the perceived benefits of NGN are linked to the efficiency of the network operator***.

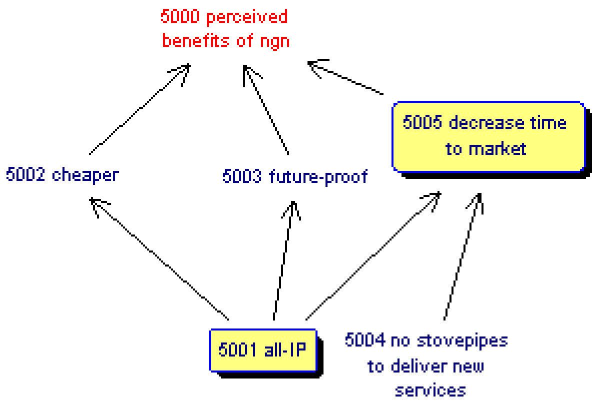

Figure 5-10: Primary (expected) benefits of NGN by Dutch market players

Perceived benefits of NGA

As shown in Figure 5-11, societal benefits [concept 4012], which are expected to emerge from various dimensions, are the main benefits expected with the deployment of next-generation access networks.

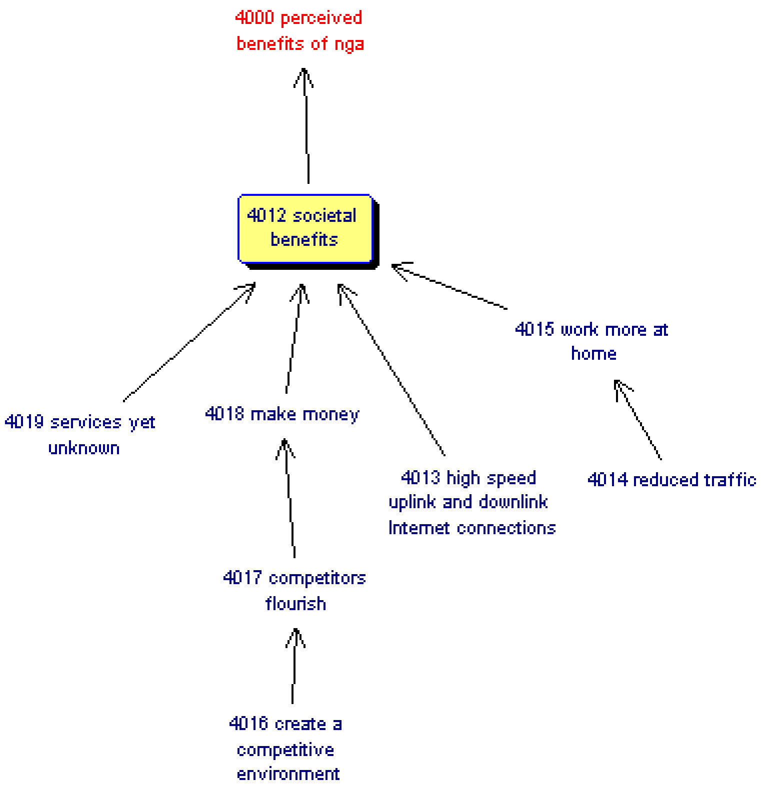

Figure 5-11: Primary (expected) benefits of NGA by Dutch market players

NGA is also expected to enhance the competitive nature of the telecommunications industry [concept 4016], increasing, in turn, the competitiveness of operators and other companies [concept 4017]. In this way, firms can increase their profit, which is expected to have a knock-on effect on the society [concepts 4018 and 4012]:

> "*of course, creating a competitive environment in which competitors flourish and make money is good to society as well.*"

An upgraded access network is expected to improve the upload and download speeds available to end-users, again leading to societal gains [concept 4013]. The increased capacity potential facilitated by NGA infrastructure will encourage consumers to tele-work [concepts 4014 and 4015]:

> "*If it offers high speed uplink and downlink to the Internet, or perhaps traffic jams can be solved and people would work more at home.*"

A highlight of Figure 5-11, however, is that provision of new services, the specifics of which are yet unknown, are also expected to bring benefits to the society [concept 4019]. Although some participants identify services and applications that are expected to be delivered by NGA, a few participants also admit that much of it is visionary and still left to be proven:

"*So, it might be a huge amount of benefits but we don't know all these yet.*"

"*Other services we don't know yet might offer benefits as well…*"

"*I think that's the thing. It's all guesses and you find all these reports on the effect of broadband on employment rates, competitiveness of companies, and reduction of the amount of traffic jams on the roads, but we'll see.*"

It can be inferred, therefore, that while ***there are many expectations, particularly in the socio-economic domain, there is still uncertainty with regard to the service benefits that NGA can realize***.

5.4 Conclusion

This chapter highlights that key aspects of the Dutch telecommunications sector influence the perceptions of and considerations for next-generation broadband investment, with some factors having a greater impact than others. For example, while NGA is generally defined in terms of speed, bandwidth and service delivery capability, the key defining factors are technology and speed, as a result of the significance of copper and cable network infrastructure in The Netherlands. While the Dutch believe that NGA can be technology-neutral, for practical reasons, the definition focuses on optical fibre at the present time. However, more generally, a tight definition of NGA is not important to this market. Similarly, a range of defining attributes is identified for NGN, but unlike that of NGA, the definitions cannot be linked to any particular market condition and no single characteristic is identified as being particularly important.

The main drivers for investment in next-generation broadband are encouraging NGA investment in particular, revealing that the Dutch market conditions are more favourable to NGA investment than to NGN investment. Cable competition, commercial/business requirements and consumer trends and demands, in particular, are the primary drivers for investment in the access network. Several demographic and geographic attributes, too, have facilitated the deployment of optical fibre to upgrade the current access infrastructure. While investment in access networks has been undertaken by a range of players – cable and DSL operators, municipalities, local communities – NGN deployment is less of a priority. Undertaken primarily by the incumbent, core network development is shown to be supply-driven.

In terms of technology, the analysis shows that particular criteria are linked to particular technology choices. Competition and path dependency, for example, dictate the use of optical fibre as the next-generation technology. As fixed technologies have traditionally dominated the Dutch broadband market, they are considered to be more 'next-generation' than wireless and mobile ones. Furthermore, the high penetration of copper and cable access technologies influences industry members to view NGA, which is an upgrade of these technologies, as optical fibre and DOCSIS 3.0 networks. Today, optical fibre is the most widely viewed next-generation technology for both technical and practical reasons, including its achievable data rates and ability to compete with other infrastructure such as cable/DOCSIS 3.0. Though wireless technologies are identified as a potential NGA technology, the choice for wireless is driven by the geographical characteristics of the region in which the network is being deployed and limited by its technical capabilities.

With NGA, the largest benefit is expected in the societal domain. However, a highlight of the discussion is that there are many expectations, particularly in services, but no guarantees of what can and will be delivered. The expected benefits of NGN are limited to the network operator's efficiencies, the core ones being a reduction in the time to market new services and the move to an all-IP network. The minimal discussion on this topic, however, suggests that there is less significance of NGN than NGA in The Netherlands and/or fewer direct benefits to the wider society.

With these findings, the chapter provides empirical insight into how market conditions in The Netherlands influence the perceptions, status and decisions made with regards to next-generation broadband deployment. The results show that a range of factors inform the investment decisions. Many aspects of next-generation broadband, however, remain uncertain among the Dutch. Table 5-1 summarizes these main findings, which are used for the cross-case comparative analysis in Chapter 9.

Research question	Main conclusions
RQ1 How do telecommunications operators define next-generation broadband networks?	NGA is of greater interest than NGN Technology and speed are key defining factors of NGA There was no view of NGN of particular importance Market conditions do not influence how NGN are perceived Although open to other technologies, NGA is associated with optical fibre now for practical reasons
RQ2 How do market factors influence investment in next-generation broadband networks?	The market conditions are more conducive to NGA deployment than to NGN deployment The desire for an upgraded network infrastructure was the major motivation for NGN investment NGN investment is supply-driven Services and demand do not drive NGA investment NGA investment is primarily supply-driven Cable infrastructure competition is the greatest driver of NGA investment Geography is a facilitator of NGA investment Regulation is a facilitator of NGA investment
RQ3 What drives the choice of access technology?	The use of wireless technologies is driven by the geographic characteristics of the region The general choice of technology is most greatly influenced by the technical limitations of wireless technology and the status of existing infrastructure Geographic conditions are important in the technology decision Operators are open to using a combination strategy Infrastructure competition is the key driver for optical fibre investment Optical fibre is considered to be important in the enhancing the competitive advantage of operators/investors The use of wireless technologies is limited by their technical capabilities
RQ4 What are the perceived benefits of next-generation broadband networks?	The perceived benefits of NGN are linked to the efficiency of the network operator Benefits are expected particularly in the socio-economic domain There is still uncertainty with regard to the service benefits that NGA can realize

Table 5-1: General conclusions emerging from the Dutch analysis

6 Sweden

6.1 Introduction

This chapter describes the Swedish case study, highlighting the relationships between the Swedish market conditions and investment in next-generation broadband that emerged from the interviews. The discussions begin in Section 6.2, which presents an overview of Swedish telecommunications. In this section, the development of the Swedish telecommunications sector, the structure of the market and regulation, and the broadband status are outlined. Section 6.3 presents the results of the data analysis, discussing the key considerations for Swedish market players in the migration to next-generation broadband. Section 6.4 ends the chapter with a summary of the main findings.

6.2 The Swedish telecommunications market

This section describes the development of the Swedish telecommunications sector and the current standing of its broadband market. This description is useful for contextualizing the discussions in both this chapter and Chapter 9. A historical synopsis of Swedish telecommunications is first presented followed by details of the current-generation and next-generation broadband markets.

6.2.1 Overview

In the early 1900s, telecommunications services in Sweden were provided by the single state-owned national operator, Televerket (Swedish Telecom) (Lindskog, 2004). As there was never a legal monopoly condition, the operator was not formally regulated (Laesadius and Berggren, 2000; Lindskog, 2004).

Sparked by political and public motivations, telecommunications deregulation was initiated in the 1970s, accelerated in the 1980s and formalized in the early 1990s (Lindmark et al., 2006; Hultkrantz, 2002; Lindskog, 2004). By the end of 1989, the last barriers to a liberalized telecommunications market were removed (Thorngren, 1990). In 1993, the first version of the Swedish Telecommunications Act was passed, finalizing the liberalization of the market. In conjunction with this, in July 1993

Televerket was stripped of its government association and became a limited corporation, Telia AB (Muller et al., 1993).

In 1996, Telia still had a majority share (71%) of the Swedish telecommunications market and, in 2002, formed a merger with the Finnish telecommunications operator, Sonera (Berkman, 2010). The merged company, TeliaSonera, is still partly state-owned (37.3%). The Finnish state also owns 14% of TeliaSonera while the remaining shares are held by private and other investors (Berkman, 2010; TeleGeography, 2011b).

In terms of regulation, a national telecommunications agency, Telestyrelsen, was established in 1992. In 1994, the NRA became known as the Post-och telestryrelsen (PTS), the Swedish National Post and Telecom Agency (Lindskog, 2004). Since then, PTS has been responsible for the regulation of telecommunications, IT, radio and post. PTS is overseen by the Ministry of Enterprise, Energy and Communications and has the responsibility of acting as an adviser to the government for broadband development and IT strategy (Berkman, 2010).

Swedish regulation is also influenced by EU policy. In 2003, the Electronic Communications Act (EkomL) was developed and represented the translation of the 2002 European Union Regulatory Framework to Swedish law (Berkman, 2010; Lindskog, 2004). The Act covers communication networks and services in Sweden with an aim to "ensure that electronic communications are as accessible and efficient as possible and are open to free competition" (Messing, 2003, p2).

Competition has evolved in Swedish telecommunications since the 1993 market liberalization. Five major players exist - TeliaSonera, Tele2, Telenor, ComHem and Hi3G (Analysys Mason, 2011c). TeliaSonera dominates both the fixed and mobile voice markets with 61.5% and 41.0% of subscriptions respectively (PTS, 2011a). ComHem is the largest Swedish cable TV operator with a subscriber base of 1.76 million households at February 2011 (TeleGeography, 2011b). Hi3G, a Hutchison MNO, is the fourth smallest mobile operator but was the first in both cases to launch a 3G network and HSDPA services, in 2003 and 2006 respectively (Buckland and Tee, 2010). A smaller mobile operator, Net1, also operates in the mobile market, providing CDMA services to customers in the rural and coastal areas of Sweden (Buckland and Tee, 2010).

6.2.2 The broadband market

A study undertaken by the Said Business School revealed that Sweden ranked ninth in broadband leadership in 2010 based on broadband quality and penetration (Cisco, 2010)[16]. At the end of June 2011, 96.8% of active Internet subscriptions in Sweden were broadband, representing an increase of 36% from the previous year (PTS, 2011a). The number of dial-up subscriptions decreased by 20% over the same period (PTS, 2011a). At the end of December 2010, the broadband penetration rate was 31.9 lines per 100 inhabitants, with more than 87% of the Swedish population covered by a high-speed network[17] (Eurostat, 2011; PTS, 2010a). These figures illustrate the rapid advancement of broadband in the Swedish market.

The broadband market is shared among TeliaSonera (37.4%), Telenor (21%), Tele2 (15.6%), ComHem (7.5%) and Hi3G (9.3%) and several others, albeit small players (PTS, 2011a). Figure 6-1 shows that the mobile operators, Tele2 and Hi3G, have increased their share of the broadband market over the six years from 2006 to 2011, while the fixed line operators have lost market shares, although only slightly. This observation, along with the information presented in Figure 6-2 below, illustrates that mobile broadband is increasingly overtaking fixed broadband subscriptions in Sweden.

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[16] Taken from the Cisco Press Release, quality was measured as follows: “Quality was evaluated by scoring the combined download throughput, upload throughput, and latency capabilities of a connection, the key criteria for a connection's ability to handle specific Internet applications, from consumer telepresence to online video and social networking. These criteria are expressed as a single 'Broadband Quality Score' for each country. By combining this Broadband Quality Score with broadband penetration figures for each country (i.e. the proportion of households who have access to broadband, obtained from Point Topic in 2010), the researchers were able to map out the world's broadband leaders – those with the best combination of broadband quality and penetration (Note: For a full explanation of how the scores are calculated, see page 4 of the Broadband Quality Study 2010).”

[17] These figures relate to at least 10 Mbps access.

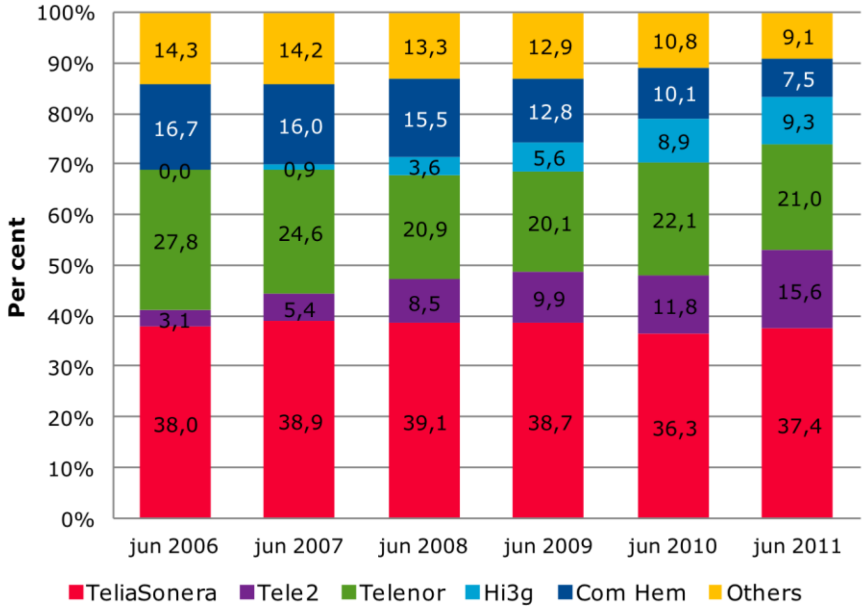


Figure 6-1: Swedish market shares of broadband subscriptions, June 2006 - June 2011
Source: PTS, 2011a

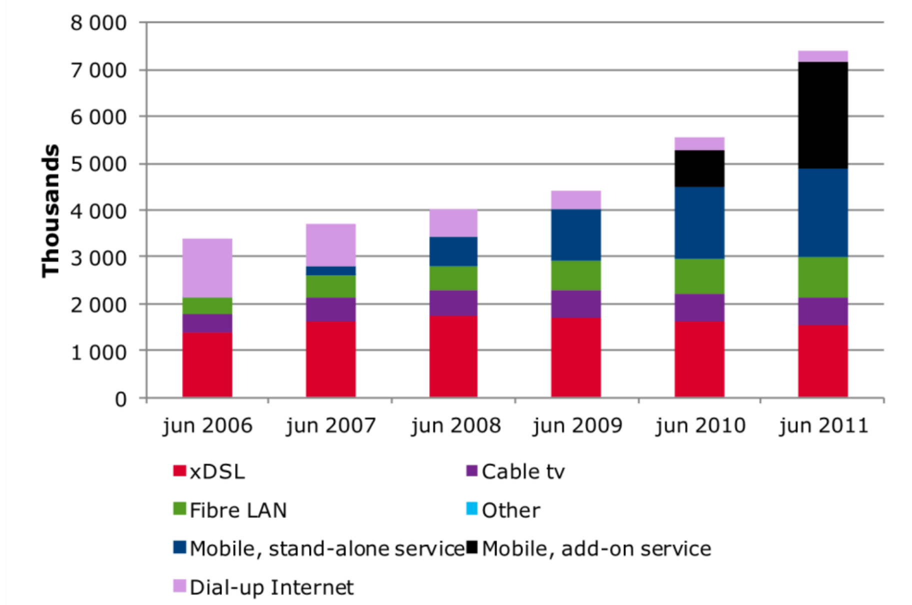


Figure 6-2: Swedish Internet subscriptions by technology, June 2006 - June 2011
Source: PTS, 2011a

Figure 6-2 shows that the number of dial-up and DSL subscriptions has decreased between 2006 and 2011, while fibre and mobile broadband technologies have become more popular. The diagram also highlights a comparable subscriber base for DSL and mobile broadband (stand-alone), with mobile broadband ‘catching up’ to DSL. Generally, however, broadband services are delivered over all technological platforms - DSL, cable, wireless and fibre infrastructures - with approximately 21.6%, 8.5%, 58.2% (mobile broadband) and 11.8% respectively of the total Internet broadband subscriptions at the end of June 2011 (PTS, 2011a). Figure 6-3 shows the household penetration of fixed broadband technologies at the end of June 2011. While 3G coverage was available to 99.6% of the population by June 2010, 4G was also deployed in 2010 and 2011 (Buckland and Tee, 2010).

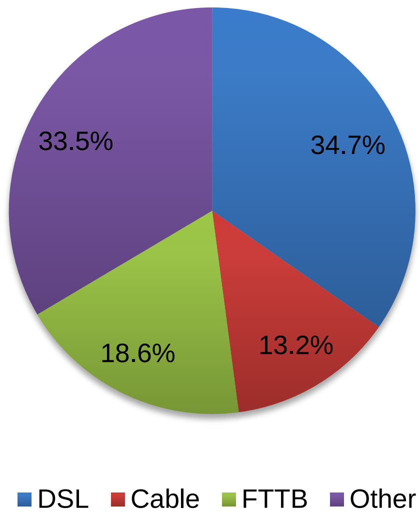


Figure 6-3: Swedish percentage population penetration of fixed broadband technologies, June 2011
Source: Analysys Mason, 2011b

Despite its optimistic development, Swedish broadband has historically been shaped by an urban-rural divide, with a high percentage of the population to be found outside the three main areas of Stockholm, Gothenburg and Malmo. Northern Sweden is relatively sparsely populated. As a result, broadband distribution has been non-uniform and national broadband policies have played a crucial part in developing the sector and the society. Lindmark et al. (2006) explain that, for example, the Swedish Government offered tax subsidies on personal computers bought by companies for their employees’ personal use in 1997. This resulted in an increase in both the diffusion of computers and the use of the Internet among

Swedish citizens. From 1995 to 2002, the number of dial-up Internet connections escalated from 54,000 to 3.2 million because of this 'employee computer program'.

Subsequently, in 2000, the Swedish Government published an ICT strategy that was targeted at stimulating the deployment of broadband infrastructure across the country and, thus, ensuring broadband availability (MIECS, 2000). The strategy committed approximately €400 million (4150 SEK) to broadband infrastructure roll-out during the period 2000-2005 (CEC, 2005). The focus was on developing open networks at the local and regional level where broadband availability was, at the time, stunted. Two thirds of the government money was used to subsidize local authorities and municipalities in this venture (CEC, 2005). Assistance was also provided to end-users and to the development of networks at the national level. In the first instance, the government was concerned about technology adoption. At the national level, monies were used to build a backbone infrastructure that would provide competition to the incumbent's core network. This ICT initiative by the Swedish parliament made Sweden the first European country to have an active broadband policy.

Following on, in 2004, the Swedish Government Bill was established. The bill was targeted at making Sweden a "sustainable information society for all" (Ministry and Industry, Employment and Communications, 2005, p7). In the particular case of broadband, the requirement was to deploy high-speed physical infrastructure to provide IT services to the entire country and thereby provide access to interactive public e-services (New America Foundation, 2010).

6.2.3 Developments in next-generation broadband

The vibrant nature of the Swedish broadband sector has also promoted interest in next-generation broadband. This section provides an overview of the developments that have taken place in this market until the present time and highlights the role of the Swedish government in the advancement to next-generation broadband.

Investments to date

At the end of 2004, TeliaSonera proclaimed its deployment of Sweden's largest IP network to serve the 3,650 representatives of the Swedish gaming company, Svenska

Spel (ITU, 2009a). This network was estimated at €19 million (SEK 200 million). In 2009, the incumbent had already started using its IP NGN solution to create a PTP fibre network (Telegeography, 2009). In 2007, Telenor announced a planned upgrade of its core network with a focus on a fixed and mobile converged IP Centrex application (Ericsson, 2007). This upgrade was targeted at business customers in the first instance. Also in 2007, Hi3G declared their investment in an IP-based NGN provided by Cisco (Telegeography, 2007).

In terms of NGA, as Section 6.2.2 described, broadband in Sweden has been delivered by a range of technologies. In the advancement to next-generation broadband access, investment has been made in each of these platforms, upgraded to some degree to achieve higher-speed Internet access. For example, the cable TV operator, ComHem has upgraded its cable network using DOCSIS 3.0 with the aim of providing up to 200 Mbps Internet access speeds to its customers Telegeograhpy, 2011b). In March 2010, ComHem's DOCSIS 3.0 network was serving 1.5 million customers (Analysys Mason, 2011d).

In the fibre domain, Sweden achieved the second highest rank for FTTH/FTTB household penetration within Europe in December 2010, with a 13.5% penetration (Montagne, 2011a). This investment, however, has been primarily led by third parties – local municipalities and utility companies – in conjunction with the government. Some 150 such fibre projects exist in Sweden, the largest being Stokab, which is owned by the Stockholm municipality. Stokab provides 5600 km. of dark fibre to businesses and operators in and around Stockholm (PTS, 2010b; Buckland and Tee, 2010).

While several of the large operators have put forward fibre investment plans, their deployments have been minimal. For example, in June 2011 TeliaSonera announced its plan of covering 1 million households with direct fibre by the end of 2014, but with a "remaining cautious" caveat (TeleGeography, 2011b). At June 2011, the incumbent had 320,000 homes passed while, at the same time, Telenor claimed 500,000 FTTB/H homes passed (Montagne, 2011b). Telenor also committed to FTTB/LAN upgrades to cover all its customers in Stockholm by 2010, but after a trial in November 2007, no further announcements were made (Buckland and Tee, 2010).

In December 2009, TeliaSonera launched what was cited to be the first LTE network in the world in Stockholm (and Oslo) (Telecoms.com, 2009). The Swedish incumbent's 4G network is expected to eventually deliver access speeds of 20 to 80 Mbps to, initially, mobile laptop users (Gardner, 2009).

In general, there is evidence in Sweden that the use of higher transmission capacities is increasing. Figure 6-4 shows the trend in the number of broadband subscriptions from 2008 to 2011 in relation to transmission capacity. Given the growth in the use of higher speed access shown in Figure 6-4, it can be expected that continued lack of investment in NGA by the national operators can hamper the development of competition in this market.

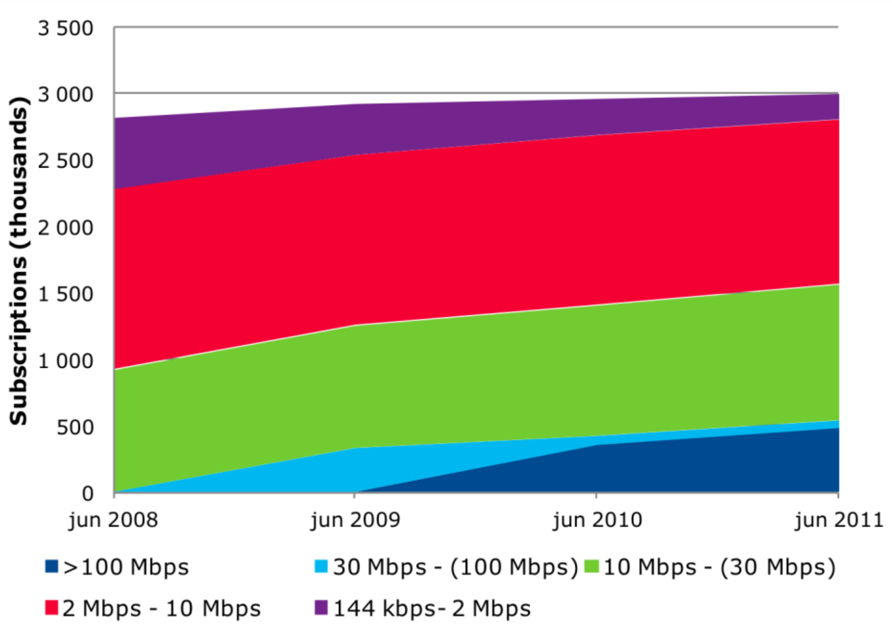


Figure 6-4: Swedish broadband subscriptions in relation to transmission capacity, June 2008 - June 2011
Source: PTS, 2011a

The role of the Swedish Government

Following its key role in the diffusion of current-generation broadband, the Swedish Government continued in this trend for NGA deployment so that Sweden shall have world-class broadband (Ministry of Enterprise, Energy and Communications, 2009). The government developed a national broadband strategy in November 2009 to deliver broadband access of at least 100 Mbps to 40% of households and business by 2015 and to 90% of households and businesses by 2020 (PTS, 2011b; New America

Foundation, 2010). The strategy is also aimed at providing proper access to all households and businesses to public electronic services (PTS, 2011b). Working in collaboration with PTS, and both the private and public sector, the government aims to ensure that both infrastructure and effective regulation be put in place in order to achieve its objectives.

6.3 Analysis

The previous section presented a brief insight into the Swedish telecommunications sector. The market conditions and industry events described in Section 6.2 are used as a starting point for understanding the discussions presented in the current section. This section details the findings of the data analysis and, hence, identifies the relationships between the market conditions and the development of next-generation broadband as viewed by the key stakeholders in Sweden.

6.3.1 What are next-generation broadband networks?

The participants of the study differentiate between next-generation core networks and next-generation access networks in their discussions of next-generation broadband. While there is agreement among the interviewees that there is a distinction between NGN and NGA, the belief that next-generation networks are part of the underlying architecture of next-generation access networks is a popular one. However, there is an obvious focus on next-generation access in this country, as the definitions, discussions and references made to next-generation access surpassed those linked to next-generation networks. These two network categories are discussed below.

Definition of next-generation networks

The definitions of NGN provided by the participants are limited in both quantity and scope, as Figure 6-5 illustrates. Although there is a common view that NGN comprises fibre in its core, it is also believed that the core is based on IP and provides a more cost efficient platform [concepts 2004 and 2005]. The main definition is that NGN is a merged access and aggregation network that contains a lot of dynamics [concepts 2001 and 2002]. However, there is little support to build on this definition and it can only be recognized that ***NGN is perceived in terms of a technological upgrade of the core network*** and that ***there is little focus on and/or understanding of NGN in the Swedish market***.

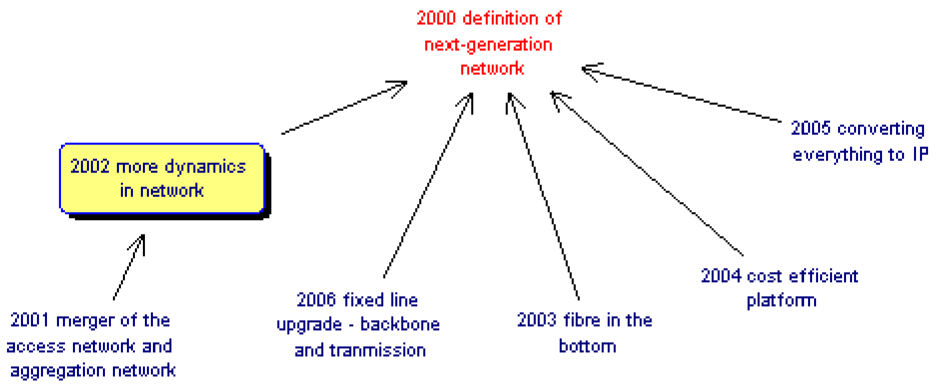


Figure 6-5: Swedish definition of NGN

Definition of next-generation access

Three main definitions of next-generation access networks are revealed from the Swedish interview data. These are captured in Figure 6-6 along with their relationships.

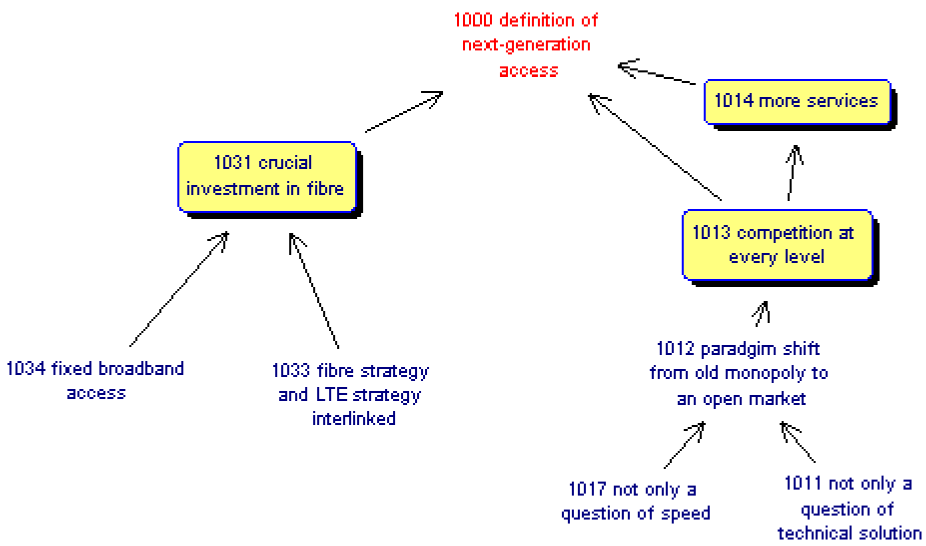


Figure 6-6: Swedish definition of NGA

The most important view among the participants is that NGA is an access network that facilitates competition at every level of the network and market [concept 1013]. In this regard, NGA is not only associated with an improvement in speed [concept 1017] or other technical enhancements of the access network [concept 1011], but more broadly with a shift from a single-provider system (monopoly) to a market with the potential for many providers to compete [concept 1012]. Linked to this is the second key definition - that the possibility for a more competitive network and market results in a network/market that can provide a wider range of services to consumers [concept 1014]:

> "*It's a paradigm shift from the old monopoly system to an open market where we have competition at every level. That's quite new in Europe and of course all over the world.*"

> "*I think it's more, it's not only a question of technical solution and not a question about speed, it's more a shift of the system, a system that we used to have monopoly and we go to more open market with more competition, which also gets more services.*"

Finally, participants consider NGA to be linked to technology. While the Swedes are indeed open to the use of various technologies, there is a widely held view that, inevitably, fibre must be at the core of the network upgrade [concept 1031]. While some thought that NGA is only an upgrade to the fixed network [concept 1034], using optical fibre [concept 1031], others open to a mix of technologies also thought that, despite the potential of LTE and other wireless technologies, there was still a dependence on fibre at some level [concepts 1033 and 1031]:

> *"You do need a lot of fibre in order to get good capacity at the base station so you still need to have fibre in the ground in order to be able to use LTE for example. So, the crucial investment is still in laying down fibres."*

“*The next generation in my word is linked very much to upgrade of the fixed network…Besides that, certainly the fibre strategy and LTE strategy are inter-linked.*”

“*But you also have, of course, the wireless solutions but to my view it is so that without the fibre infrastructure there will be no fourth generation wireless solutions or fifth generation because it won’t be possible to develop the wireless solutions without the capacity that fibre can bring.*”

The analysis shows that there is a general belief that NGA can be realized using a combination of technologies based on fibre. More importantly for the Swedish participants, however, is that the network provides an open architecture and, thus, increases competition by allowing a range of providers to deliver services over the same access infrastructure. Based on the results of this NGA analysis, it can be concluded that ***NGA is viewed as a network that will enhance the competitiveness of the Swedish market*** and ***the Swedish are open to mix of technologies in NGA deployments***.

6.3.2 Next-generation broadband investment

An initial observation from the Swedish data is that the main factors influencing next-generation broadband investment encourage investment in the NGA market, rather than the development of NGN. This suggests, at a very basic level of analysis, that ***the conditions of the Swedish telecommunications market are more conducive to NGA investment than to NGN investment***. More detailed analyses are presented in the following sections, firstly on NGN investment and then on NGA investment.

NGN investment

Like the interviewee input for the definition of NGN, the discussions related to NGN investment in Sweden are limited. However, an interesting outcome of the basic analysis that was possible is that there is little drive for NGN investment, as two of the three direct influential factors for the NGN investment decision had negative impacts on investment, as Figure 6-7 shows. The single positive influence results from an increase in network traffic [concept 3133]. The traffic needs are "growing rapidly", one interviewee explained, motivating TeliaSonera to enhance their core network in order to address the growth. Thus, the incumbent has increased its capital expenditure budget and is investing in an upgraded core infrastructure [concept 3134]. This combined influence of traffic growth and increased capital expenditure demonstrates that ***a mix of demand and supply factors is influencing investment in NGN***.

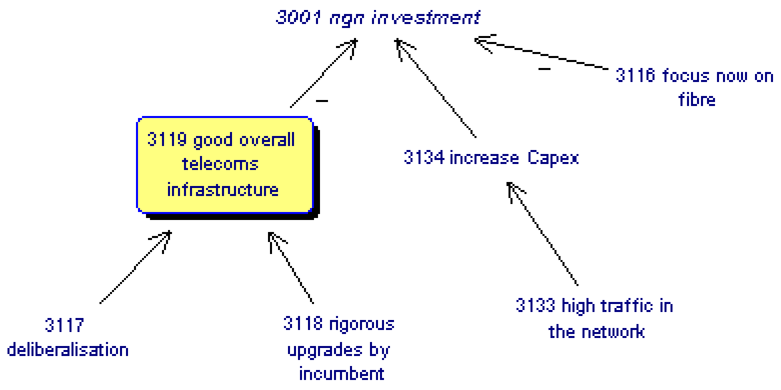


Figure 6-7: Main market factors influencing NGN investment in Sweden

However, the main influence in the investment decision is the current status of the legacy network [concept 3119]. As a result of continuous upgrading by TeliaSonera over the years, the core network that exists today is in relatively good condition [concept 3118], discouraging any further investment in core infrastructure. The liberalization of the Swedish telecommunications sector that began in the 1970s also contributes to the good condition of the network [concept 3117]. With a focus now on the access part of the network and investment in fibre, NGN is overlooked [concept 3116]. These opinions are expressed in the following statement made by a participant:

> "*Now the focus is on fibre, the last mile or the access network, but still the overall infrastructure is quite advanced, because it goes back to the early deliberalisation, etc. from the mid 1970s and upgrades and Telia as the monopoly has been doing quite rigorous and extensive upgrades over the years, so that leaves Sweden in a quite good position with regards to that, the overall telecoms infrastructure.*"

NGA investment

Swedish operators are influenced by a variety of market factors in their decision to invest in next-generation access but Figure 6-8 captures those market factors that are identified as being at the heart of the NGA investment decision.

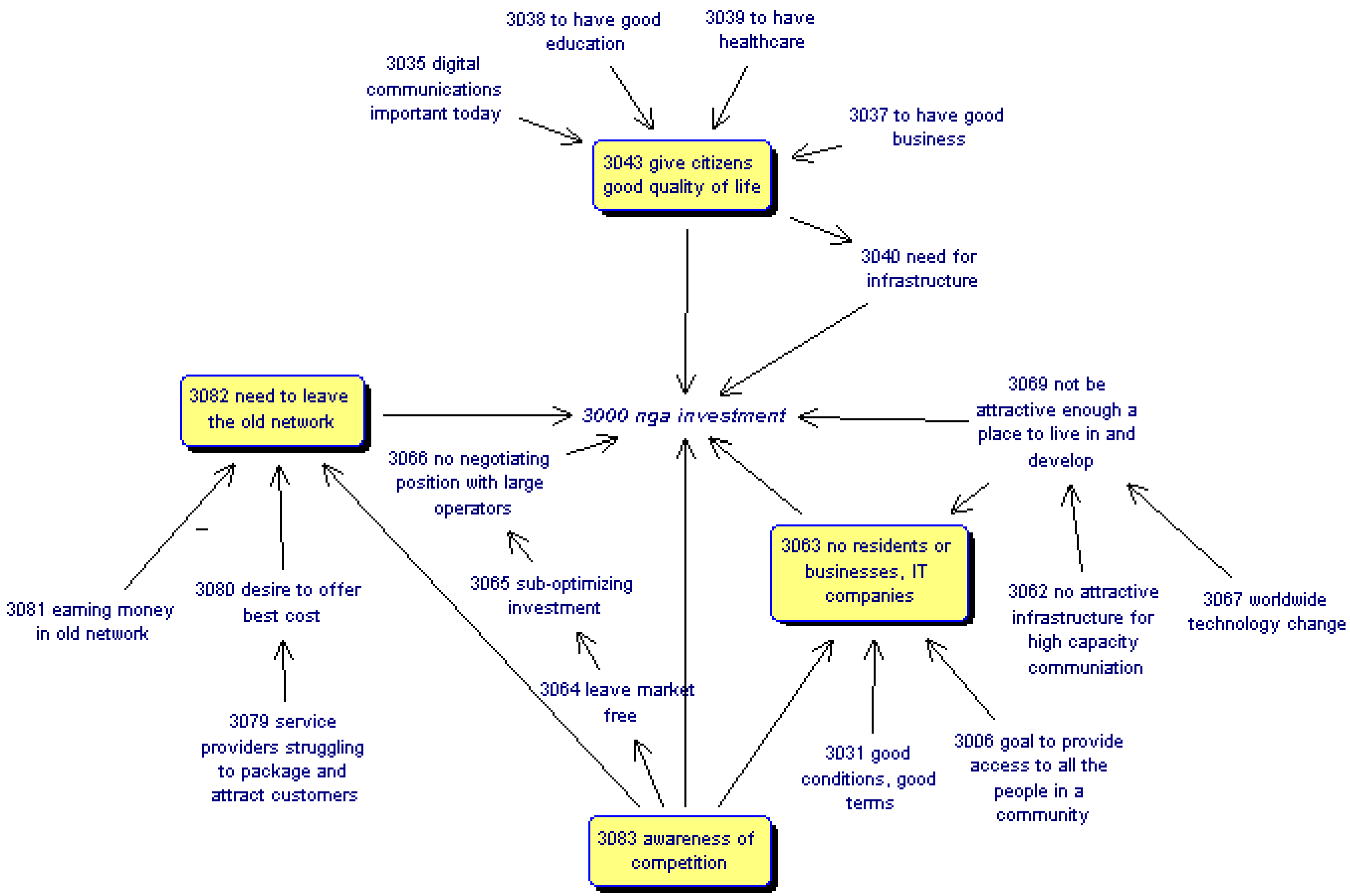


Figure 6-8: Main market factors influencing NGA investment in Sweden

Of greatest influence is the ability to provide a better quality of life for citizens [concept 3043]. This is true on both local municipal and country-wide levels. The view among participants is that communications has always been a prime driving force of a society and, today, the most important form of communications is digital communications [concept 3035]. Thus, digital communications is essential for the provision of a good quality of life for citizens [concept 3043]:

> "*But I would say, if you go further and more philosophic way, that communication has always been the most important driving force for the society, always. From the beginning, you were building cities close to the water and then you have the railway and some cities died and some others appeared because of the infrastructure. So communications is probably the most important driving force, and today we do not communicate on water, railroads on the same way as we do digital, and I think we have to realize that and also consider how could we make a good society, how could we create a good life for the citizens? So, it's more than just a technical question.*"

A good quality of life means that citizens can have access to good education, healthcare and business [concepts 3038, 3039 and 3037]. As these all require reliable communication, infrastructure that can provide this is necessary [concept 3040]. Thus, investment in NGA is encouraged.

Next in significance is the need to attract residents and businesses to the community or country [concept 3063]. In the first instance, there is recognition in Sweden that a technology change is taking place – the country is shifting away from an industrial one to "something else" [concept 3067]. This change is happening on a global level with other countries having one form of stimulus or another to advance their infrastructure. If Sweden does not act similarly, the risk of not being a sufficiently attractive country to live in or to develop economically is high [concept 3069]. In a participant's words,

> "*I guess actually that on a national Governmental level it is kind of a threat. They do, we have to do. So, it is a technology change. We are going from an industrial country to something else. The industrial part is in China and India*

these days, so to survive. I have met many different groups from other countries and they have a tremendous lot of stimulation in Portugal and lots of countries so this issue is really on the agenda everywhere. If we don't do, we will be lost in the future competition and we will not be attractive enough a place to live in and develop."

Secondly, on a local level, the lack of high capacity infrastructure makes a municipality or a local community/city unappealing for potential residents and businesses [concept 3062], as one interviewee explained:

"*I would say this is a threat for the local society to not invest in the future…they have realised after a while that if we don't have an attractive infrastructure for high capacity communication, we will not be an attractive municipality, both for private persons or families to live here as well as for commercial operations.*"

Participants also explained that many of the municipality projects are aimed at providing access to all the residents within the community, thereby encouraging current residents to remain in the given area [concepts 3006 and 3063]:

"*I think most of the communities in the country have as a goal to provide access to all the people. It's a way to attract people to come and be established in the community, to have access to networks for Internet.*"

Yet another opinion is that Sweden is a cluster for ICT and ICT companies and, to initiate investment in the ICT sector, the government must provide good terms and conditions for potential candidates, of which communications is an integral aspect [concept 3031]. Sweden is competing with other countries for such cluster opportunities [concept 3083]. An interviewee remarked:

"*This is a cluster for ICT and you have all the IT companies, all the communications companies, they are based here. That could not be possible if you can't offer them good communication. They would never be here. How could we get them to do investments here, to start offices here, to start* *factories here? By giving them good conditions, good terms. So, we are competing with other cities on the other side of the Baltic Ocean.*"

Linked to this is the third influence of NGA investment – an awareness of competition at all levels [concept 3083]. At the municipal level, if the communications market is left open to the large national operators for service provision, the risk of a sub-optimal investment in the municipal emerges, as the national operators are not interested in developing the community but, rather, in undertaking a profitable venture [concepts 3064 and 3065]. The possibility of negotiating with the national operators for the benefit of the municipality is also low [concept 3066]. With these considerations in mind, municipals thought it was essential to invest in their own fibre infrastructure.

From a national perspective, it is believed that Sweden is competing with the rest of the world in the advancement of technology and its associated impact (such as the development of businesses and the country) [concept 3083] and, therefore, that it is necessary to migrate from an old infrastructure with limited capabilities to an upgraded infrastructure with more potential [concept 3082]. A statement made by an interviewee conveys this:

"*The question was really how could we survive, how could our enterprises compete with the rest of the world? So what are we talking about? We're talking about a national network or a metro network and an access network, and in our terms the network goes also inside the dwelling units.*"

In addition, it is viewed that service providers are challenged in their offerings to consumers and are desirous of providing the best price, for example [concepts 3079 and 3080]. In order to do this, participants believe that there is now a need to move away from the old copper infrastructure:

"But, we're also in a situation I would say right now where the service providers are struggling with different types of packaging and what to offer to attract the customers, so what you see today in advertisements on the TV for example is a battle where the different service providers try to offer everyone the best cost, cheapest and everything. But, I think there is still some

technology development still to be done or that they take a strategic choice – now we leave the copper structure."

Although there is awareness of competition and the need to improve the old networks, some participants acknowledge that there is still money in the copper network thus making the investment in NGA not a priority at present.

"*But we are still I would say, in using the terms of the Boston Consulting matrix, in a time where there is a lot of cows out in the market and they try to bring out the most money from the cows, but they are of course extremely aware of the different service providers. At some stage, we have to leave the old, but we are earning money there right now.*"

While it is clear that ***the Swedish telecommunications environment is generally favourable towards NGA investment*** and ***is driven primarily by the desire to improve socio-economic conditions***, several negative and conditional factors emerge from the discussions. The negative influences are shown in Figure 6-9. It is evident from the diagram that existing infrastructure and the desire for operators to "milk" the old copper network as much as possible are preventing some operators from investing in NGA [concepts 3003, 3055, 3056, 3090, 3101 and 3105].

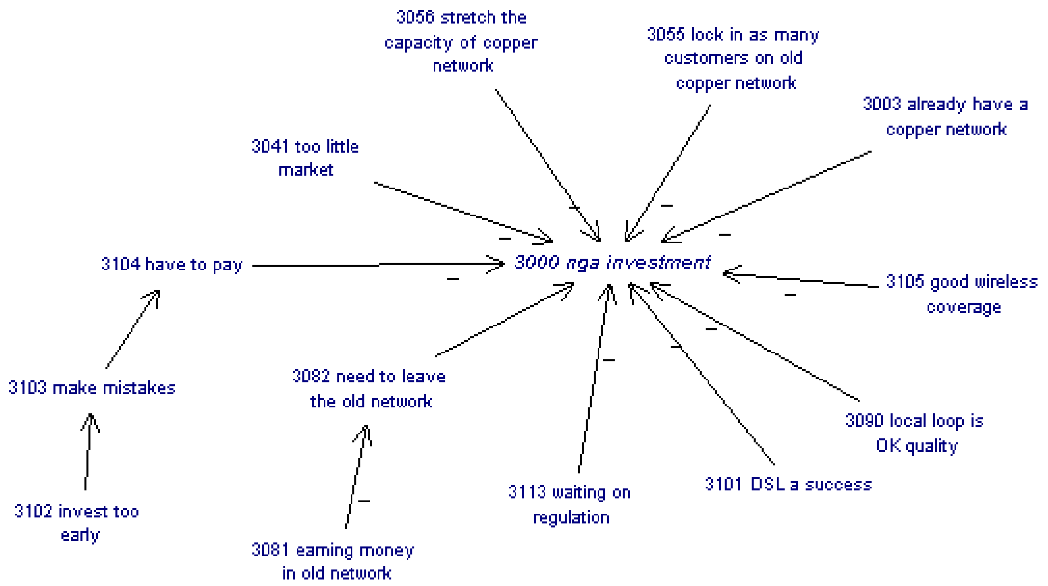


Figure 6-9: Negative influences on NGA investment in Sweden

The old network is still profitable for some [concept 3081], lowering the motivation for investment in new networks, as expressed by one participant in the following:

"*At some stage, we have to leave the old, but we are earning money there right now*."

There is also some concern about consumer demand, as participants indicate that there is insufficient consumer market for NGA deployment for some operators [concept 3041]. This is particularly so in the less populated areas of Sweden. This interviewee explained:

"*…but the reason why they did the self-deployment is that they asked all these operators and no one was interested to do anything – too little market, we're not interested*."

A regulatory influence is also highlighted. According to the interviewees, some operators refuse to invest in NGA until there is some knowledge of the next-generation access regulatory framework while some are cautious about making a premature investment with the risk of making errors [concepts 3102, 3103, 3104 and 3113].

While the factors in Figure 6-9 have a definite negative impact on NGA investment, those in Figure 6-10 can influence the decision either positively or negatively. As the diagram illustrates, the decision depends on the regulatory framework, specific details of the company's operations, the scale of the investment and the legacy networks owned [concepts 3094, 3095, 3110 and 3114] for some participants. For others, there is a more pronounced degree of uncertainty arising from other factors. For example, as an interviewee explained, some companies just do not know what investment decision to make [concept 3112]:

"*When it comes to NGA and investments, it's still on the planning and the companies are not so interested to share because to some extent they have not made up their minds. It's also a question of they don't know, they have not made up their minds.*"

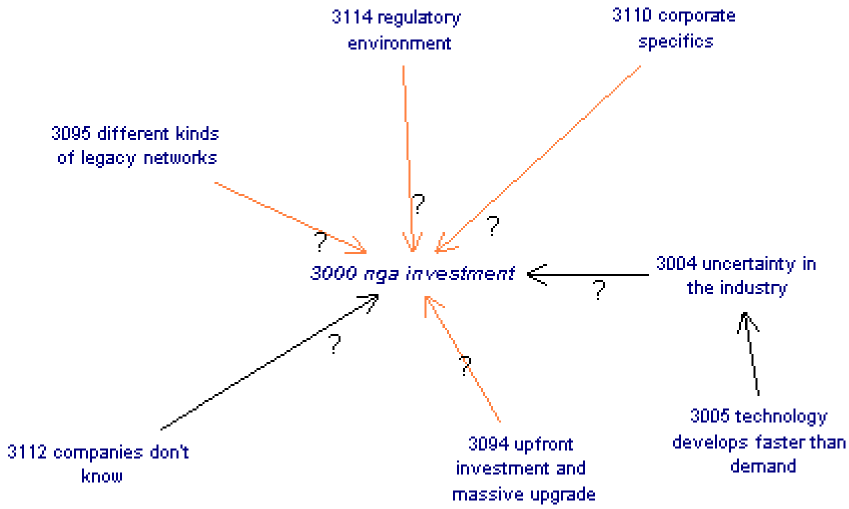


Figure 6-10: Conditional and uncertain influences on NGA investment in Sweden

Finally, a lot of uncertainty exists within the telecommunications industry itself as advances in technology have been more rapid than growth in consumer demand [concepts 3005 and 3004]. As a result, there is reluctance to invest in NGA at the present time. One interviewee highlights this existing degree of uncertainty in the following statement:

> "*This industry is complicated in many ways but one aspect is that the technology develops faster generally than the demand, because the latest news in laboratories is not being used in the markets up until ten years or something later. So it's a very difficult industry as there is a lot of uncertainty. And, who will take the risk of investing and who will wait and make the right decisions?*"

Two further key observations were made from this analysis. As mentioned earlier, ***one of the influential factors in Sweden is regulation***. Secondly, the Swedish state involvement in next-generation broadband access, at both a central government and local municipality level, has been significant.

6.3.3 The technology dilemma

The data analysis reveals that many factors influence operators' decision in the choice of access technology for NGA but the majority of factors lean towards optical fibre as the ultimate choice. In addition, the main factor influencing the choice of technology is consumer demand, also driving the use of optical fibre. It was also observed that no factor discouraged the use of optical fibre. These observations suggest ***optical fibre most suitably satisfies the needs of NGA deployment in Sweden***.

Isolating those factors that dictate the use of a specific technology, the main factors that operators consider in their decision for the choice of access technology are the ability to make money from the investment and the geography of the region in which the network is being deployed, the former of which is more important. These factors are shown in Figure 6-11 as concepts 6047 and 6044 respectively. Figure 6-11 also repeats the finding of Section 6.3.1 that ***a combination strategy for NGA deployment is foreseen*** [concepts 6007, 6008 and 6009]. Beyond these general findings, the key factors that influence the use of one technology or another were identified and are now described.

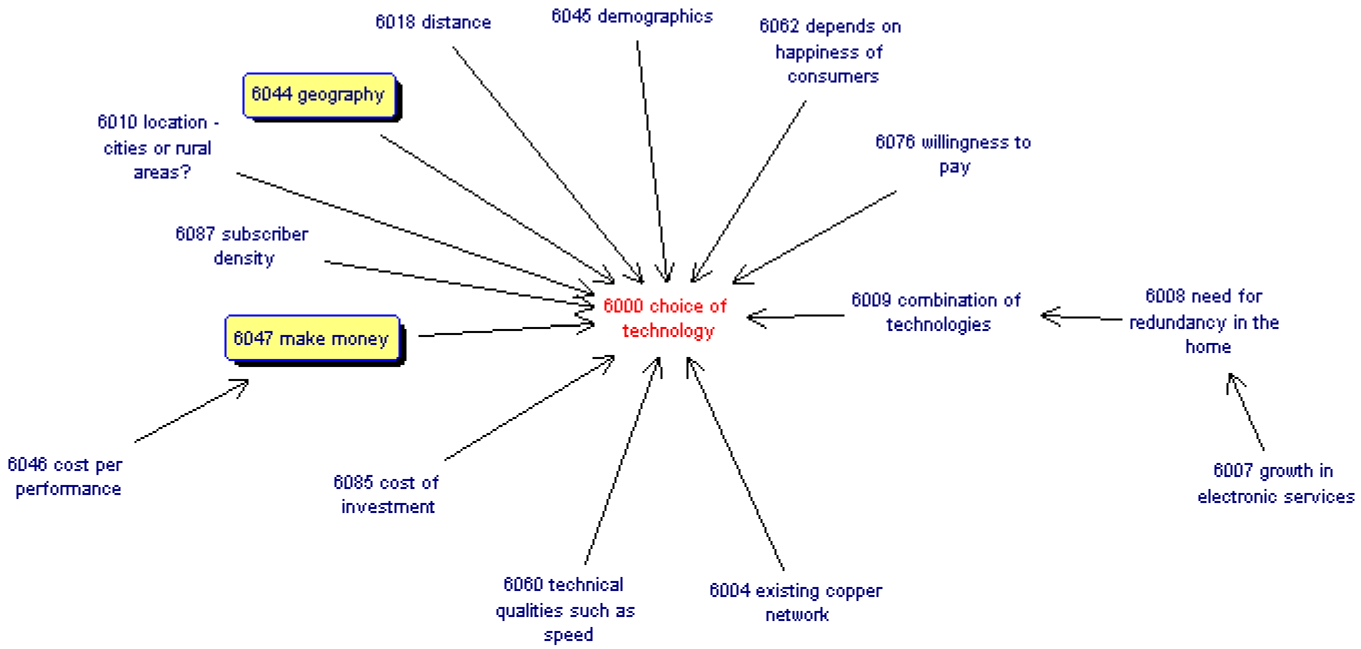


Figure 6-11: Main market factors influencing the choice of technology in Sweden

Optical fibre

The discussions presented herein focus on the main factors influencing the use of optical fibre. The relationships, presented in Figure 6-12, reveal that ***the most important driver for optical fibre is consumer demand*** [concept 6080]. Many factors have increased consumer demand in Sweden. Firstly, the government broadband support programs that were administered during the early 2000s increased the penetration of personal computers among Swedish citizens [concepts 6067 and 6068], another factor that has also been identified as a key driver for optical fibre. In turn, the demand for Internet access has grown [concept 6080]. Swedish consumers have also been used to a high quality of services over the years [concept 6065] and are, consequently, demanding more.

Interviewees also explain that the trend of increasing demand is even more evident among younger users. Younger consumers are beginning to use more high-speed applications and are increasing the time spent online [concepts 6074 and 6073], driving an increased demand for even better access. An interviewee commented that

> "*…if you take the young users, you can see that they are using specific applications that require high bandwidth like file downloading, for example, Torrent clients. They also use it for much longer times than their peers in older age groups and they use several applications simultaneously. This also means that there are user patterns that drive demand for bandwidth.*"

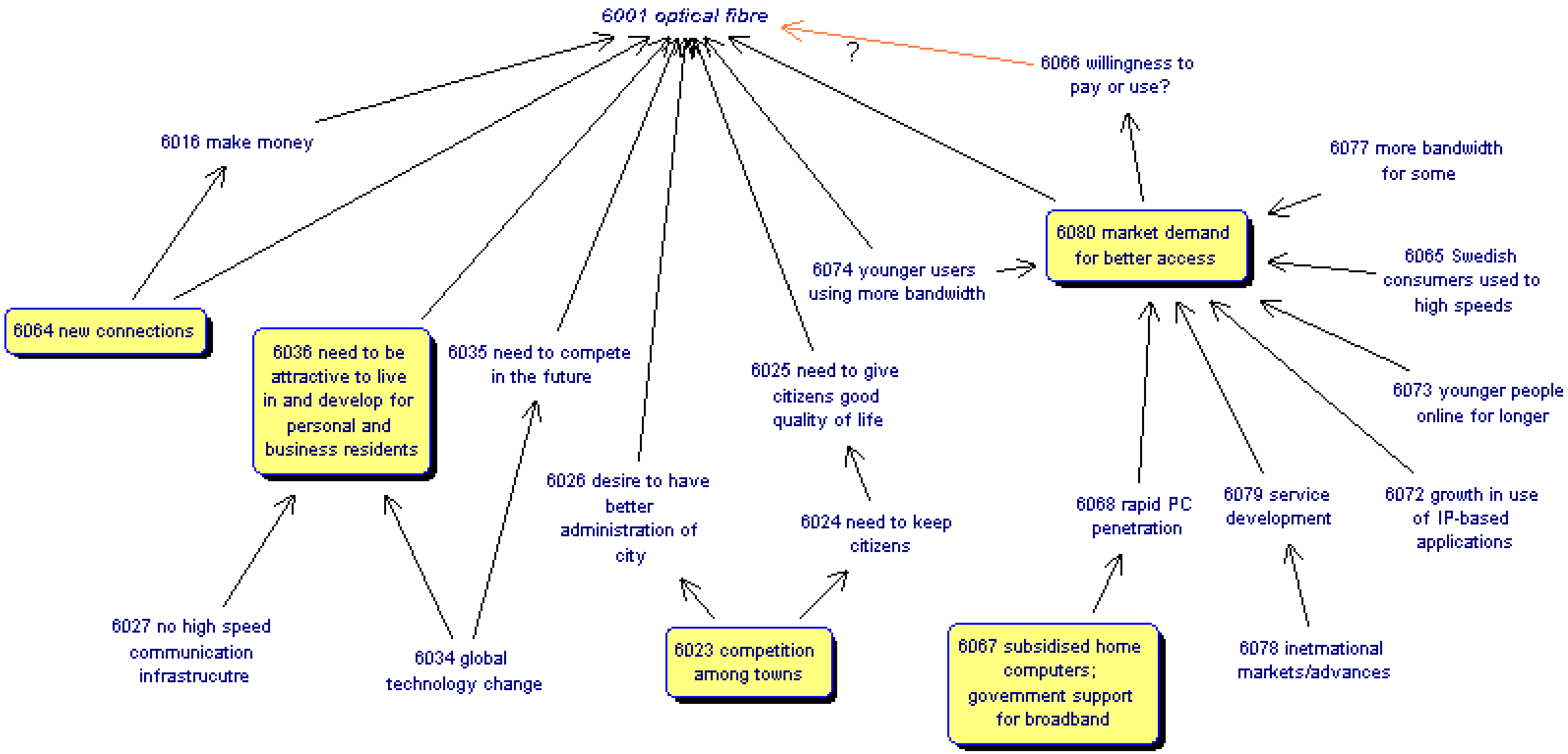


Figure 6-12: Main market factors influencing the use of optical fibre in Sweden

A growing trend towards the use of IP for the transmission of broadband services is evident among Swedish consumers [concept 6072]. This, too, has encouraged a greater general demand, as one participant of the study explained:

"*You can also add that more and more applications are used on the IP-based networks – you use for television, for radio, for all kinds of applications that used to have separate networks – so that also drives the demand for more bandwidth among the consumers.*"

The availability of and demand for broadband has had a domino effect. As consumers gain access to greater capacities, those with little or less show a tendency to want more as well [concept 6077], as a participant explained:

"*But, it's also the case of the more bandwidth some people have the more service everybody wants and that's what, in turn, drives the demand for bandwidth for the customers who don't have it.*"

Finally, advances in other (international) markets have influenced and are expected to further influence the demand pattern in Sweden [concept 6078]. For example, as international markets increase their fibre deployments, the availability of high-speed services will also be enhanced. As a result, demand from consumers will increase on a global level:

"*We start out with quite a lot of fibre so we're in that sort of segment but I think that the more fibre there is in the world and the more services require, taking advantage of the large bandwidth there will be, that will influence what can you do, what do you need, so I think because what happens in the rest of Europe, what happens in the US, that will drive service development and that in itself will drive consumer demand which will drive investment. So, I think it's always important*."

However, while the increase in consumer demand for higher capacities generally drives investment in optical fibre, the question of consumers' willingness to pay for the higher capacity can threaten the investment, as expressed by this quote:

"*I think the ultimate driver is probably consumer demand. The ultimate driver is that consumers want high speed accesses. To what extent they want that and how much they're ready to pay for it also sort of puts the cap on the investments too. I think that Swedish consumers have been rather expecting higher speeds. I think we have pretty high speed access so…I don't always know if people know what they're going to do with it. They want higher accesses but they're not always ready to pay what it actually costs, but I think that ultimately drives the investments.*"

The second most important driver for optical fibre is the need to be an attractive place to live in and to develop [concepts 6036 and 6023]. This was also identified as a key contributor to NGA investment in Section 6.3.2. To avoid repetition, the relationships linked to this factor will not be repeated in this section. However, the key result is that optical fibre is considered to be essential to creating attractive regions, both communities and the country in general, for private and commercial residents.

Thirdly, optical fibre has proven to be the choice of technology for new connections in Sweden, for municipalities, housing corporations and national operators [concept 6064]. According to participants, the cost of new connections using fibre and copper are comparable and, given the technical advantages of fibre over copper, the "future-proof" technology is opted for. This interviewee's remark supports this:

"*Currently you can say that when someone connects new end customers or rather new buildings, they always use fibre. So, new connections are fibre accesses.*"

Participants believed that, for national operators, the investment in new connections is linked to profits [concept 6016]:

"*I think that one reason for [operator] to deploy fibre now is that they make money out of it otherwise they wouldn't do it, that they build fibre to new houses.*"

Wireless technologies

The factors highlighted as being influential in the decision to use wireless technologies are limited to the nature of the region being rural [concept 6041] and the cost associated with providing wireless services [concept 6061], as Figure 6-13 shows. In the first instance, participants agree that ***wireless technologies should be used where there is low population density***, as the investment cost for optical fibre or fixed access in such areas will be significant. The second factor is linked to the cost of providing wireless services on a national level. Participants believe that the cost of deploying wireless technologies to deliver broadband services to all citizens will be high [concept 6061]. However, since the discussions on the potential for wireless technologies were limited, no other decisive conclusions can be made with regard to using this technology in Sweden.

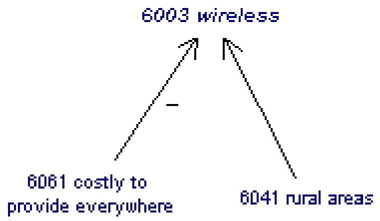


Figure 6-13: Factors influencing the use of wireless technologies in Sweden

Mobile technologies

A differentiation between wireless technologies and mobile technologies was made by the participants and, as a result of its recent introduction in Stockholm, the discussions on mobile technologies were concentrated on LTE. Figure 6-14 shows that mobile technologies/LTE are considered to be useful as they increase the flexibility for consumers “on the move” [concept 6022] and to serve distant regions where it is expensive to maintain the old copper network [concept 6090]. In addition, as LTE equipment prices have been reduced [concept 6091], this technology is attractive for investment. Thus, ***LTE is considered to be a potential mobile NGA solution***. However, as is the case with wireless technologies in general, a mobile solution is considered to be expensive for a nationwide deployment [concept 6061].

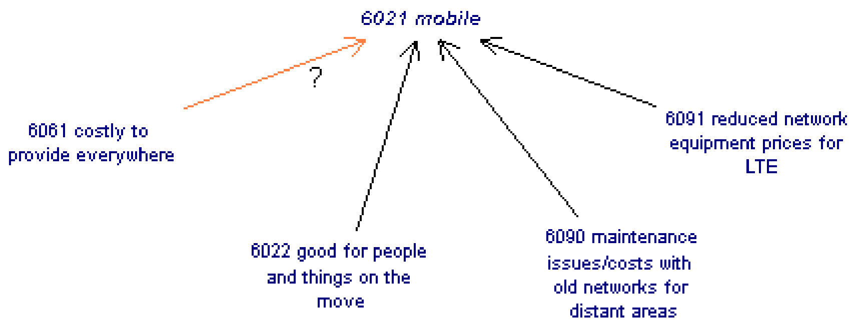


Figure 6-14: Factors influencing the use of mobile technologies in Sweden

6.3.4 Perceived benefits of next-generation broadband

The benefits expected with the deployment of next-generation access networks significantly outnumbered those expected with NGN. This supports the deduction that ***NGA is more important than NGN in Sweden***. In the following paragraphs, the perceived benefits of NGN are first discussed and then some detail on the expected benefits of NGA is provided.

Perceived benefits of NGN

An understanding of the benefits associated with the deployment of NGN is limited among the Swedish participants. Figure 6-15 shows the results. As the diagram illustrates, the main expectation is that operators will become more competitive [concept 5004]. With the move to an IP-based core, it is expected that the quality of services and service delivery will be increased while the price will be lowered [concepts 5002, 5003], making the operator more competitive in the wider market:

> "*then you have the market argument that you might be able to increase quality and decrease price so you will be more competitive.*"

NGN is also expected to make the network platform more cost-efficient [concept 5001]. As these benefits are all linked to enhancing the operators' efficiencies, it can be concluded that ***the benefits of NGN are operator-related***.

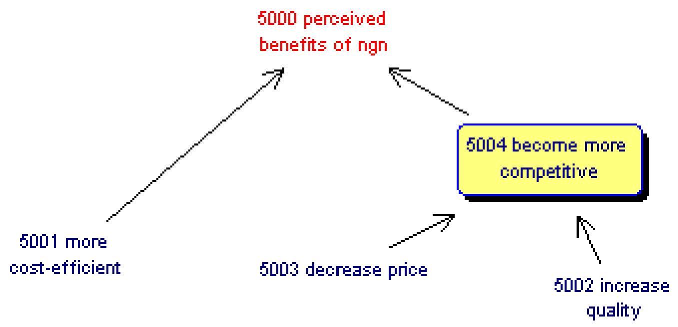


Figure 6-15: Primary (expected) benefits of NGN by Swedish market players

Perceived benefits of NGA

The discussions presented herein focus on the main benefits of NGA as highlighted by Swedish participants, captured in Figure 6-16. As the diagram illustrates, the most significant benefit expected by the Swedish interviewees is a reduction in operating cost for operators [concept 4045]. Interviewees believe that staffed administration services are a waste of resources for an operator in terms of people and time. With NGA, more self-service functionality for customers will be possible, thus reducing the need for both human and time resources for the provider [concepts 4013, 4014 and 4015].

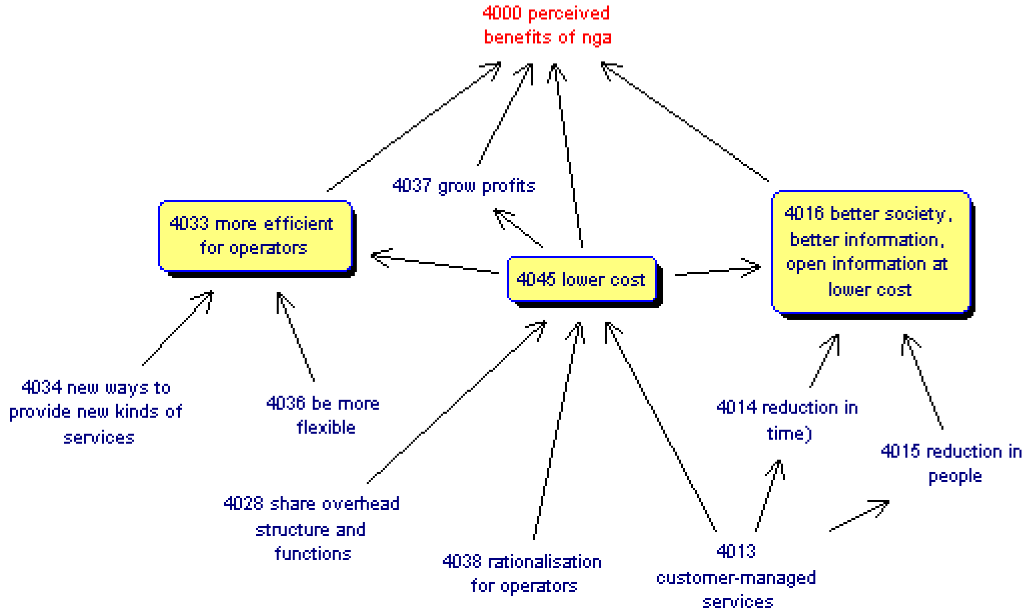


Figure 6-16: Primary (expected) benefits of NGA by Swedish market players

In support of this, an interviewee commented:

> "*The other is the public sector, because they can't afford to have administration based on manpower. They can't have people sitting and waiting for phone calls and give all the information in phone calls or in person. It costs too much time and money and people. So, what we need is a system where the consumer manages the service by themselves. They go directly into the system and find the information that they want and they can also administrate it to have their own service.*"

According to the interviewees, as a result of the shift of administrative services from the operator to the customer, customer services and service provision are improved, as customers have more open and more frequently available access to information [concept 4016]. An interviewee explains this:

> "*Then they are also getting better services, 24 hrs, without anyone involved. So, you have a better society, better information, open information, for a lower cost.*"

With the provision to share functionality over several services [concept 4028], reduced costs are also expected, albeit in the long term. One participant explained,

> "*...you need overhead functions. If you can add a new operation where you can share the same overhead structure, it will decrease the costs also for the other ones, but that is also something that I think will take some time before we are there.*"

Finally, costs are expected to lower with the rationalization of networks as maintenance requirements are reduced [concept 4038]. The reduction in costs as a result of these three factors is expected to lead to an increase in profits, thereby presenting an economic incentive for operators [concept 4037].

The third key benefit foreseen by Swedish market players is greater efficiency for operators [concept 4033]. As explained in an earlier paragraph, NGA reduces costs for operators, including their operational costs. A reduced OpEx, combined with the facility to provide new services in new ways [concept 4034] and the ability to be more flexible in their operations [concept 4036], are expected to improve operators' efficiencies [concept 4033]. These findings show that the ***benefits of NGA are realized by both supply and demand sides***.

6.4 Conclusion

The analysis of the Swedish interviewee data provides key insight into the issues and factors related to the development of the next-generation broadband market in this country. The analysis shows that NGA seems to be more important than NGN, but this is as a result of the incumbent's continuous investment in its core infrastructure over the years. Today, this infrastructure comprises a high percentage of fibre and is considered to already be upgraded and in a good condition. Therefore, the focus *now* is on NGA. With recent increases in consumer demand, primarily, operators have begun to shift their efforts towards an upgrade of the access network. The discussions and key issues raised by the participants were centred on their current activities and focus – the development of NGA.

The main understanding of NGN is that it is an advanced core network that has the potential for a lot of dynamics. NGN is also considered to be IP- and fibre-based. On the NGA front, there is a general perception that an NGA can be realized using more than one access technologies, though optical fibre is cited as the key technology to be able to realize the high transmission speeds usually linked to NGA. However, NGA is not only considered to be a network that can deliver high speeds. Rather, NGA is principally defined as a network that can deliver greater competition and hence more services. It is believed, however, that next-generation networks and next-generation access networks should operate in combination.

In terms of investment, the good condition of the incumbent's existing infrastructure discourages further upgrade of the core network. However, this is countered, to some extent, by the increases in traffic on the network, which requires the infrastructure to be improved. Investments in next-generation access, on the other hand, are more positively influenced. Upgrade of the access network and, more specifically, investments in fibre access networks, are mainly driven by the central government and local municipalities. The biggest drivers for both parties are the desires to improve the lives of their citizens and to create an attractive region for businesses and residents. With competition from other towns and regions in fibre investment, municipalities are motivated to enhance the marketability of their own communities. However, regulation, or rather the lack of it, prevents many of the larger national operators from substantially investing in NGA. Although several other issues and uncertainties exist, such as active investments in the old copper network and the technology-demand relationship, the positive influences in the Swedish telecommunications market currently outnumber and outweigh these deterrents of NGA investment.

Current NGA investments are based on optical fibre. While geography and the profitability of the investment are the general key considerations for operators in choosing their access technology, continuously growing consumer demands for high-speed services and Internet access drive operators to deploy optical fibre. Wireless technologies, however, are not disregarded. Since TeliaSonera has recently deployed an LTE network in Stockholm and with an increasing growth of mobile broadband, participants acknowledge the potential of both fixed and mobile wireless technologies in NGA delivery. However, it is generally believed that optical fibre is still required as the backhaul for wireless and mobile technologies. On its own, wireless technologies are considered to be apt for remote and/or rural areas.

The deployment of NGN in Sweden is expected to enhance the competitive advantage of operators, as operational and maintenance costs will be lowered and a better core network infrastructure will be realized. A reduction in costs for operators is perceived to be the main benefit of NGA as well, again increasing the efficiency of operators and creating a better society in general.

Apart from these findings, it is evident from the discussions and analysis that the Swedish government has played an important role in initiating and accelerating the roll-out of fibre networks on both a local and a national scale. There is a great desire to make Swedish communities and cities, and Sweden as a nation, appealing markets. Consumers, too, have been of great significance. Trends of increasing use of high capacity applications and longer times spent on the Internet, particularly among younger users, have been identified within the Swedish consumer population. These observations are key inputs for the discussion presented in Chapter 8. The main, general findings are captured in Table 6-1. These are used as the basis for the case study comparisons presented in Chapter 8.

Research question	Main conclusions
RQ1 How do telecommunications operators define next-generation broadband networks?	NGN is perceived in terms of a technological upgrade of the core network There is little focus on and/or understanding of NGN NGA is viewed as a network that will enhance the competitiveness of the Swedish market The Swedish are open to a mix of technologies in NGA deployments
RQ2 How do market factors influence investment in next-generation broadband networks?	The conditions of the Swedish telecommunications market are more conducive to NGA investment than to NGN investment A mix of demand and supply factors is influencing investment in NGN Swedish telecommunications environment is generally favourable towards NGA investment Regulation is an influential factor for NGA investment NGA investment is driven primarily by the desire to improve socio-economic conditions
RQ3 What drives the choice of access technology?	A combination strategy for NGA deployment is foreseen Optical fibre most suitably satisfies the needs of NGA deployment in Sweden The most important driver for optical fibre use is consumer demand Wireless technologies should be used where there is low population density LTE is considered to be a potential mobile NGA solution
RQ4 What are the perceived benefits of next-generation broadband networks?	NGA is more important than NGN in Sweden The benefits of NGN are operator-related The benefits of NGA are realized by both supply and demand sides

Table 6-1: General conclusions emerging from the Swedish analysis

7 United Kingdom

7.1 Introduction

This chapter describes the last of the case studies examined as part of this research. Like the previous two case studies, the chapter aims to determine, from interview data, the empirical relationships that exist between market conditions and investment in next-generation broadband, the focus in this instance being the United Kingdom.

The first section, Section 7.2, starts with an overview of the British telecommunications market, describing its historical development, structure and regulatory framework. A more detailed discussion of the UK's standing in both current-generation and next-generation broadband is then presented. Section 7.3 contains the bulk of the chapter. This section describes the findings of the interview data analysis, linking market conditions with the investment considerations and decisions made by the British broadband stakeholders. Section 7.4 ends the chapter with a summary of the key findings.

7.2 The UK telecommunications market

This section describes the UK telecommunications market, outlining its historical development and the current status of broadband. This introduction lays the foundation for later discussions in both this chapter and Chapter 9 on the impact of the market on next-generation broadband development. An overview of UK telecommunications is first presented before describing the current generation and next-generation broadband markets.

7.2.1 Overview

The British telecommunications market is home to the oldest telecommunications company in the world, BT, and has evolved from monopoly to duopoly to its present highly competitive status (BT, 2011a).

The monopoly status of British telecommunications existed in the very early years, from 1912 to 1969, during which time the industry was under the control of the General Post (GPO) (BT, 2011a). The GPO was a Government Department headed by a Government Minister, and was a monopoly in both telecommunications and postal services (ITC, 2011). In 1969, the legislation of the Post Office Act 1969 resulted in the separation of the GPO into two divisions – Post and Telecommunications – though maintaining a single entity structure. The PO was to continue to have monopolistic power or an "exclusive privilege" in the provision of telecommunications services in the UK.

In 1979, however, with the inauguration of the Conservative Government, liberalization discussions were initiated. In 1981, the British Telecommunications Act split the PO and BT, and the latter took over the telecommunications sector. An alternative carrier, Mercury, was established and its licence issued in 1982 (Solomon, 1986). The British telecommunications sector was no longer a monopoly. Following these events, the Conservative Government ruled in favour of the privatization of BT, which was formalized in 1984.

Since the full liberalization of the sector in 1991 as a result of the Duopoly Review, UK telecommunications has been subjected to massive growth and aggressive competition. Only in recent times (2009) has a slight decline been observed, as Ofcom (2010a) shows that the communications industry revenue decreased by 2.3% during 2009, reaching a figure of £52.8bn.

At present, there are eight major fixed line operators in the UK, although BT and Virgin Media own most of the network infrastructure and together receive the greater part of the total fixed line revenues (Budde, 2010a; Ofcom, 2010b). There are over 200 fixed broadband Internet Service Providers (ISPs) (Ofcom, 2011a). Three major mobile network operators (MNOs), including Telefonica O_2, Vodafone, and a merger between Orange and T-Mobile (called Everything Everywhere) provide 2G and 3G services to UK consumers (Ofcom 2010b; Business Monitor International, 2010; BBC, 2010; Analysys Mason, 2011e) while a fourth MNO, Hutchison Whampoa's 3, provides only 3G services (Business Monitor International, 2010). In addition, numerous MVNOs and mobile service providers exist, with Virgin Mobile being the largest of this group (TeleGeography, 2011c). Although competition exists to varying degrees, all market segments are generally competitive (ITU, 2010).

As in many other countries, growth of the UK telecommunications sector has traditionally been within the fixed line telephony market. However, recent upsurges in mobile usage, broadband and data services have reduced the revenues in the fixed voice market. As Figure 7-1 shows, an overall decrease in fixed voice of 16.9% over the five-year period from 2005 to 2010 has been experienced while mobile voice, mobile data and broadband revenues have generally increased. The key message of Figure 7-1 is that there is a recent general trend among UK consumers of a shift from fixed-line to mobile-based services and a greater focus on data than on voice services.

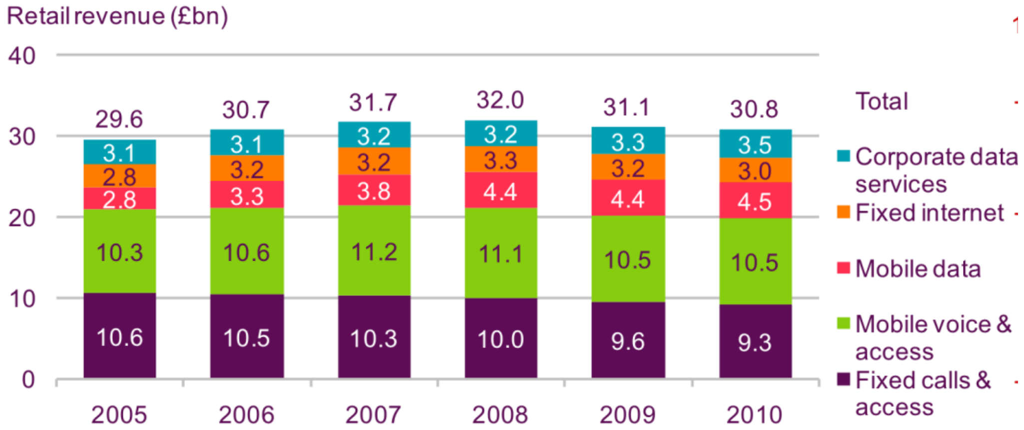


Figure 7-1: Retail revenue of telecommunications services in the UK
Source: Ofcom, 2011b

In terms of regulation, UK telecommunications is regulated by an independent body, Ofcom, in accordance with the Office of Communications Act 2002 (ITU, 2009b; Ofcom, 2010c). Ofcom is responsible for translating European Union (EU) directives into UK regulation and conducts frequent public consultations to monitor and ensure the market's development. Of significance to this study was its Strategic Review of Telecommunications in 2004, which incited a proposal for functional separation from BT (Whalley and Curwen, 2008). Ofcom accepted BT's proposed undertakings in September 2005 and the incumbent subsequently created an independent access service division, Openreach, in January 2006 (Whalley and Curwen, 2008; Openreach, 2011).

7.2.2 The broadband market

At June 2011, the UK had approximately 20.3 million fixed broadband subscribers, an increase of almost 3% from December 2010 (Analysys Mason, 2011e). Seventy-four percent of the UK population had access to broadband at home at this same time

(TeleGeography, 2011c). While many active providers exist in the broadband market, BT, Virgin Media, TalkTalk and Sky are the major (fixed-line) participants. BT, however, leads the market with a 28.7% share at the end of June 2011 (Analysys Mason, 2011e).

With regards to technology, DSL is undoubtedly the most widely penetrated form of fixed broadband delivery to British consumers, as shown in Figure 7-2. The first commercial DSL deployment occurred in 1999 by Kingston Communications. Since then, DSL service has been provided by BT but numerous ISPs entered this market with the introduction of BT wholesale services. In addition, since 2005, LLU has contributed to the proliferation of the DSL market (Ofcom, 2009b). All exchanges in the UK are now either unbundled or DSL-enabled.

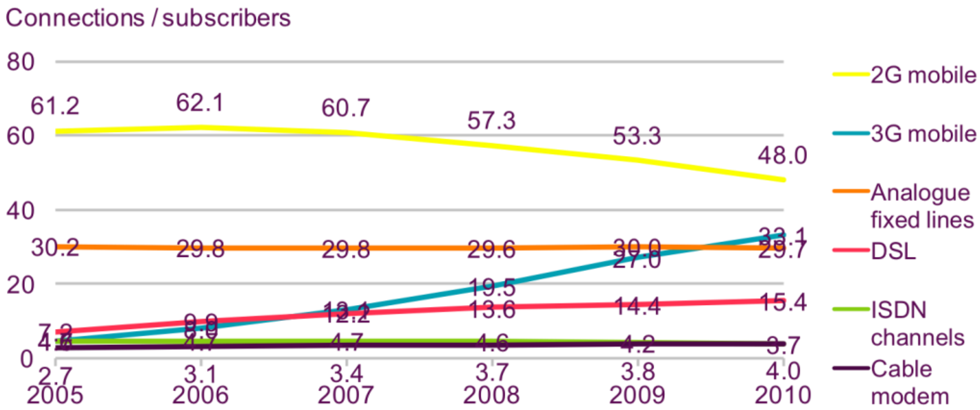


Figure 7-2: Broadband penetration by technology, December 2010
Source: Ofcom, 2011b

Despite the growth of DSL, cable infrastructure has maintained a strong presence in the UK and is dominated by Virgin Media. Almost half of the UK households (48%) have access to cable broadband (Ofcom, 2011b). Wightcable and Smallworld Media are two smaller independent companies that provide broadband services in the Isle of Wight and to Scotland and Northern England respectively (SamKnows, 2009). The availability of optical fibre, however, is limited, but growing. The initiatives for FTTx deployment in the UK began with small-scale community-based projects, which until December 2009, led the deployments in the UK with 58.3% of total NGA connections. Both BT and Virgin Media have since undertaken several deployments and, by early 2011, 4 million homes had access to

Virgin Media's 100 Mbps service and 5 million to BT's 40 Mbps FTTC service (Ofcom, 2011b). However, when compared to regional fibre progress such as in Denmark and Sweden, for example, the UK is still behind.

Mobile broadband is playing a significant role in the growth of the UK broadband market. Broadband take-up grew by 3% in the first quarter of 2011; mobile broadband contributed 2% to this growth (Ofcom, 2011b). The increase in mobile broadband is particularly driven by young users, with more than 50% of users in the 16-24 age group relying on mobile rather than fixed broadband access (Ofcom, 2011b). In addition, there has been a growth in the use of mobile phones for Internet services, increasing from 26% to 32% of users from 2010 to 2011 (Ofcom, 2011b). Almost two thirds of these consumers use mobile broadband for home Internet access (Ofcom, 2011b). The introduction of smartphones, advanced game consoles, portable media players and other devices such as Internet TVs have also encouraged users to access mobile broadband services (Ofcom, 2010b). Dongles, too, have become popular with British consumers. In its latest mobile broadband study, Ofcom states that there were approximately 4.8 million active mobile broadband subscribers in the UK using datacards or dongles at the end of December 2010 (Ofcom, 2011c). This figure had increased to over 5.1 million by June 2011, representing an increase of 10% in only six months (Analysys Mason, 2011b). For a yearly indication, the corresponding figure was 2.6 million at the end of 2008, exhibiting a growth of 85% over the two years between 2008 to 2010 Ofcom, 2011c).

Despite the widespread availability of broadband in the UK, there is evidence that the distribution across the country is varied. At the end of 2008, over 99.8% of UK households were already connected to a DSL-enabled exchange[18], with 100% in England, Northern Ireland and Wales and 99.87% in Scotland (Ofcom, 2009c). However, the ability to receive broadband services is dependent on the distance of the premises from the local exchange, wiring in the home and other network issues, and consequently, not all of the connected of the households can actually obtain DSL-based broadband services (Ofcom, 2009c; Ofcom, 2011b). Broadband adoption

[18] As DSL is the most widely penetrated broadband technology in the UK, Ofcom used the availability of DSL to measure the overall broadband availability in the UK (Ofcom, 2009c).

stood at 76% in England, 75% in Northern Ireland, 71% in Wales and 61% in Scotland at year-end 2010 (Ofcom, 2011b).

Ofcom (2009d) also explains that local loop unbundling (LLU) has high capital costs and, as a result, LLU providers tend to unbundle exchanges that serve a large customer base. The combination of distance and population density results in urban areas having higher broadband availability than rural areas. While 89% of UK households were connected to an LLU-enabled exchange, (91% in England, 75% in Northern Ireland, 84% in Wales and 81% in Scotland), 94% of connected households were located in urban areas and only 46% in rural regions (Ofcom, 2011b; Point Topic, 2010a). Even within the regions, the urban-rural divide in LLU is evident, as Figure 7-3 shows (Ofcom, 2011d).

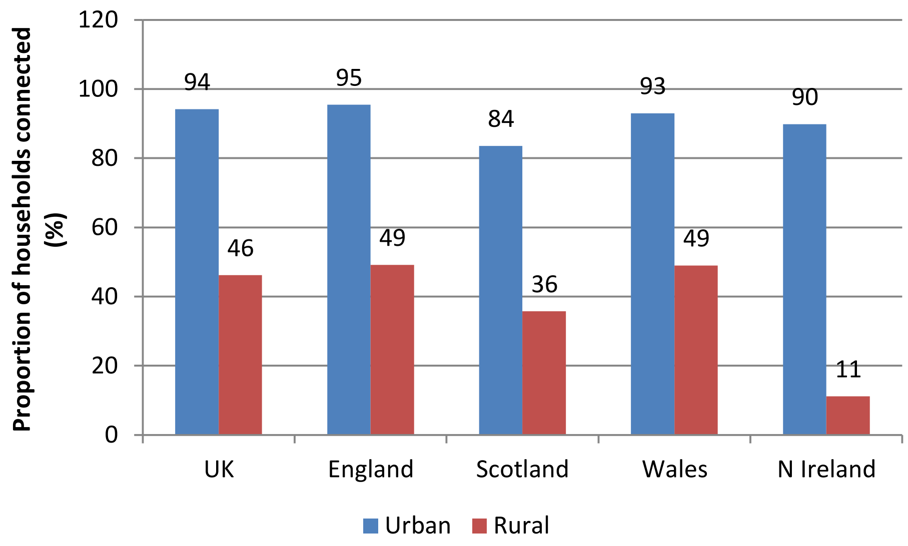


Figure 7-3: LLU exchange distribution by region, UK, December 2010
Source: Ofcom, 2011d

7.2.3 Developments in next-generation broadband

It is evident from the discussions in Section 6.2.2 that the UK broadband market has been a dynamic, advancing and competitive one. This section examines the progression of the market to the next generation of broadband. The discussions describe what the UK has done thus far to take this next step and the status of the British next-generation broadband market as it exists at the time of writing.

Investments to date

Until the time of writing, major investments have been undertaken in upgrading core telecommunications infrastructures in the UK. The incumbent, BT, for example, has targeted and begun its next-generation broadband venture to upgrade its core network to what is marketed as its 21st Century Network (21CN). The NGN upgrade will cost BT £10bn but the expected savings in operating costs amount to £1bn per annum (Parliamentary Office of Science and Technology, 2007). The first customers began using the 21CN network in November 2007 in West Midlands (Parliamentary Office of Science and Technology, 2007). Alternative fixed-line operators such as COLT, Cable & Wireless (C&W)/THUS and Sky have also been serving (business) customers over NGNs for some time (Parliamentary Office of Science and Technology, 2007).

Unlike NGN, next-generation access deployment has experienced a delayed start. Virgin Media was the first operator to invest in NGA with a DOCSIS 3.0 trial in December 2008 (Point Topic, 2009a). 2009 saw the first deployment of an FTTx network in the UK (Point Topic 2009b). Since then, several small-scale fibre networks have been deployed across the country. An early initiative by BT was a new housing development in Ebbsfleet, Kent. While this was one of the first NGA deployments in the UK, it is now cited as a 'slow burner' with an envisioned completion date of 2020 (Point Topic, 2009b).

However, investment in NGA has been increasing. Despite the slow start, there were over 3,000 NGA connections in the UK at the end of 2009 (Point Topic, 2010b). Until this time, the largest operators, BT and Virgin Media, had modest investments and the alternative operators held the lead in NGA deployments. However, soon after this, also at the end of 2009, Virgin Media launched its 'up to 50Mbit/s'. At the end of January 2010, BT increased its number of NGA connections, taking the lead in the UK (Ofcom, 2010a; Point Topic, 2010b). By mid-2011 BT's 'up to 40Mbit/s' Infinity network covered 5 million households, with further plans to extend the coverage to 66% of UK households by 2015 (Ofcom, 2010a; Ofcom, 2011b). In March 2011, Virgin Media increased its 'up to 20 Mbps' service to an 'up to 30 Mbps' service and by June 2011 was offering a 100 Mbps service to 6 million UK households (Ofcom, 2011b; Analysys Mason, 2011d).

Local fibre deployments have also been increasing in number. In 2009, fibre was installed in new homes for the West Whitlawburn Housing Co-operative in Glasgow (West Whitlawburn Housing Co-operative, 2008). Also in 2009, Rutland Telecom installed “the fastest fibre-optic broadband in the UK for a rural village” in Lyddington (Rutland Telecom, 2010). In September 2010, a ‘Fibremoor’ network was built as part of a project to connect all residents and businesses to superfast broadband in Alston Moor (Cybermoor News, 2010). This was the UK's first fibre optic network both owned and built by its community (Cybermoor News, 2010). However, perhaps the most significant announcement has been the Japanese Fujitsu’s commitment to fibre deployment to 5 million homes and businesses in rural areas of the UK (Fujitsu, 2011). Announced in April 2011, this project will receive financial support from the UK government. Although these are signs that the UK is on its way to the next-generation of broadband, the market is still far from complete next-generation broadband status.

The role of the British Government

The uncertainties and lack of investment in NGA in the UK raised a series of consultation exercises and research to determine the most effective and feasible means of accelerating NGA rollout. In 2009, the Department for Business Innovation and Skills published the Digital Britain report. This report announced an aim of securing “the UK’s position as one of the world’s leading digital knowledge economies” (Department for Culture, Media and Sport and Department for Business, Innovation and Skills, 2009, p7). One of the steps emerging from the report towards NGA development was the Final Third Project. It is believed that next-generation broadband will reach two thirds of the UK population by market-led forces (that is, competition and the investment of private operators), leaving the ‘final third’ with current generation broadband. The aim of the project is to ensure that this last third of the population will also benefit from next-generation broadband services. The recommendation was that the deployments be funded through a Next-Generation Broadband Fund (the Fund), established by imposing a 50p levy on all fixed line connections in the UK. The Fund would have been used to support next-generation access roll-outs in regions where the market will fail to provide NGA services and, therefore, where a subsidized intervention is required. From the time of its announcement, the Fund raised many issues. Uncertainties about the target broadband speed, the deployment approach, the duration of the intervention and the impact on the natural market investment, among others, surfaced. Subsequent to this, when the Labour Party advocating the Fund was voted out of government in May 2010, the recommendation for the tax was withdrawn (BBC, 2010).

Subsequently, in October 2010, the new Conservative-Liberal government earmarked £530 million of public funds for the roll-out of NGA over four years from 2011. The fund consists of the underspend from digital switchover in the UK (£230 million) and a contribution from the BBC licence fees (£300 million) from 2013/2014 (BDUK, 2011). In October 2010, £300 million of the money was committed to the delivery of fibre services in North Yorkshire, Cumbria, Hertfordshire and the Highlands (Broadband Watchdog, 2010). The roll-out is expected to deliver fibre broadband services to an estimated total of 2 million households (Broadband Watchdog, 2010). The Fujitsu project mentioned earlier will also be funded through this scheme.

7.3 Analysis

Section 7.2 described the British telecommunications industry, highlighting the developments in both the current-generation and next-generation broadband markets. This section shifts the discussion to the analysis of the empirical data, the outcome of which is an understanding of the pragmatic relationships between the market conditions described in Section 7.2 and the development of and investment in next-generation broadband. A similar structure to the previous two case study chapters is adopted for the discussion.

7.3.1 What are next-generation networks?

The UK discussions reveal that market players make a clear distinction between NGN and NGA, indicating a general recognition that NGN and NGA are technically different networks. The individual definitions of NGN and NGA, however, are less standard, as a variety of interpretations emerge from the discussions. These are highlighted in the following paragraphs.

Definition of NGN

NGN is viewed primarily to be a converged core infrastructure [concept 2029] based on IP [concept 2041], as Figure 7-4 illustrates. These properties result from the perception that NGN is based on packet-switching [concept 2040] and the convergence of protocols, network, services and so on [concept 2048]. Sixty percent of the participants made a link between NGN and MPLS/IP or packet-switching, more generally, leading to the conclusion that ***NGN is a technical upgrade of core infrastructure in both technology and architecture*** for UK operators.

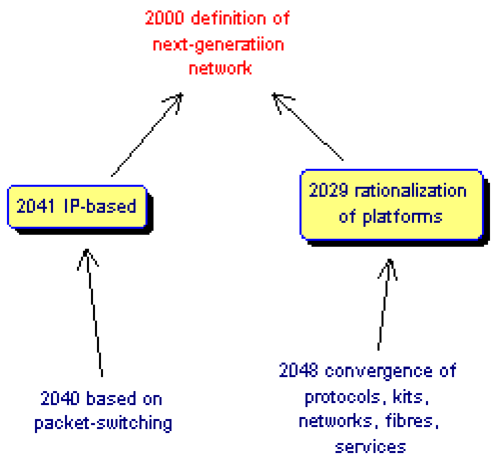


Figure 7-4: UK definition of NGN

Definition of NGA

The understanding of what NGA is is vaguer among interviewees. The main perspective is that, ***while NGA should only be described in terms of capacity***[19] [concept 1019], ***a definite capacity is difficult to identify*** [concept 1017]. This is shown in Figure 7-5. The key difficulty in quoting a specific capacity results from the view that, with rapid advances in telecommunications, capacity is a "moving target" [concept 1020]. The existence of several networks in the UK delivering different degrees of speeds contributes to this uncertainty in defining capacity [concept 1021]. As a result, it is difficult to define what NGA means from a capacity

[19] The term "bandwidth" was used by most of the interviewees, if not all, to mean data rate or capacity. As a result, "bandwidth" is replaced by "data rate" or "capacity" in the report. The maps show the original use of "bandwidth".

perspective. NGA thus remains “a vague concept” for the UK market players, as quoted:

“*We’ve always left that rather vague because the only real way that you could define it would be in terms of data rate, which you said, or bandwidth…its one of those moving targets really…it’s always a bit tricky because it’s not as if we’ve got a network at the moment that delivers just one speed, it’s not as if everyone gets just 1.3Mb and that’s it.*”

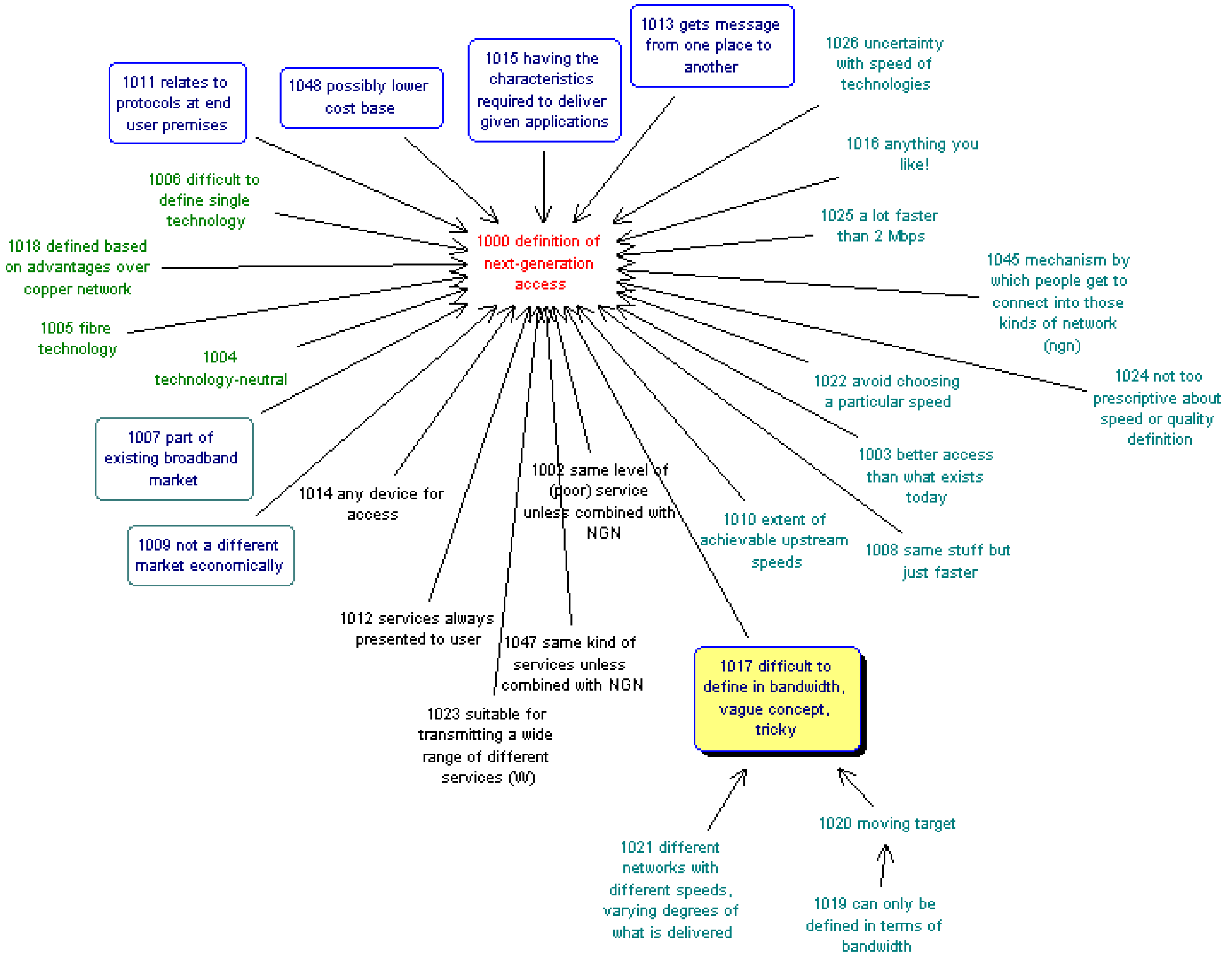


Figure 7-5: UK definition of NGA

From a more general perspective, NGA is defined in terms of technology, speed, services and markets, but the uncertainty that exists with its description in terms of capacity is also evident within each of these classifications. For example, from a technological perspective, there is a mixed perception of NGA being a fibre-based network, being technology-neutral and, more generally, being based on a technology that is advantageous over copper [concepts 1004, 1005 and 1018]. Sixty percent of the interviewees consider NGA to be technology-neutral. Even with regard to speed, NGA is considered to be faster than existing access networks, with one interviewee quoting a benchmark of 2 Mbps, but no specific speed target emerged from the interviews. Based on these observations, it can be deduced that ***NGA is considered to be technology-neutral but must provide enhancements to the existing service delivery offered by current copper-based technologies***.

In the service domain, NGA is considered to be a network that delivers multiple services to a user, at anytime, anywhere and from any device. However, one interviewee commented that NGA will deliver the same level of (poor) service unless combined with NGA and that they must not be considered in isolation:

> "*There's a next-generation network, or NGN, and then next-generation access or NGA. I think that too many people consider them in isolation from each other. So, if you do next-generation access, what you typically provide yourself with is hopefully better access to what exists today. So you may have a 100M fibre connection but you still have the same kind of services and dare I say the same, sometimes, poor level of service.*"

More general perceptions of NGA in the UK are the ability to connect with core networks and transmit messages, having the features to deliver the required services and possibly a network with a reduced cost base. Despite the various interpretations and characteristics postulated, it can be deduced that ***the definition of NGA remains largely unclear in the UK***. As one interviewee remarked:

> "*It can be anything you like!*"

The difference in certainty between the meaning of NGN and that of NGA highlights to some degree the relative importance of these networks to this market: that ***NGA are not as vital to the UK as NGN are at the present time***.

7.3.2 Next-generation broadband investment

Investment in next-generation broadband networks in general is largely influenced by commercial factors in the UK, particularly driven by the need to enhance business operations and service offerings due to changes in the market. The analysis shows that, significantly, these ***factors are more encouraging for NGN investment than for NGA investment***. With this motivation towards NGN, British operators have focused their investments to date on upgrading core networks, rather than on next-generation access. The discussions that follow more closely examine the factors that are affecting investments in the individual NGN and NGA markets.

NGN investment

In addition to the commercial factors mentioned in the preceding paragraph, NGN investment in the UK is driven by the need to change the kind of business that the company undertakes [concept 3040] and the need for open networks and systems [concept 3024]. By examining the frequency with which the factors were mentioned, it was determined that the 'need for a step change in the cost base' and 'the need for the company to make radical changes in order to survive' in the present telecommunications industry [concepts 3030 and 3042] are also important factors in the NGN investment decision. These seven key factors and their relationships are illustrated in Figure 7-6. As they all relate to the network operator, it can be deduced that ***NGN investment is supply-driven***.

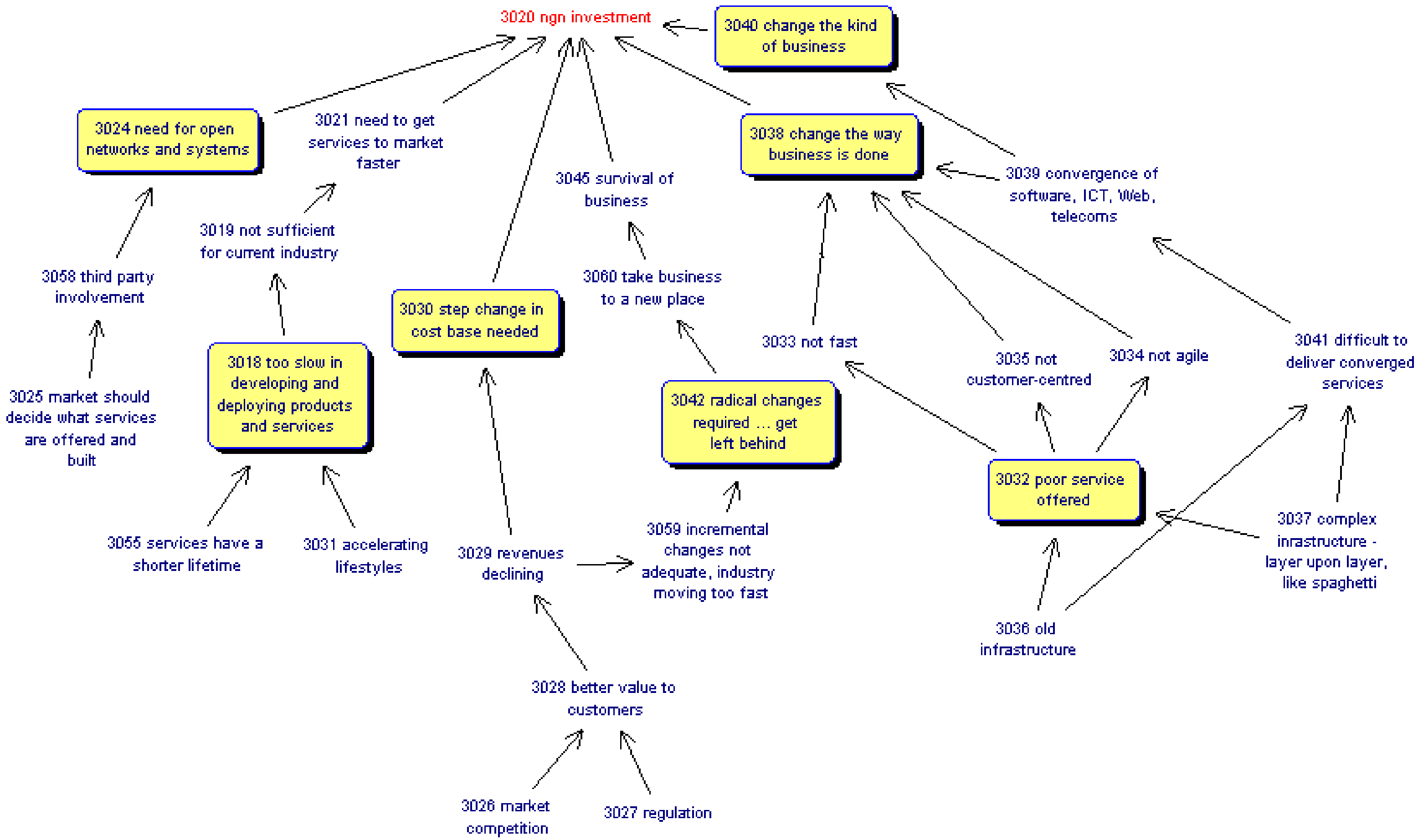


Figure 7-6: Main market factors influencing NGN investment in the UK

A closer examination of Figure 7-6 reveals the existence of several themes among the core concepts. The first of these is extracted as Figure 7-7, for easy reference, and is linked to operators' dissatisfaction of current service delivery. The legacy telecommunications infrastructure was built several decades ago [concept 3036] and has been further developed over the years by the addition of layers as required [concept 3037]. As a result of the age of the networks, operators find it difficult to provide a level of service to consumers that is acceptable [concept 3032]. Service to customers is not as fast, agile or customer-oriented as they (operators) would like it to be [concepts 3033, 3034 and 3035]. As such, there is a desire among operators to modify their operations to improve their level of customer-service [concept 3038], providing an incentive for them to upgrade their core networks to an NGN [concept 3020]. This sentiment is reflected in the following remark made by an interviewee:

> "*I guess the third one was another frustration that we had with ourselves that we don't deliver a very good service sometimes. When it works it's great, ………But it's not as fa*st, *it's not as agile, it's not as customer-centered as we'd like it to be.*"

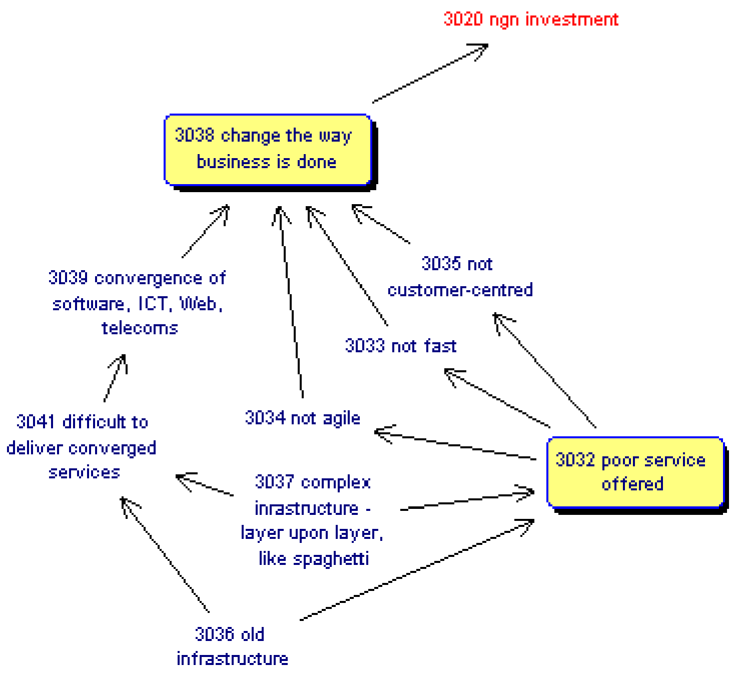


Figure 7-7: Relationships attached to poor service and changing the way business is done in the UK

The second theme emerging from Figure 7-6 is that of convergence. The convergence of services, industries and markets makes it necessary for operators to restructure the way that they conduct business in the service domain. The complex, multi-layered, multi-platform architecture of the legacy network not only makes it difficult to deliver converged services, but also presents a challenge in amalgamating the existing platforms [concept 3041] and in delivering a high quality of service. With the increasing trend of convergence, this integration is crucial to the business of a telecommunications operator [concepts 3038, 3039 and 3040]. Operators, therefore, see a need to change the kind of business they do, that is, enter new markets, and also change the way that they conduct business, that is, improve their efficiencies [concept 3038]. Both these objectives drive the investment in next-generation networks for these operators, as an interviewee revealed:

> "*… … we're managing an infrastructure that in some cases is decades old, that was built up layer upon layer upon layer………We kind of said the best way to get a new cost base, change the way we do business and also change the kind of business that we are…*"

Thirdly, recent trends of accelerated activity and increased innovation drive operators to believe that an upgraded core network is essential. Figure 7-8 below shows this segment of the investment map of Figure 7-6. The increase in activity in the sector is evident in both service and product turnover, and consumer behaviour. Today, products and services are continually being upgraded or replaced by newer models, significantly reducing their market lifecycles [concept 3055]. Consumers, too, exhibit accelerated lifestyles [concept 3031]. Central to these changes are operators' concerns that they are too slow in bringing products and services to market [concept 3018]:

> "*I guess the second one was a general frustration within [company] that the way that we've done things is too slow. And as we look into the future, where, with lifecycles accelerating, certainly too slow. So it was about accelerating time to market new products and services.*"

Figure 7-8: Relationships attached to being too slow in developing and deploying products and services in the UK

While they (operators) have expressed a general dissatisfaction over the years in the time to market of their products and services, it is now a crucial issue because of the fast pace of innovation in the industry [concept 3021]. As a result, operators aim to reduce product and service delivery times by upgrading their core network to an NGN infrastructure [concepts 3021].

Finally, it is evident from Figure 7-6 that regulation and competition also influence NGN investment in the UK. Regulation and competition result in increasingly better value for consumers, such as the reduction of prices for products and services [concepts 3026, 3027 and 3028]. Increasingly, consumers are offered lower prices for higher quality products and services, eroding the revenues that operators and service providers can realize from these goods [concepts 3028 and 3029]. Consequently, operators and providers need to reduce either their operational cost or the amount of investment that they make, that is, they need to make a change in their cost base [concept 3030]. In addition, because the industry is moving at an accelerated rate, changes made to manage the decline of revenues need to be radical, rather than incremental, to "take the business to a new place" and ensure its survival in the market [concepts 3045, 3059 and 3060]:

"*You can stay where you are and if you do that, you get left behind. You can try to make incremental improvements, but with the rate of change you almost* *can't make the incremental changes as fast as the changes are required, so again you can fall behind. Or, you can bite the bullet and say we are going to make a transformational change."*

NGA investment

The NGA story in the UK is more complicated. On one hand, it is similar to that of NGN investment, with a variety of factors affecting the decision to invest. On the other hand, only few of these are actually *driving* NGA investment. Rather, the NGA investment factors comprise a mixture of positive, negative and 'uncertainty'/'consideration' links to investment, suggesting that the drive to invest in NGA is weak. These various influences are described herein.

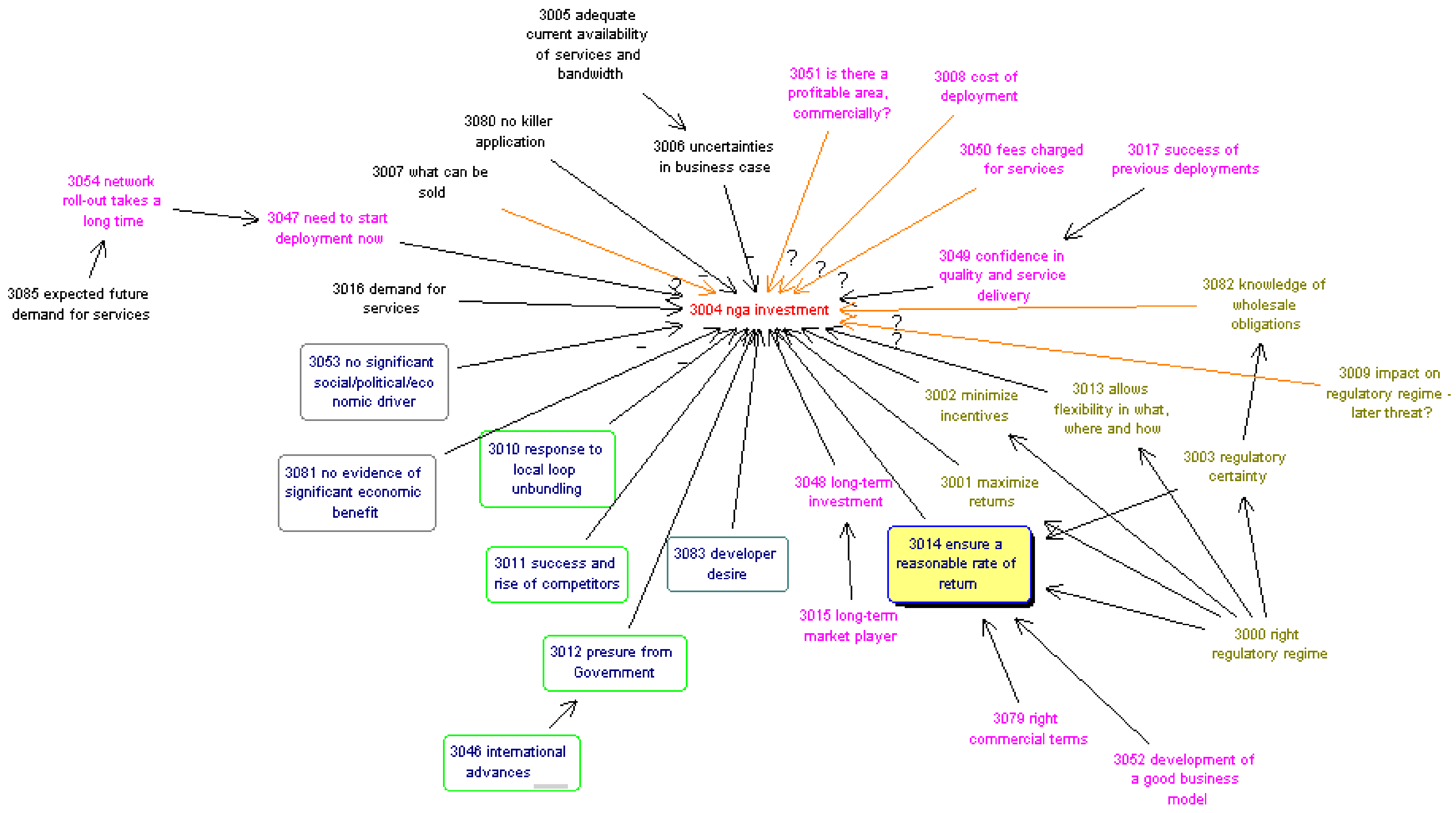


Figure 7-9: Main market factors influencing NGA investment in the UK

The predominant argument for NGA investment by British operators is the ability to make a profit on the investment [concept 3014]. Interviewees explain that this, in turn, is dependent on the regulatory regime enforced [concept 3000]. As Figure 7-9 illustrates, the right regulatory framework ensures that the operator makes a reasonable return on the network investment. The right regulatory regime also provides a degree of regulatory certainty [concept 3003], guaranteeing operators a reasonable return on their investment for some period of time [concepts 3014]. Commercial challenges such as the development of a business model can also affect the rate of return for the operator [concepts 3052].

The close link between regulation and NGA investment, identified above, has resulted in a lack of investment in NGA in the UK. With a lack of regulatory certainty from Ofcom in the initial stages of NGA discussions, operators had little or no interest to sink substantial amounts of money in rolling out next-generation access infrastructures. BT, for example, did not want to invest because there was no regulatory certainty in the early days of the NGA discussion:

> "*…we needed to make sure that the regulatory regime was right so that we can maximize returns and minimize incentives and so forth…*"

UK operators also consider the socio-economic benefits of NGA in their decision and currently see no evidence of benefits from NGA investment in other markets [concept 3081]. Therefore, they are not convinced that NGA is necessary from this perspective. These sentiments are expressed by an interviewee:

> "*The fact that there is no killer application even in Korea, unless you count downloading pornographic movies and doing online gambling as killer applications, which frankly personally I don't – there isn't something that says they've benefitted economically massively from having super-*fast broadband."

NGA investment is also affected by the fact that, in the UK, there appears to be no great political or sociological drive for it; if there were, the government would also advocate the investment, as an interviewee explains:

> "*At the end of the day if there was a sociological/political/economic requirement for national roll-out of fibre, it wouldn't just be [company] that*

thought it was a good idea. The government would be wanting it to happen far more. The government has been pretty rational about it as well. They've sat back and said, look we haven't got the deepest pockets either, European law probably prevents them from going out and massively subsidizing fibre and all that, and if there was an economic benefit it would be happening anyway."

Furthermore, in the service domain, UK operators fail to identify a service that can realize compensatory profits on their investment [concept 3080]. In addition, the perception in the UK that the current services and their features are adequate for consumers makes it difficult for operators to justify investment in NGA as a valid business case and hence discourages the investment [concepts 3005 and 3006]. Services that are driving other markets to invest in next-generation broadband access, such as television services, are offered in the UK with a variety of options. The services offered by Sky, for example, were cited by an interviewee as being one of the reasons why UK consumers are neutral about access to IPTV, for example.

"*We've also got BT Vision in the UK. Everyone takes Sky because Sky has got the premier league football and most of the best sporting events. So there's lots of uncertainties around the business case which will relate to the commercial roll-out.*"

More optimistically, several external market factors[20] seem to encourage some NGA investment in the UK, with the request of developers of new housing sites [concepts 3083] being identified as an important driver based on the frequency with which it was mentioned in the discussions. Developers are keen to integrate fibre access into their buildings as a differentiating factor among competing housing developments.

The expectation of future demand for higher-speed services has led some operators to believe that it is necessary to begin developing access networks now, as network development is time-consuming [concepts 3047, 3054 and 3085]. British operators also make other commercial considerations. For example, while the

[20] External market factors refer to those that are not directly linked to the network operator.

success of NGA trials has been a motivating factor for operators to continue deployments, commercial issues related to the business model and ensuring the right commercial terms - profits, deployment costs, fees for services and the geographic location - that is profitable for investment need to be resolved before a firm investment decision towards NGA can be made [concepts 3008, 3017, 3049, 3050, 3051, 3052 and 3079]. Some operators, however, view their market position as an influential factor in NGA investment: an operator who is likely to be a long-term market player does see the need to invest in next-generation access [concepts 3015 and 3048]:

> "*I think overall [company] is a player that is going to be in the UK in the long term and any investment in any kind of access infrastructure is a long term investment.*"

This combination of market influences in the UK leads to the conclusion that while there is a range of factors influencing investment in NGA, ***the conditions are currently unfavourable for operators***. With the absence of a "killer" application and consumer demand for next-generation broadband service, operators are currently only driven by profitable regions and external forces such as housing developers in order to meet their 'reasonable returns on investment' requirement. However, if 'next-generation' applications and demand for them can be identified, UK operators will invest in next-generation access. In essence, ***the ability to make profits is a main requirement for NGA investment.***

In addition to the findings described above, Figure 7-9 reveals that regulation plays an important role in the NGA investment decision, as explained earlier. It can be deduced that, in the UK where there is little other market incentive to invest in NGA, ***regulation is important in encouraging investment***.

7.3.3 The technology dilemma

Figure 7-10 shows the relationships among the main factors in the technology decision. It was observed that, with the exception of one factor, the key factors influencing the choice of technology also drive the use of optical fibre. These links to fibre are illustrated as dashed green lines to show an implied relationship. This observation indicates that optical fibre satisfies the requirements that operators consider to be vital in choosing an access technology, leading to the proposition that ***optical fibre fulfils the technology requirements for next-generation access for UK operators***. More detail on this, along with the factors influencing the choice of wireless technologies, is provided in the sub-sections that follow.

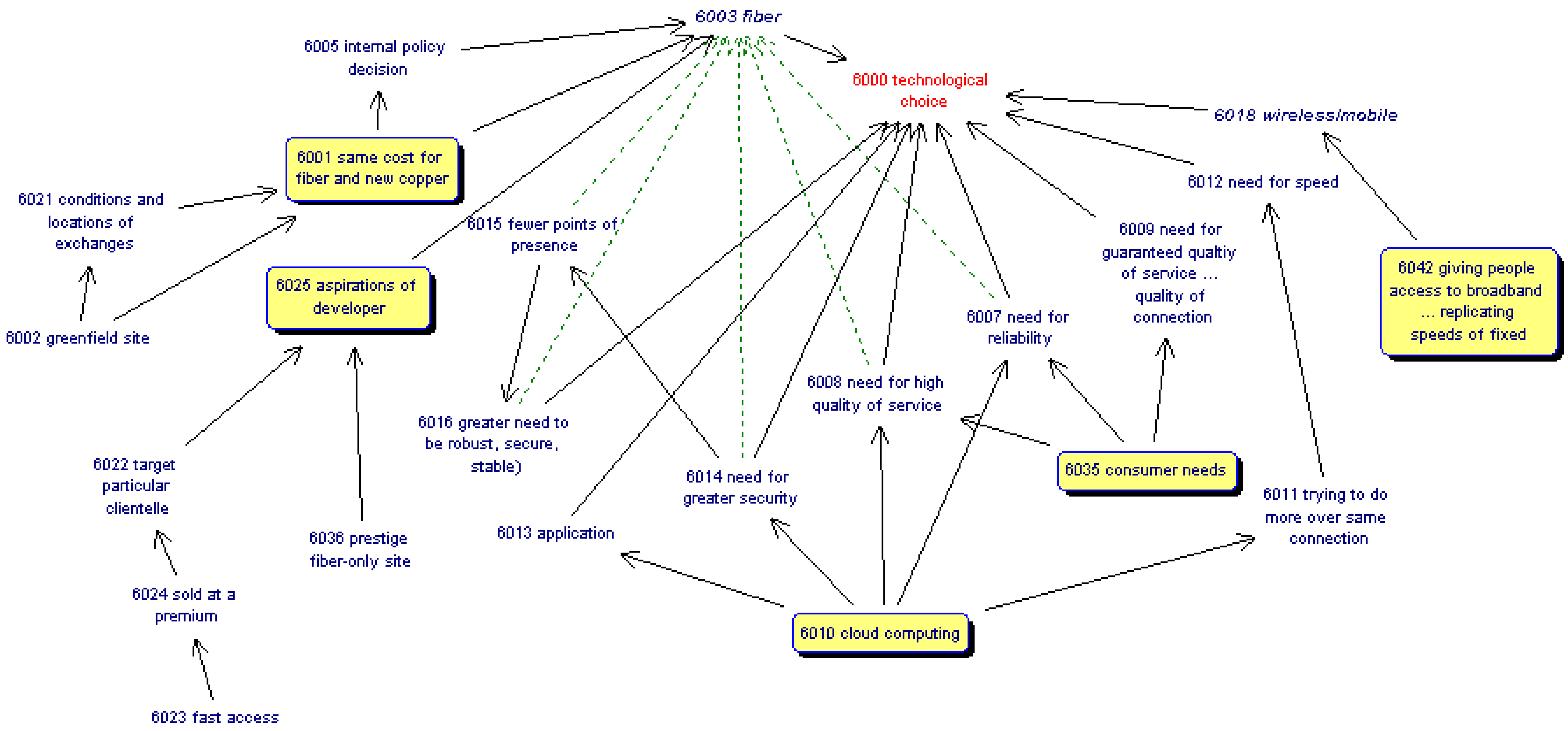


Figure 7-10: Drivers of technological choice and optical fibre in the UK

Optical fibre

Figure 7-10 shows that the choice of access technology in the UK is primarily driven by market activities (such as consumer demand and trends in service usage) and the region where the network is being installed. For example, growth in the use of cloud computing and the expectation that this will continue as more businesses move their activities online, impose several requirements on operators [concept 6010]. For example, the need for more secure, reliable and high quality service delivery is growing [concepts 6007, 6008 and 6014]. Although operators admit that these requirements do not necessarily dictate the use of optical fibre, they acknowledge that the characteristics of fibre adequately satisfy these requirements, thereby encouraging the deployment of this technology. Such a link to fibre is shown in the following statement by an interviewee:

> "*Fibre doesn't give you any greater physical security than copper does but the need for security in whether it be next-generation networks or next-generation access does increase particularly when you have fewer points of presence.*"

Although the application of cloud computing is more relevant to corporate customers than to the retail market, retail consumers are becoming more accustomed to and reliant on a guaranteed quality of service for their own entertainment, and therefore, expect a general reliable and high quality service [concepts 6007 and 6008]. Among retail consumers, the need for a *guaranteed* quality of service rather than a high quality of connection is more important [concept 6009]. These sentiments are expressed in the following:

> "*There are some features that are common to whether people have services over copper or fibre. They want quality of service. If I'm using my telephone line, because that's what we're talking about effectively, to access television, live television, great - it better be reliable. So, if I'm watching football, and it's one each, and there's four minutes to go, and it's my club playing, it has to stay up, it can't go down. So, there's a need for reliability. There's also a need for quality of service, which is a different thing. A thing that will be an*

increasing feature is the need to have guaranteed quality of service as opposed to quality of a connection for the services that I'm using…"

Operators must, therefore, ensure that their choice of technology can deliver this and have, in many cases, indicated that optical fibre is the preferred technology to deliver these service characteristics.

The developers of housing sites in the UK are also driving significant fibre investments [concept 6025]. Developers of new housing sites are keen to provide prestigious fibre-based network access as part of their housing package, a mechanism which not only provides fast access for the residents, but also enhances the value of the homes [concepts 6023 and 6036]. Therefore, at the same cost of installation as new copper, optical fibre allows developers to sell their homes at a premium and to premium customers [concepts 6022 and 6024]. The operators selected to roll out these networks are, therefore, obligated to deploy optical fibre.

However, the decision to use fibre, even in the previous two circumstances, is largely influenced by the geographic nature of the target site and the related economics [concepts 6001 and 6002]. According to the participants, the economics of installing new optical fibre or new copper are almost the same in greenfield locations. In brownfield sites, previously installed copper has the economic advantage over new fibre or copper since the capital costs associated with new installations is high. As a result, there is an increasing tendency in the UK for operators to target greenfield sites for optical fibre investments.

An important observation from the interviews is that speed is not a key consideration for the choice of technology or a key driver for the use of optical fibre in the UK. In addition, although services such as HDTV and broadcast services are cited by operators as drivers for optical fibre, they are not among the most important factors for choosing this technology in the UK. These observations imply that ***business users drive the use of fibre*** but ***fibre is not currently driven by services or speed requirements by the consumer market***.

Wireless technologies

Figure 7-11 shows the influences for the use of wireless technologies in the UK. The key observation from Figure 7-11 is that investment considerations are, for the most part, linked to the target region. For example, wireless is the preferred technological medium within a region that is difficult to reach [concept 6020] or in a region where operators are reluctant to invest in fixed-line technologies [concept 6033]. Figure 7-11 also indicates that considerations such as the cost associated with delivering certain speeds and the subscriber base influence the use of wireless technologies in the last mile [concepts 6040 and 6041]. It is clear, however, that operators in the UK consider ***wireless technologies primarily as a means of providing citizens with access to broadband in areas where there is no access rather than as a means of replacing fixed-line networks and reproducing the speeds of such networks*** [concept 55].

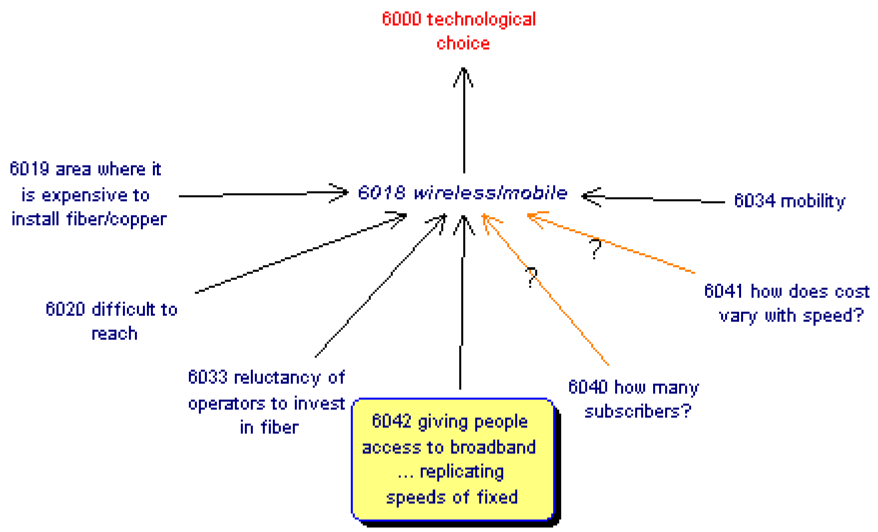


Figure 7-11: Main market factors influencing the use of wireless technologies in the UK

7.3.4 Perceived benefits of next-generation broadband

The perceived benefits of both NGN and NGA are discussed in this section. As the discussions will show, the NGA benefits expected by UK operators are limited, highlighting the previously identified focus on NGN in the British market. NGN and NGA benefits are discussed in turn and the main findings of the data analysis are highlighted.

Perceived benefits of NGN

Three primary benefits of NGN deployment emerged from the interviews. More significantly, these three core benefits result from the rationalization of the multiple networks into a unified core [concept 5000]. Network rationalization is also considered to be a key benefit by 80% of the interviewees and is, therefore, considered to be a main benefit. This initial observation highlights a common belief among the UK broadband market players, and a conclusion of this research, that ***the improved network architecture of NGN is the underlying reason for NGN benefits***. The relationships among the four core benefits are shown in Figure 7-12.

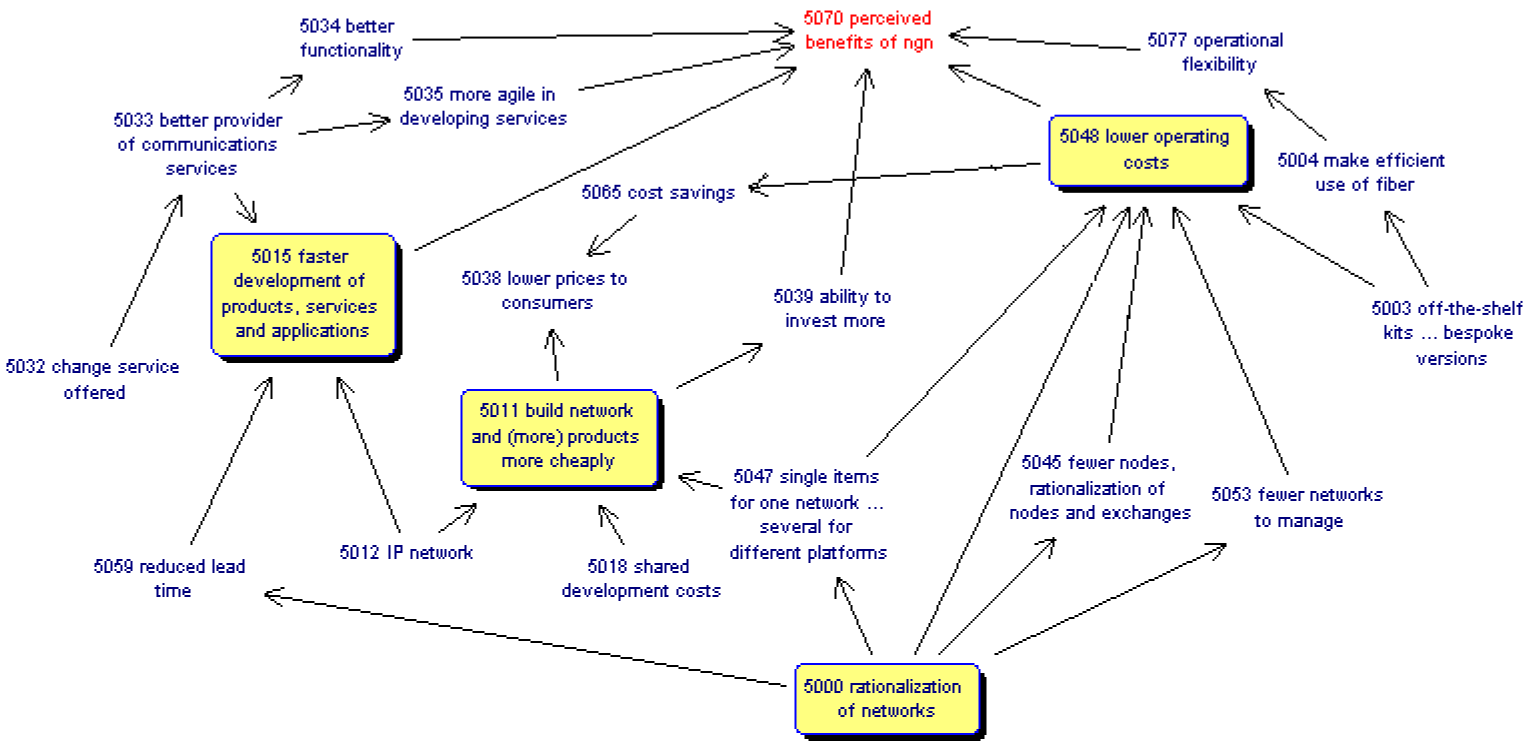


Figure 7-12: Primary (expected) benefits of NGN by UK market players

For a variety of reasons, UK network operators expect that the rationalization of separate telecommunications infrastructures into a single, converged core network, as is the architecture of NGN, will bring significant benefits to their business and, consequently, to their consumers [concept 5000]. Firstly, operators expect a reduced operating cost [concept 5048]. By rationalizing the multiple networks into a converged core, fewer nodes, exchanges and networks will need to be managed, reducing the running costs for operators [concepts 5045 and 5053]. The ability to use off-the-shelf kits in the converged network rather than having to customize kits also reduces the operational cost [concept 5003]. BT expects operating costs to be reduced by £1 billion per annum. As individual networks converge and only one network needs to be built, operators calculate that less equipment will also be required [concept 5047]. These insights are expressed in the following:

"*The predominant one is about the fact that if you can rationalize the number of networks you need fewer people to maintain it.*"

"*...the operating costs are lower, because you are essentially taking a kit off the shelf rather than having to have bespoke UK versions.*"

Secondly, network operators expect that networks, services and products will be cheaper to build and that the development of more products will be possible [concept 5011]. Services will be developed over an IP network, simplifying product development and reducing the associated development costs [concept 5012]. As a consequence of the open network architecture of NGN, it is expected that development costs will be shared among operators, third parties and other interested parties who choose to enter the NGN market [concept 5018]. The reduction in the cost base facilitated by these factors enable operators to invest more in the network and in service provision [concept 5039]. In addition, reduced investment costs increase savings for operators [concept 5065], enabling them (operators) to offer products and services at a lower cost to consumers [concept 5038]:

"*...fundamentally change the way we build products.*"

“*…the products are actually applications that run across an IP network so you can accelerate your time to market…*”

“*If you open up your network and your capabilities to third parties and allow them to build applications as well, then you accelerate the innovation…you can build more products more cheaply.*”

Finally, the consolidated network architecture of NGN is expected to accelerate the time to market of products and services [concept 5015]. Operators predict a reduced lead-time to the development process and, thus, the ability to deliver products and services in less time. The IP-based nature of the core network also quickens the service development process as this will now be, in most part, software-based [concept 5012]. As these findings clearly show, ***the main benefits of NGN in the UK is linked to the network operator***. These sentiments are conveyed in the following quotes:

“*…building products in software and using reusable components rather than building from scratch.*”

“*…you're assembling products as much as building them.*”

“*So it was about accelerating time to market new products and services.*”

Perceived benefits of NGA

The expected benefits of NGA, as viewed by the UK interviewees, are captured in Figure 7-13. The map shows that, in general, improvements in consumer access and their use of services, and in the variety of services that will be available to them are expected. This leads to a general conclusion that ***NGA benefits are linked to the consumer***. However, because the responses are few in number, this observation must be considered with a degree of caution.

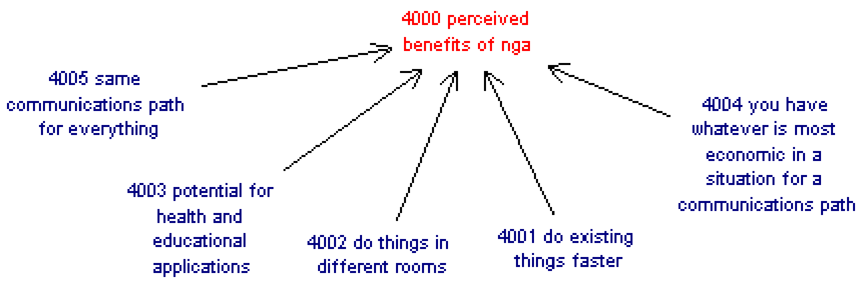


Figure 7-13: Primary (expected) benefits of NGA by UK market players

7.4 Conclusion

One of the key findings from the interviews is the view of market players that there is a distinction between NGN and NGA. While NGN is acknowledged to be an improved core network, NGA are widely considered to be an upgrade of the access infrastructure. By itself, NGN is viewed as a converged core infrastructure based on IP and capable of delivering all types of traffic. The definition of NGA, however, is vague. While capacity emerges as the key defining factor among the participants, there is great uncertainty in specifying a value of capacity. On a more general level, NGA are considered to be access networks that can deliver better services than what is available today using any technology, but no specific attributes are yet attached to its description. This difference between the understanding of NGN and NGA leads to the conclusion that NGN is more important to the UK broadband market than is NGA.

With regard to investment, next-generation broadband is encouraged by the need to enhance business operations and service offerings due to changes in the market, consequently driving investment in NGN rather than in NGA. More specifically, NGN investment is driven by operators' dissatisfaction with their current level of service, convergence of markets, industries and networks, accelerated lifestyles and technology development, and the effects of regulation and competition.

The NGA situation is more complex. A variety of factors is considered by operators but the data reveals that, at the time of writing, the conditions in the UK were generally adverse towards NGA investment. The most important consideration for operators is the potential to realize a reasonable return on the investment. Regulation, geography and other commercial factors influence this. On the positive side, the expectations of future demands in services and the aspirations of developers of new-build sites have encouraged investments to date, albeit localized and on a small scale. Additionally, some operators view their market position as a necessity to invest. However, as British operators are not aware of significant socio-economic benefits of NGA from the experience of other countries, and they fail to identify a killer application, justifying the business case for NGA investment is a challenge and investment is, consequently, limited.

From the discussions on investment, it is apparent that both the NGA and NGN decisions are affected by a range of factors. It is evident, too, that the move to NGN is more attractive than NGA migration in the UK. There are more definite drivers for NGN and changes in the market, such as an increase in traffic, convergence and the fast pace of telecommunications and consumer behaviour, are making it an essential 'next step' for operators. The definite drivers for NGA are few. NGA still holds uncertainties in terms of services that can be offered to make a significant return on the investment. There is more motivation for operators to invest in NGA from external pressures rather than for the benefits of the telecommunications company, making this a delayed investment in the UK. It can, therefore, be inferred that the more influential factors for next-generation broadband investment in the UK drive NGN investment rather than NGA investment.

The choice of technology for access network deployment in the UK has many trade-offs. While business services, housing developers and the economics of fibre versus new copper are driving the use of optical fibre, the costs and practicalities associated with its deployment limit its reach to some areas. Wireless technologies are used as an alternative. However, wireless technologies are limited in capacity and are liable to suffer from contention issues in dense areas or during peak usage times. As a result, wireless solutions are preferred for those areas that are not served by any other technology and are used to deliver some level of service rather than consumers having no service at all. However, since many of the requirements imposed by market factors are driving operators to deploy optical fibre as their access network technology, it is propositioned that optical fibre fulfils the NGA requirements for UK operators.

The UK analysis shows that neither specific services, apart from cloud computing, nor a demand for higher speeds has influenced the choice of technology or encouraged fibre investment. It is believed that this is due to a lack of knowledge of services that actually require such high speeds and/or the adequacy of current generation broadband to the UK residential consumer market. These observations lead to the conclusion that there is potential for the corporate world to influence the choice of access technology but little or no thrust from the residential market.

Three benefits of NGN appear to be most important to network operators and other market players – the reduction of operating costs, the ability to build networks, products and services at a lower cost and the ability to provide these to the market at a faster rate. These benefits all stem from the rationalization of networks into a single converged core network and it can therefore be inferred that the underlying improved network architecture characteristic of NGN is the root of the benefits that industry expects from these networks.

In contrast to NGN, NGA has been linked to few benefits. In general, improved access is expected for consumers, in terms of both quality and range of services. The lack of information on the expected benefits of NGA in the UK is evidence that there is not yet a need for NGA and, as a result, there is low drive towards and interest in NGA investment.

The findings presented herein are reflective of the opinions of key broadband stakeholders in the UK and of next-generation broadband as it exists at the time of writing. While NGN seems to be the way forward for several of the fixed-line operators, many uncertainties still plague the development of NGA. It is clear that there is a greater understanding of NGN, a greater need for NGN and a more conducive environment for NGN deployment. Thus, the advancement of next-generation broadband in the core network is rapid. A general satisfaction with current broadband services and the lack of a regulatory framework that is favourable towards NGA investment has resulted in limited investments being made in the access network. These findings and the underlying details are used in Chapter 9 to compare next-generation broadband developments in the three case studies. The main findings are summarized in Table 7-1 and are used for the cross-case analysis in Chapter 9.

Research question	Main conclusions
RQ1 How do telecommunications operators define next-generation broadband networks?	The definition of NGA remains largely unclear NGN is a technical upgrade of core infrastructure in both technology and architecture NGA is considered to be technology-neutral but must provide enhancements to the existing service delivery offered by current copper-based technologies NGA is understood in terms of capacity, which is difficult to specify NGA are not as vital to the UK as NGN are at the present time
RQ2 How do market factors influence investment in next-generation broadband networks?	Market factors are more encouraging to NGN investment than to NGA investment NGN investment is supply-driven Market conditions are unfavourable for NGA investment The ability to make profits is a main driver for NGA investment Regulation is important in encouraging investment
RQ3 What drives the choice of access technology?	Optical fibre fulfils the technology requirements for next-generation access for UK operators Business users drive the use of fibre Fibre is not currently demand driven by services or speed requirements in the consumer market Wireless technologies are primarily used for providing access to broadband in areas where there is no access
RQ4 What are the perceived benefits of next-generation broadband networks?	The improved network architecture of NGN is the underlying reason for NGN benefits The main benefits of NGN are linked to the network operator NGA benefits are linked to the consumer

Table 7-1: General conclusions emerging from the UK analysis

8 Discussion: Cross-case comparison

8.1 Introduction

Chapters 5, 6 and 7 highlighted the influence of market conditions, as determined from empirical data, on the development of next-generation broadband networks in The Netherlands, Sweden and the UK respectively. In doing so, these chapters examined four of the five research themes from a country-level perspective. The current chapter, Chapter 9, collates and compares the findings for each theme in order to answer the overall research question – 'how do market factors influence the development of next-generation broadband?' More specifically, this chapter identifies the similarities and differences among the three countries, examines the underlying factors and relationships, and presents an overall picture of the links between market factors and the development of next-generation broadband.

To this end, a theme-based comparative case study discussion and critical analysis make up the rest of this chapter. In Section 8.2, an examination of the link between market conditions and the understanding of next-generation broadband is undertaken. Section 8.3 investigates the impact of market conditions on investment and investment drivers. Section 8.4 takes a closer look at technology – how do market factors influence the choice of technology adopted for NGA? Section 8.5 discusses the role of markets in influencing the perception of the potential benefits of NGN and NGA deployment. Causal maps that highlight the emerging relationships are produced for each theme. The maps are then used to examine the final theme in Section 8.6 - the interaction of market factors in the development of next-generation broadband. The chapter ends with a summary of the key findings in Section 8.7.

8.2 Theme 1: Understanding next-generation broadband

The study reveals that market conditions influence the relative importance of NGN and NGA to market players. Some focus on NGN while others focus on NGA, in turn influencing their understanding of the wider 'next-generation broadband' term. Secondly, the research shows that the technical definition of NGN is generally standard in the three countries and not particularly linked to market conditions, though there is a more agreed understanding of what NGN are among the UK participants. Finally, it is obvious that the meaning of NGA is influenced by market conditions. However, there is consensus among participants in the three countries that NGA refers to better access than what is currently available and is, at the present time, delivered by optical fibre. These three findings are discussed in greater detail in the following sub-sections.

8.2.1 NGN, NGA or both?

The understanding of ‘next-generation broadband’ in terms of core and access networks varied across the three countries. While the Dutch and Swedish participants initially linked next-generation broadband networks to NGA, the British interviewees made an outright distinction between the core and access network upgrades but highlighted a clear practical focus on NGN. However, as participants were able to distinguish between NGN and NGA and appreciate that there is a difference between the two, it can be suggested that the (initial) automatic links made to NGA in the Dutch and Swedish markets resulted from the focus of the market players at the given (present) time. This, in turn, is linked to the respective market conditions. Figure 8-1 that follows depicts the causal relationships between market conditions and understanding as observed from this comparison of the three countries, discussed hereunder.

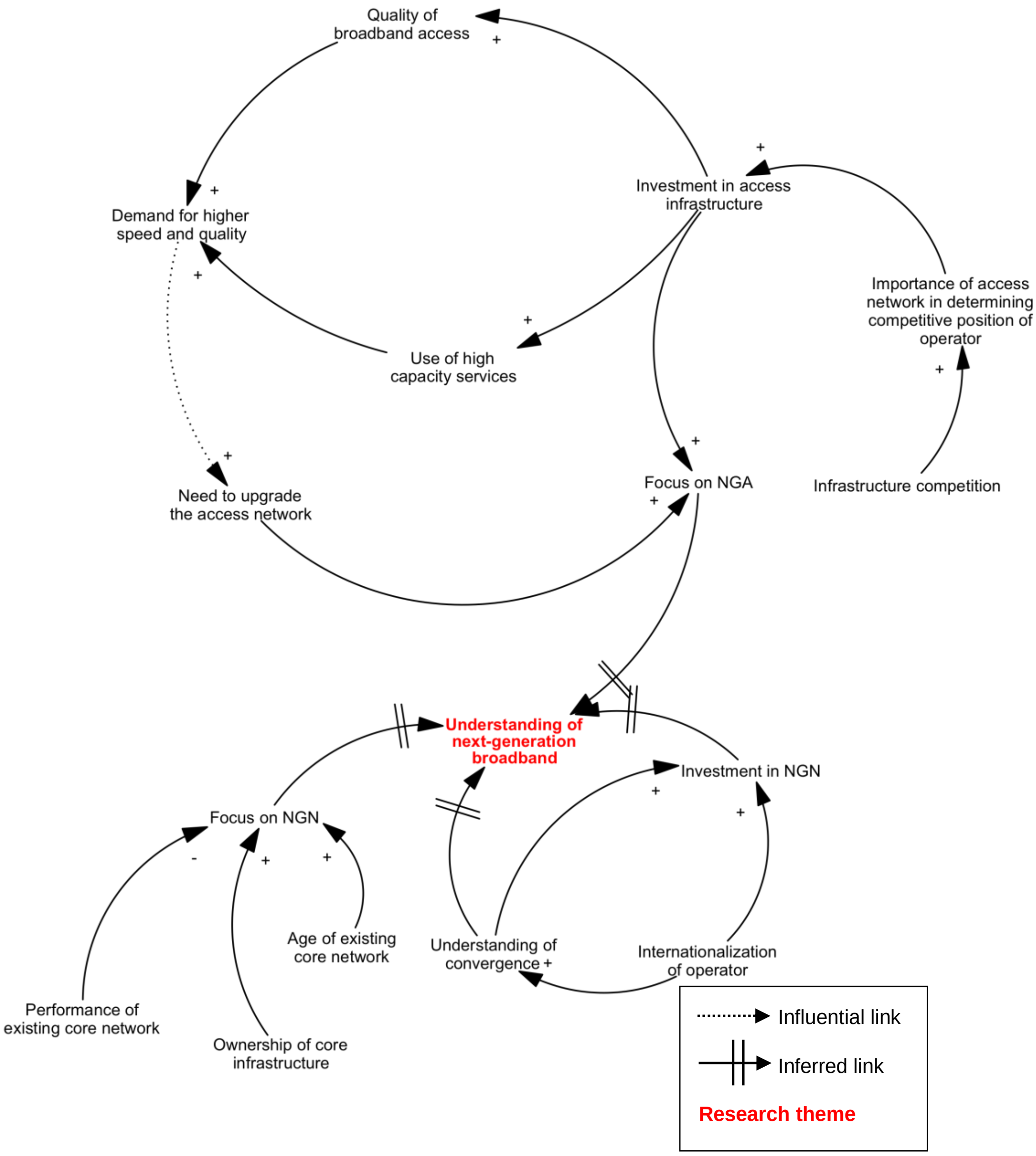


Figure 8-1: The impact of market factors on the understanding of next-generation broadband

In The Netherlands, aggressive access infrastructure competition increases the significance of the access network for operators, driving continuous investment in access infrastructure. Consequently, increasingly high quality broadband access is available to consumers, driving further use, growth and investment. In Sweden, the situation is similar, though not the same. Growth trends in the use of higher speed services by consumers have focused the attention of operators and the government on upgrading the access network. In contrast, the focus for the UK broadband market players is the core network.

For BT, the focus on NGN is driven by the fact that the incumbent owns the oldest core network infrastructure in Europe (Brown, 2011; BT, 2010c). In addition, being an international telecommunications player with operations in over 170 countries, the implications of NGN investment are more deeply understood by and have a greater impact on BT than on a pure domestic operator (BT, 2011b). For alternative British fixed-line operators, such as COLT and C&W, ownership of extensive core network infrastructure coupled with little evidence of consumer demand for higher speed services, unlike the situation in the Dutch and Swedish cases, make investment in the core more worthwhile than investment in NGA at the present time. While it can be argued that both KPN and TeliaSonera conduct telecommunications operations in international markets, the extent of their presence in terms of countries is not comparable to that of BT: KPN operates in a handful of European countries such as Belgium, Germany, France and Spain and TeliaSonera in Nordic and Baltic countries, Spain and Eurasia (KPN, 2011; TeliaSonera, 2010; TeliaSonera, 2011).

8.2.2 Definition of NGN

The impact of market factors on the understanding of next-generation networks was also examined through the definitions proposed by the participants. The definition of NGN was limited with participants in The Netherlands and Sweden but well-elaborated by those in the UK, a result of the focus of the country as described in the preceding section. The difference in focus is further exemplified by the diversity among the few definitions provided by the Dutch, suggesting that there is little agreement and motivation to understand what NGNs are, and the even fewer definitions provided by the Swedish interviewees. However, based on the definitions that were provided, it can be concluded that market conditions influence the perception of NGN to some degree, as illustrated in Figure 8-2.

The influence is most evident when comparing Sweden and the UK. The Swedes define NGN in terms of an upgrade to fibre in the core network. This perception of NGN can be linked to the role of fibre in this country, as Chapter 6 explains that, for various reasons, recent investments in fixed-line infrastructure in Sweden has been in fibre. In comparison, the main belief in the UK is that NGN is a converged IP-based network. The focus on convergence in this definition can be attributed to the growth of convergence of services, networks and markets in the UK and to the international dimension of its incumbent, BT, as explained in the previous section. BT has an in-depth knowledge of what convergence is and, therefore, understands the implications of NGN to a greater extent.

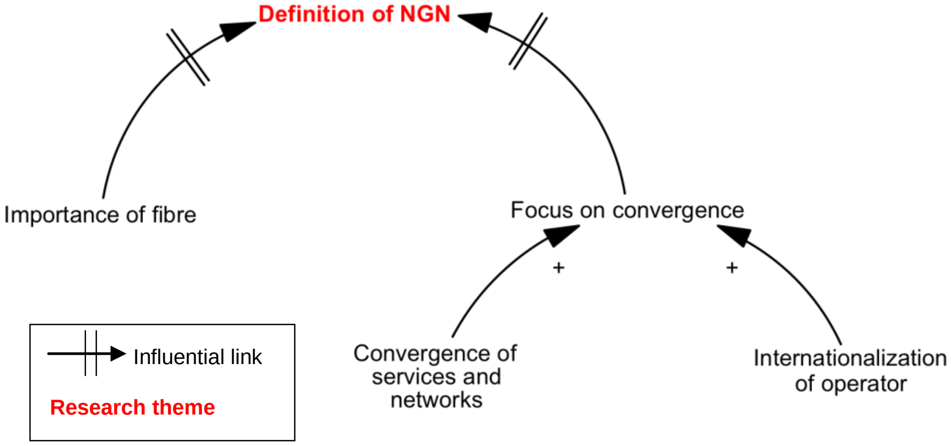


Figure 8-2: The impact of market factors on the perceived definition of NGN

On a purely technological level, however, the main perception of NGN is standard across all three markets; NGN is defined as an upgrade to an IP-based core network. This implies that market conditions do not affect the understanding of NGN from a technical perspective. This finding emphasizes the fundamental nature of NGN – that it is more of a technical upgrade than a market-based change.

8.2.3 Definition of NGA

Participants in the three countries define NGA based on different primary characteristics. In The Netherlands, NGA is defined from a technological and speed perspective and is considered, primarily, to be based on optical fibre at the present time. There is a general agreement that wireless technologies do not qualify as NGA technologies in this market. In Sweden, the focus for NGA definition is the creation of an open market and increased competition. There is some consideration, too, that NGA must comprise optical fibre, but a combination strategy is more strongly advocated. In the UK, NGA is viewed on the basis of speed, though a precise value of speed could not be identified. Rather, an enhancement of the speeds currently available is expected.

An examination of these differences highlights that market conditions have indeed influenced the perception of NGA in the three countries. This examination has led to the creation of the causal map presented in Figure 8-3, which shows the nature of the relationships (that is, positive or negative) between the market factors and the definition of NGA. The identification of the relationships and, hence, the development of the causal map is described below.

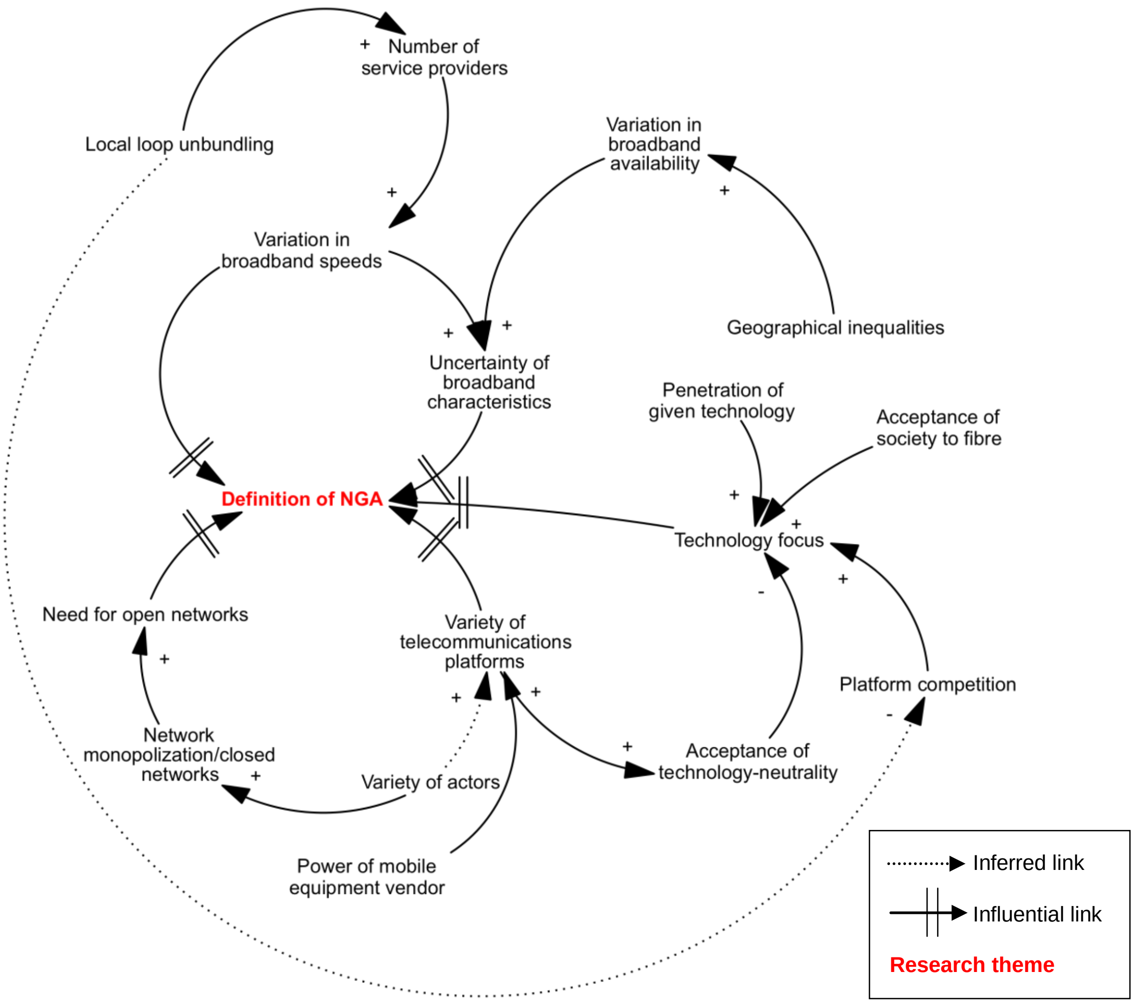


Figure 8-3: Influence of market factors on the definition of NGA

For The Netherlands, the technology-based definition underscores the significance of infrastructure competition at both the inter- and intra-platform levels. The Dutch broadband market is shaped by infrastructure competition among DSL, cable and fibre networks, making technology an important focus for Dutch operators.

Secondly, the penetration of fixed infrastructure and the competitiveness of the fixed market are greater than that of wireless. In addition to the fierce competition that exists in the fixed access network, the physical challenges of deploying fixed infrastructure, such as terrain and population density, are not significant in The Netherlands. Combined with the limited capability of wireless technologies, the geographic factors make investment in fixed access technologies, rather than wireless technologies, the preferred choice at the present time.

Although there is some view in Sweden that NGA comprises some optical fibre, this is not the focus for the Swedish broadband market players as in The Netherlands. In Sweden, consumers are becoming more accustomed to fibre access, but the penetration of other technologies is also high. Thus, the focus for NGA is not as a fibre-based technology. Instead for several reasons, Sweden adopts a combined technology strategy outlook for NGA.

Firstly, both fixed and mobile platforms have played and continue to play an important role in Sweden. Of particular significance is the deployment of the first LTE network in the world in Stockholm in December 2009 (Ofcom, 2010e). In general, mobile broadband has grown in Sweden. From December 2009 to December 2010, mobile broadband subscriptions increased by 73% (PTS, 2011c). At the end of 2010, 49.4% of broadband connections were mobile compared to 27% via DSL (PTS, 2011c). Fibre is also widely available in Sweden. With a penetration of 13.5% of total households in December 2010, Sweden ranked second at the time in the penetration of FTTH/FTTB within Europe (Hunt, 2010; Montagne, 2011a). Secondly, Sweden is home to Ericsson, one of the largest mobile equipment vendors and a significant player in the development of telecommunications in Sweden and the Nordic countries in general. The operations of Ericsson in Sweden place a great focus on mobile infrastructure.

As a result of the diverse infrastructure platforms available, the Swedish broadband market is not fixated on a pure fibre or fixed-line access-–related definition for NGA. Rather, the Swedes are more open-minded towards a mixed technology implementation of NGA. Both the Dutch and Swedish cases demonstrate that the link between NGA and technology can be attributed to path dependency and the role of existing infrastructure in the given market.

The principal definition for NGA in Sweden is linked to the creation of an open market and increased competition. Competition in Sweden is based on different players, with a range of various actors – municipalities, utilities, incumbent and alternative operators - involved in fibre deployment. With little collaboration among the different fibre players, monopolization at the different levels of investment (local municipal and national, for example) and the emergence of closed networks are common. As a result, there is a drive from the regulator for the various actors to endorse open networks such that competition can evolve. NGA is viewed as a means of achieving this. Therefore, while there is some recognition of technology in defining NGA, a more common perception is the facilitation of an open market.

In contrast to The Netherlands and Sweden, the UK does not define NGA in terms of technology. Instead, the UK broadband stakeholders view NGA in terms of capacity and/or speed, albeit uncertain of what the capacity/speed threshold is. This difference between the Dutch and Swedes and the UK can be attributed to three factors. Firstly, broadband infrastructure in the UK has been primarily DSL with some cable from Virgin Media. At the end of 2009, DSL accounted for approximately 79% of the total fixed broadband connections while the cable contribution was approximately 21% (Ofcom, 2010a). Thus, competition in the UK does not exist within access infrastructure as it does in The Netherlands, but more on a service level with ISPs via LLU. Of the DSL connections quoted above, over 44% were based on LLU (Ofcom, 2010a).

Linked to this is the second factor – the provision of services by numerous providers, many of whom offer different packages and different speeds. SamKnows (2011) lists 15-20 major UK LLU operators with hundreds of other ISPs reselling services (SamKnows, 2011). Figure 8-4 is illustrative of the diverse offerings available in the UK. Although Sweden and the UK are similar in that service competition is more prominent than infrastructure competition, the penetration of different platforms is higher in Sweden than in the UK, driving a focus on technology among the Swedes but not among the British.

	Average download throughput speed during period	
	24 hours	8 to 10pm weekdays
BT 'up to' 8Mbit/s	4.1 to 4.8Mbit/s	3.8 to 4.4Mbit/s
Orange 'up to' 8Mbit/s	3.3 to 4.3Mbit/s	2.7 to 3.5Mbit/s*
Plusnet 'up to' 8Mbit/s	3.4 to 4.4Mbit/s*	3.3 to 4.2Mbit/s
Virgin Media 'up to' 10Mbit/s	9.5 to 9.7Mbit/s	8.9 to 9.4Mbit/s
BT 'up to' 20Mbit/s	6.9 to 8.7Mbit/s	6.8 to 8.5Mbit/s
O2/Be 'up to' 20/24Mbit/s	9.9 to 11.6Mbit/s**	9.5 to 11.0Mbit/s**
Sky 'up to' 20Mbit/s	7.4 to 8.8Mbit/s	7.3 to 8.7Mbit/s
TalkTalk 'up to' 24Mbit/s	7.7 to 9.3Mbit/s	7.5 to 9.0Mbit/s
Virgin Media 'up to' 20Mbit/s	17.4 to 18.6Mbit/s	16.5 to 18.0Mbit/s
BT 'up to' 40Mbit/s	30.5 to 33.1Mbit/s	27.4 to 30.3Mbit/s
Virgin Media 'up to' 50Mbit/s	43.9 to 47.2Mbit/s	43.1 to 46.6Mbit/s

Figure 8-4: Summary of average UK download speed by ISP package, November/December 2010
Source: Ofcom, 2011a

Thirdly, in terms of broadband the UK market is more significantly influenced, at the present time, by the variation in broadband availability across the country. The variation in availability and speed by different providers and in different geographic regions leads to uncertainty in defining the value of speed that qualifies for NGA. In recent times, much research and consultation such as the Digital Britain report and Ofcom's broadband speed survey have been focused on addressing this issue, particularly with the emergence of next-generation access. The combination of these three features of the UK broadband market has the result that broadband stakeholders consider NGA more in terms of speed rather than technology, contrary to the situation in the other two countries.

As Figure 8-3 and the discussions above illustrate, market factors do influence the perception of NGA. It is clear, however, that differences are evident in the detail (such as the type of technology) of the market conditions. Primarily, it can be deemed that infrastructure competition and penetration and the involvement of market players are the key influential factors.

8.3 Theme 2: Investment drivers

The link between market factors and investment in next-generation broadband networks was examined with regard to both NGN and NGA. Section 8.3.1 discusses the influence of market factors on investment in NGN while Section 8.3.2 analyzes the impact on NGA investment.

8.3.1 NGN investment

To some degree, operators in each of the three countries have invested in an upgrade of their core networks to NGN. Of interest, however, is that the motivating factors are different for the operators in each market, indicating that a direct link between NGN investment and market conditions exists. Figure 8-5 captures the causal relationships among the various market factors and the investment decision.

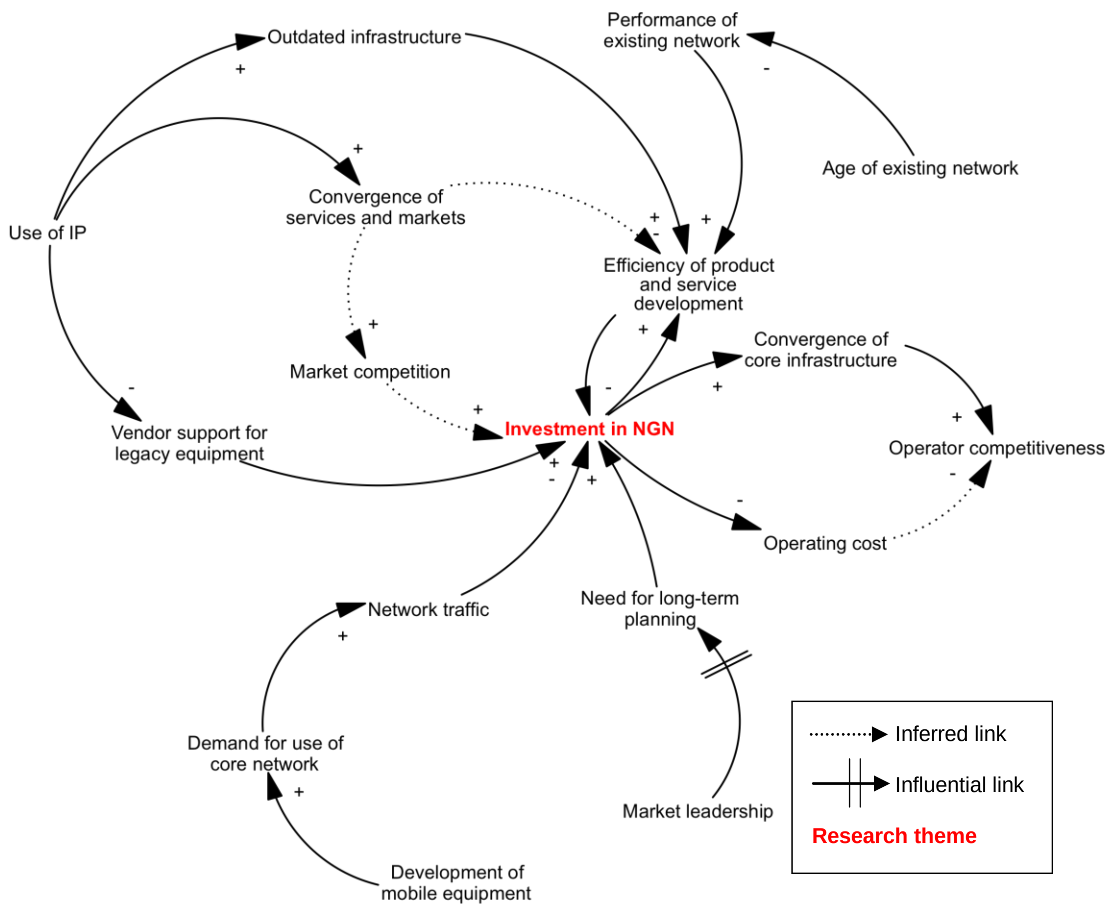


Figure 8-5: Causal relationships between market factors and investment in NGN

On a general level, investments in The Netherlands and the UK have been primarily supply-driven while a mix of demand-side and supply-side factors have encouraged investment by Swedish operators. The overlap across the three countries in terms of the supply-side influence is clear. NGN is a technical upgrade of the core network in order to provide a more efficient and cost-effective infrastructure over which services will be delivered. Inherently, therefore, the benefits of NGN are realized, in the first instance, by the network operator. Therefore, while there is some encouragement from Swedish consumers (indicated by an increase in network traffic), it is logical to conclude that, irrespective of market conditions, the first tier influence is from the supply side; that NGN is more of a supply-side development than a consumer-driven investment.

Despite this similarity among the three countries of having some degree of supply-driven investment, it is evident that the 'supply' factors are, in fact, different. This can be seen in Figure 8-5. In The Netherlands, the 'supply' stems from the operators' reaction to changes in the market – outdated equipment and infrastructure in legacy networks due to an increase in the use of IP-based technology, the need for more efficient development processes and long-term planning. Equipment vendors have begun to manufacture new equipment based on IP technology and limit their support for older versions. Thus, KPN, for example, has been compelled to adopt new equipment, in turn migrating to a core IP-based infrastructure. A key aspect of the Dutch investment in NGN is its timing - investment has taken place, not at the onset of NGN development, but rather, when costs have been reduced to the point that it has become attractive.

In contrast, British operators have adopted a proactive approach to NGN investment. Based on the inefficiencies of their legacy networks, operators in the UK invest in NGN in order to reduce costs, provide more efficient services to consumers and adapt to potential increases in convergence and competition in the British telecommunications sector. The status of BT is also key, as the British incumbent is a large international operator. However, such behaviour is not only seen with BT in the UK, as others such as COLT and THUS/C&W are also investing in NGN. One postulation for this is the price of services in the UK. Using fixed voice calls as an example, Figure 8-6 shows that, although the average price of a voice call in the UK is among the lowest in Europe, this has increased by 0.5% over the 5 years. Although the increase was marginally higher in Sweden at 0.7%, the final price is still lower in the latter. In The Netherlands, the average price for a voice call is the highest of the three countries but has not increased in the five-year period examined. For British operators, a reduction in operating costs in moving to NGN will result in a reduction in average call price for the consumer and can be cited as a driving factor for NGN investment.

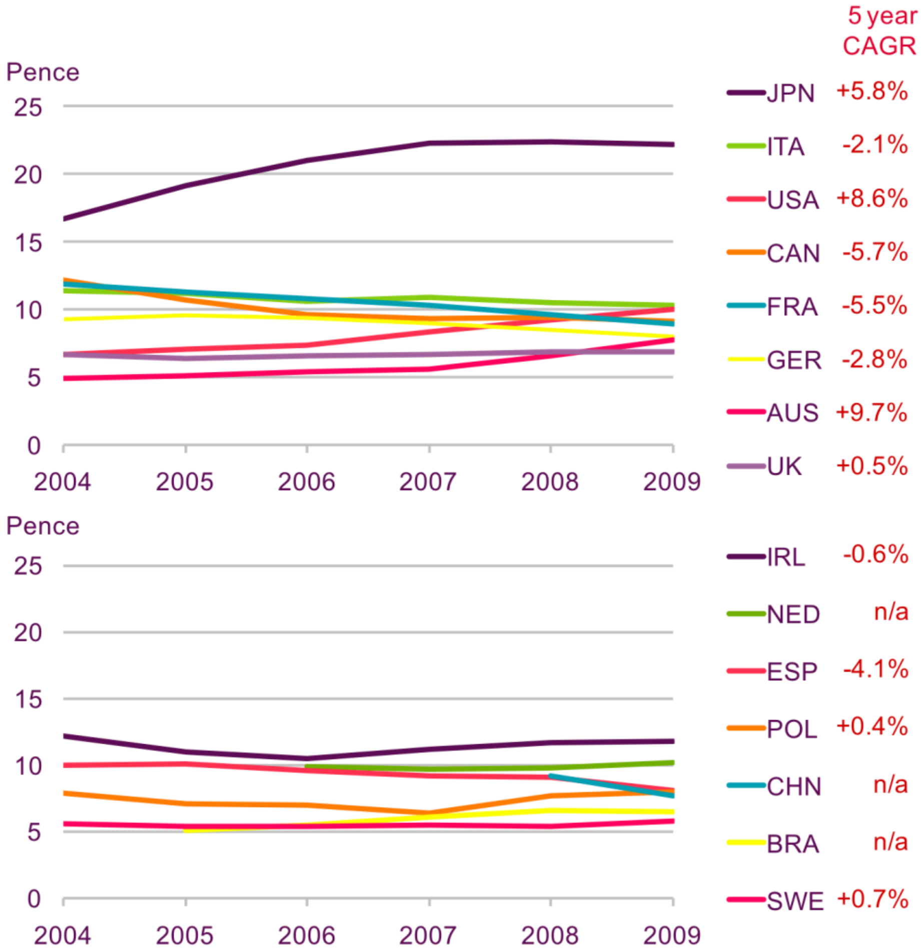


Figure 8-6: Average price of a fixed voice call minute, 2004-2009
Source: Ofcom, 2010a

In Sweden, investment in core network infrastructures has been ongoing and, as a result, the current network is upgraded, more so than that in the UK. However, recent increases in network traffic have resulted in TeliaSonera investing more in its core network. Again, the role of Ericsson as a Swedish mobile giant has been vital in this regard. As Ericsson increases its development, marketing and sales of mobile equipment, the demand for the use of the core network over which mobile services and applications are delivered is increased. Investment in Sweden is, therefore, driven by a mix of supply and demand factors and can be deemed somewhat reactive to the increased traffic on the core network.

Both Figure 8-5 and the discussions highlight the importance of the status of the operator and infrastructure in influencing NGN investment. As NGN is more directly linked to operators than to consumers, the decision to invest and, consequently, the influential factors, pertain to the operator. The status of existing infrastructure is important. Old infrastructure, such as in the UK, is a key driver for NGN investment while upgraded infrastructure and a functioning core network limits investment in Sweden.

The analysis also demonstrates that advances in technology are important in encouraging NGN investment. This has been experienced to different extents and in different ways in the three markets – obsolete equipment in The Netherlands, increased convergence in the UK, increased competition and increased network traffic in Sweden. It is evident that technology impacts significantly on the efficiency of operators and on competition.

It can also be concluded that investment in NGA does not affect investment in NGN as they are different network segments, impose different requirements and have different drivers. This distinction is particularly evident in the Dutch and UK cases. In the former, NGA investment is significant while there is some, albeit less, investment in NGN. In the UK, there is little investment in NGA but significant investment in NGN.

8.3.2 NGA investment

Infrastructure competition and expected demand from consumers for high-speed services have been driving Dutch operators to invest in NGA while, in contrast, investment has been primarily encouraged by the supply side in the UK. In Sweden, third party intervention has been important, as central and local governments have been keen on uplifting the social status of its citizens and country as a whole through NGA investment. Despite these differences in investment drivers, the three markets share similar experiences in the move to NGA. An assessment of the influence of the markets on creating these differences and similarities, the result of which are the causal relationships depicted in Figure 8-7, is presented in this sub-section.

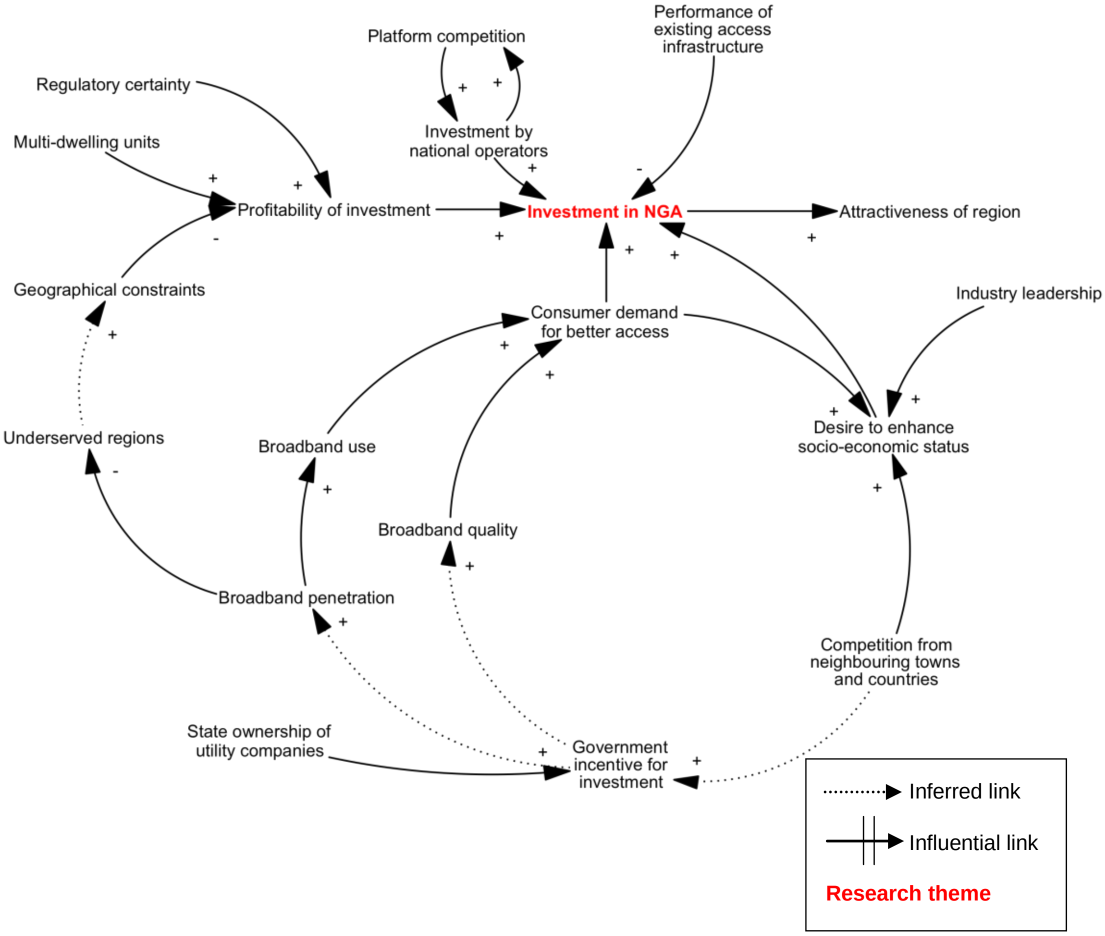


Figure 8-7: Relationships among market factors and investment in NGA

The case of The Netherlands highlights the impact of inter- and intra-platform competition on encouraging and sustaining investment in next-generation access networks. Figure 8-8 shows that Dutch national operators have invested significantly in upgraded fibre and cable access networks. In the UK, while there has been some investment in cable networks by Virgin Media, BT has played an insignificant role. In Sweden, the incumbent has invested in a meagre 6% penetration of fibre to the Swedish population (Ofcom, 2010e). Though competition is evident in Sweden, this competition exists among different parties and across cities, and the statistics in Figure 8-8 show that the level of NGA investment in Sweden by national operators is significantly lower than that in The Netherlands. In the UK, infrastructure competition is non-existent and NGA investment is limited.

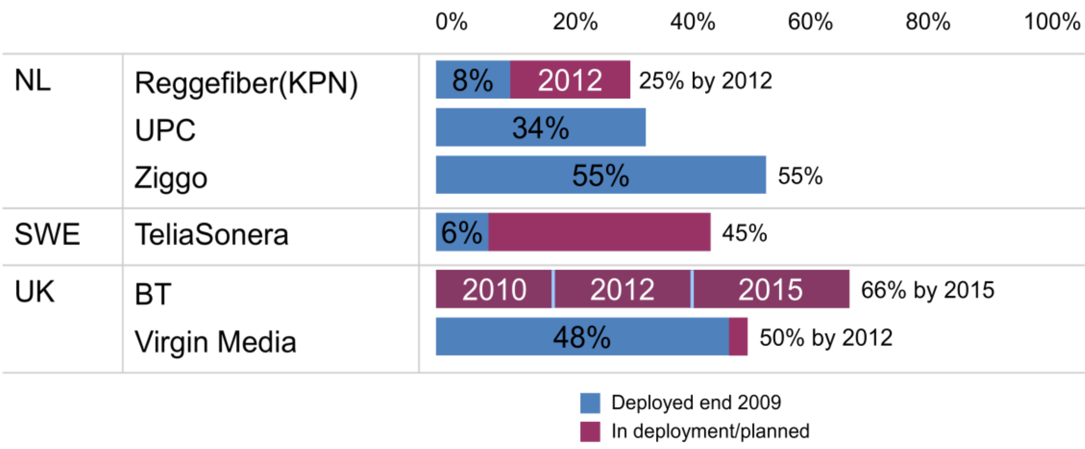


Figure 8-8: Current and planned NGA deployments
Source: Adapted from Ofcom, 2010e

Demand, too, emerges as an important driver for investment. In both The Netherlands and Sweden, there is some demand from consumers for higher access speeds, a result of the historic availability of high quality broadband for consumers in these two markets. In contrast, consumer demand is lacking in the UK. With the lack of competition and demand to encourage investment, the justification of a business case for fibre deployment is a challenge for British operators.

Despite the differences in drivers, the aims for NGA investment in the three markets are similar – to enhance the socio-economic status of the given country. The three cases reveal an overlap in the desire to deploy NGA on a micro-level. In Sweden, NGA deployment is motivated by the desire to create a more attractive region and to provide citizens with an enhanced quality of life. The objective is similar with local fibre deployments in The Netherlands, as community leaders are keen on improving the quality of life of their residents. In the UK, too, development on a small-scale basis is promoted as housing developers deploy fibre to attract a high calibre of residents. Consequently, NGA has been rolled out in targeted areas of Kent, Lyddington, Corby, Liverpool and Glasgow (Ofcom, 2010a).

In The Netherlands and Sweden, this drive for an improved socio-economic status can be attributed to the consumer demand and the general high quality and penetration of broadband infrastructure. In addition, the industrial and competitive positions of the two countries with similar and/or neighbouring countries are important. For example, The Netherlands hosts the Amsterdam Internet Exchange and is a forerunner in network development and innovation with SurfNet and its technology universities, such as Eindhoven University (Maltha and Brennenraedts, 2009). Sweden is influenced by the industrial activities and competition of the Nordic member countries with whom they compete. The UK is less influenced in this way, with its main industries being aerospace, automotive and finance. The motivation for the British investors of fibre in local communities is the knowledge of the benefits that fibre can bring to its residents and housing development and the comparable cost of new fibre and new copper.

Without the intervention of the government or other motivating factor, however, local projects are not sufficient to accelerate and/or sustain the roll-out of fibre on a country-wide level. This is supported by the comparison of the three countries and the information in Figure 8-8. In The Netherlands, although broadband deployment was accelerated by the government in 2004, investment was sustained primarily by infrastructure competition and consumer demand (van der Woude, 2005). In Sweden, government intervention initiated the roll-out of broadband infrastructure to underserved areas and the ownership of utility companies by the Swedish parliament has been a major factor in widening the penetration of fibre networks. In the UK, the story is comparable. Before the commitment of £530 million by the British Government in 2010, the future of NGA deployment in the UK was glum (The Guardian, 2010).

The challenge for NGA deployment in the UK is linked to the role of geography in facilitating investment. The Netherlands is an exemplar of favourable geographic terrain and conditions for NGA deployment. With a high population density and with over 50% of the population living in multi-dwelling units (MDUs), the cost of fibre roll-out is justifiable (Ofcom, 2010e). In the UK, the population distribution is uneven and approximately 85% of the population lives in single-family homes (Ofcom, 2010e). Thus, only profitable areas, typically new-build sites, are targeted for fibre deployment.

Regulation has proven to be an influential factor in all three markets. There is evidence, for example, that a lack of regulatory guidance deters investment in the three countries, particularly in the UK where a lack of regulatory certainty has led to delayed/limited investment. Although the absence of regulatory certainty has deterred investments in The Netherlands and Sweden, some investment has still been made in these two markets. This demonstrates that, where few alternative incentives exist for private sector investment, such as demand and competition, regulation and commercial factors (which are linked to other factors such as geography) are important. Consequently, with firmer support from competitive, political and other factors, the adverse implications of regulation are of less significance to Dutch and Swedish operators. Based on these observations, regulation can be deemed necessary for NGA investment but cannot be cited as either a definite driver of investment or sufficient to sustain investment on its own. As a result of the early stage of NGA investment, the uncertainty that still exists with NGA regulation and the likelihood of regulatory changes, however, a more detailed comparison of the implications of regulation cannot be undertaken at the present time.

The performance of existing infrastructure has played a key role in NGA investment in Sweden. Although the good condition of existing networks has discouraged investment in Sweden, in The Netherlands, where access networks are also in good condition, the force of infrastructure competition has continued to encourage investment. This comparison illustrates that infrastructure competition is more influential than the status of infrastructure in the NGA investment decision.

This discussion on NGA investment reveals that a range of factors influences the investment. In addition, and a more significant outcome, is that the factors are interlinked. This interaction is examined in more detail in Section 8.6.

8.4 Theme 3: Technology drivers

The analyses in Chapters 5, 6 and 7 reveal that three main categories of factors influence the choice of technology for NGA. Several factors drove the need for optical fibre, others were linked to the use of wireless technologies while the third category was technology-neutral, that is, not linked to a specific technology but contained general considerations. Figure 8-9 highlights the relationships, which are subsequently explained.

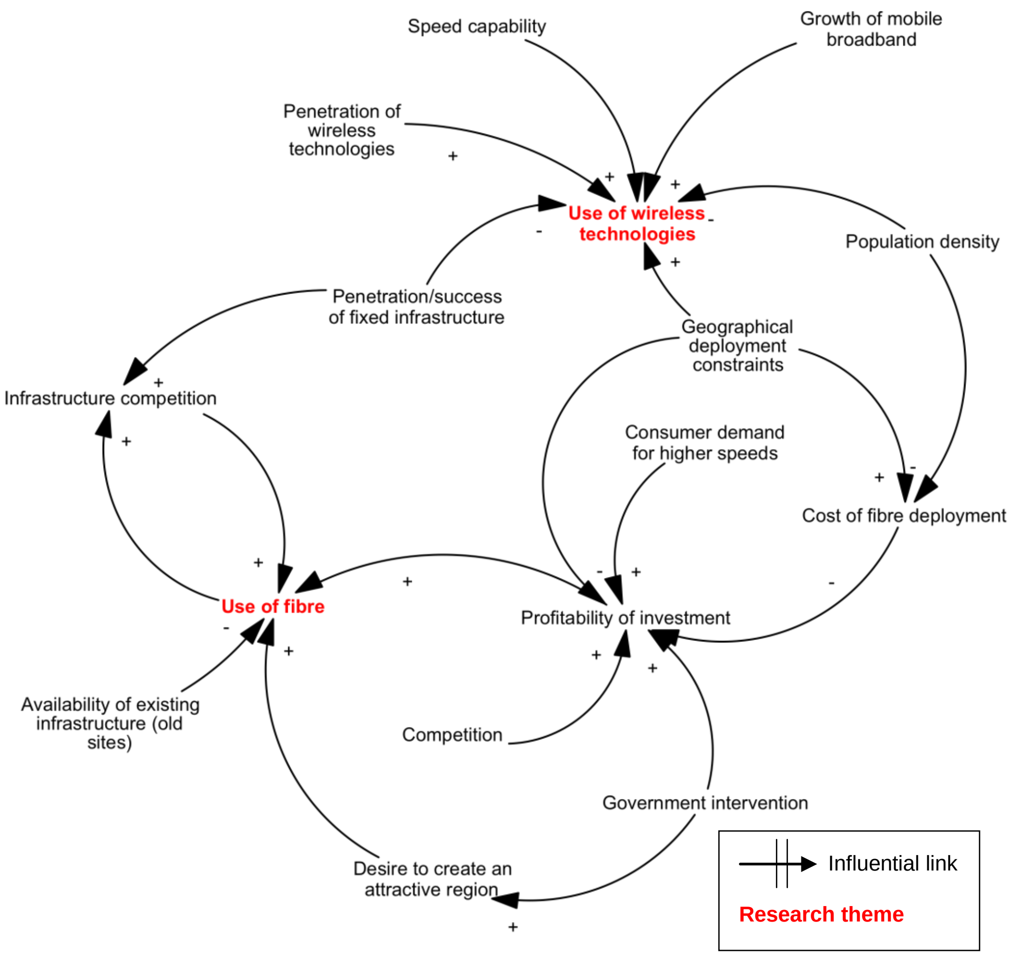


Figure 8-9: Causal relationships among market factors and choice of technology for NGA deployment

In general, factors such as path dependency and profitability influence the choice of technology for operators in the three countries. For example, in The Netherlands, the limited penetration and technical capabilities of wireless technologies combined with the success of and competition amongst fixed infrastructure is a key consideration for operators. As a result of its recent deployment in Stockholm and the growth in mobile broadband, the Swedes prefer the use of LTE as a wireless option. However, the underlying concern of the profitability of investment, which is linked to other factors such as geography as shown in Figure 8-9, is also important in this decision.

However, it is clear that optical fibre is most widely used in all three markets. While an initial conclusion based on this observation might be that market conditions do not influence the use of optical fibre, a closer examination reveals that different incentives drive this choice in the three countries. In The Netherlands, infrastructure competition is the main driver, but linked to this is path dependency, as fixed networks – cable and DSL – have high penetrations across the country, as Chapter 5 showed. Thus, the migration to NGA inherently suggests the deployment of optical fibre.

Competition also plays a key role in Sweden, albeit in a different form, as towns and municipals compete to attract residents and, on a larger scale, to make Sweden an attractive country. Swedish operators also chose fibre for new connections and as a result of demand from consumers. In the UK, although there is some drive primarily from business consumers, geographical conditions largely dictate where optical fibre is deployed, even with the initiatives of housing developers. For example, the majority of fibre deployments in the UK have been new connections or at new-build sites, such as Ebbsfleet Valley, Titanic Quarter and Wembley Park (Ofcom, 2008).

Two conclusions can be drawn from this comparison. Firstly, market factors do, in fact, influence the use of optical fibre. However, the flexibility and future-proofedness of the technology makes it suitable for use in the different markets and to satisfy the diverse requirements imposed in the three countries. Secondly, profitability is always an underlying element of the decision for optical fibre deployment. Profitability, as illustrated in Figure 8-9, is determined by the interaction of other market factors such as consumer demand, competition, geography and the cost of investment. This is less of an issue in The Netherlands and Sweden than it is in the UK as, for several reasons, profitability is firmer in practice in the two former markets. The geographic characteristics of The Netherlands are not as diverse or unfavourable towards fibre roll-out as in Sweden or the UK. Therefore, the geographical challenges for deployment are not significant for the Dutch. In addition, the competitive market forces are adequately strong to accrue a reasonable return on the fibre investment. While Sweden is similar to the UK in terms of geographical difficulties, the involvement of the Swedish Government in the deployment of broadband infrastructure and optical fibre in particular is high. These influences have contributed to stabilizing to some degree the profits that the Dutch and Swedish operators can realize. This issue of profitability, however, remains quite significant in the UK.

An interesting outcome of the comparison is that no specific services were identified as drivers for the use of optical fibre in any of the three countries. Though references were made to "high-speed" applications and "multi-room" usage, specific services were not pinpointed. This observation highlights the uncertainty, yet expectations, which exist in the service domain in relation to the deployment of optical fibre.

Unlike the diversity in drivers for optical fibre, an overlap was found across the three countries in the link between market factors and the use of wireless technologies. In the first instance, there was agreement among the participants that the use of wireless technologies is linked to the geographic conditions of the target region – the penetration of existing infrastructure, remoteness, population density and, consequently, the cost of deployment. Although population densities vary across the three countries - 493.2 in The Netherlands, 22.08 in Sweden and 252.61 in the UK[21] in 2010 - the countries are similar in that several sparsely populated areas exist within each, albeit much less in The Netherlands, as shown in Figure 8-10 (CIA Factbook, 2010)[22]. As a result, some recognition of the use of wireless technologies emerges within all three countries.

[21] These values are in persons per square kilometre.

[22] The population density increases with the darkness of the brown colour on the maps. The maps are included in order to observe the population distribution patterns across the three countries and not for the detail of the map.

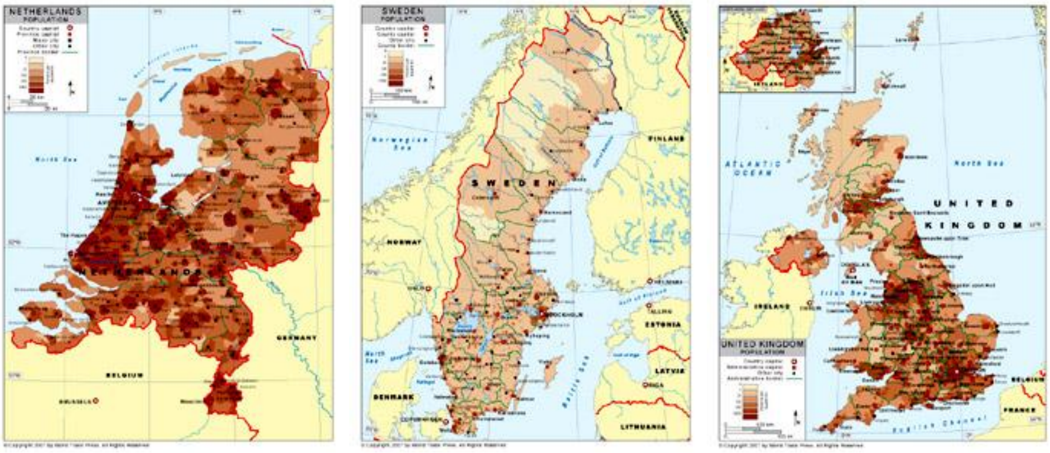


Figure 8-10: Population distribution within The Netherlands, Sweden and the UK respectively, 2010
Source: World Trade Press, 2010

Related is the belief in the UK that wireless technologies are used to provide broadband connectivity where there is no connectivity. The third link established is based on the technical capabilities of wireless technologies – that as a result of their limitations in capacity and speed, they should be used as a complement to fixed technologies, particularly fibre, rather than on their own. This is evident even with the use of LTE in Sweden as there is still uncertainty of the actual speeds achievable with the new mobile technology. As these findings reveal, while the use of wireless technologies is dependent on market conditions, the considerations for its use are similar for the three countries. Therefore, it can be deduced that wireless technologies are suitable for use under certain, but standard, market conditions.

8.5 Theme 4: Perceived benefits of next-generation broadband

This section presents a comparison and assessment of the benefits expected by the participants in the three countries with the deployment of next-generation broadband networks. In examining the perceived benefits of NGN and NGA in Sections 8.5.1 and 8.5.2 respectively, the discussions highlight any links between the market conditions and the expected benefits, and review differences and commonalities that exist within the three countries.

8.5.1 Perceived benefits of NGN

The causalities among the market factors in their impact on the benefits of NGN are captured in Figure 8-11. In The Netherlands, operators expect a cheaper and future-proof network and a decreased time to market of products and services. These benefits are expected to be derived from the all-IP core and the delivery of services over a single platform that will be possible with NGN. Swedish operators predict an increase in competitiveness as a result of lower costs and increased quality in the core network. In the UK, lower service production costs, lower operating costs and a reduced time to market of products and services are expected. British operators also believe that their capabilities as service providers will be enhanced. These benefits are linked to the rationalization of currently disparate networks into an IP-based core.

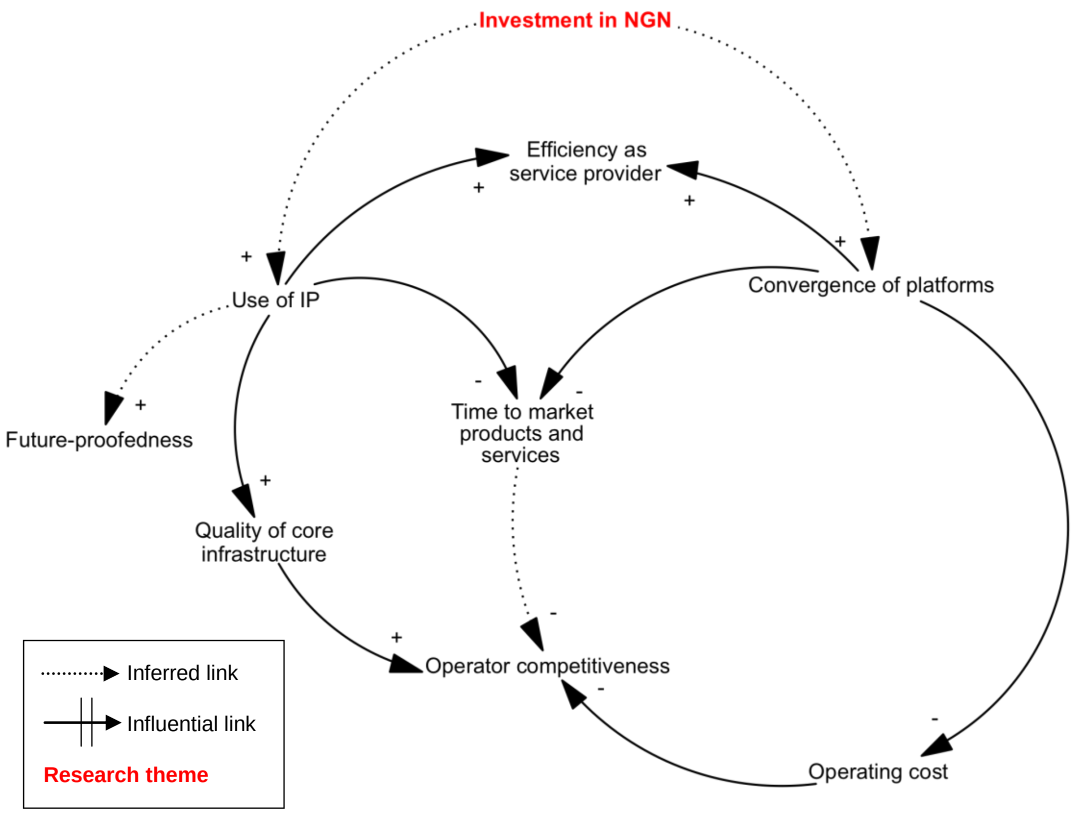


Figure 8-11: Relationships among market factors and benefits expected with NGN deployment

While it can be argued that the quality of existing core infrastructure and, in the case of Sweden, the high quality expected by consumers, influence these expectations of NGN, two counter-arguments can be put forth. Firstly, there is as yet insufficient evidence to confirm such a relationship between market factors and perceived benefits. Secondly, a clear link emerges in the data between improvement in infrastructure and the benefits expected. This is further cemented by the similarities in the benefits expected with NGN, although general market conditions and core networks are different in terms of penetration and condition in the three countries. All benefits identified have a direct impact on the efficiency of the network operator and are linked to an improvement in infrastructure – having an IP-based core and a converged core, for example. This is clearly represented in Figure 8-11.

As a result of its prominence, the association between investment in NGN and the network operator is worth exploring. As the discussion reveals, the benefits of NGN are concentrated on the supply side rather than on consumers. In general, operators' efficiencies in terms of resources, operations and, consequently, competitiveness are enhanced. This can be explained by the fact that an NGN upgrade is a technical infrastructure improvement aimed directly at improving the functionally of the core network. While it is true that improvements for the operator will be transferred to consumers, it is evident that the investment is driven primarily by the immediate benefits to operators. Furthermore, such immediate benefits to operators have emerged as a priority with the interviewees. This direct relation between technical improvement and expected benefits presents yet another line of support that the perceived benefits of NGN are less influenced by market factors.

8.5.2 Perceived benefits of NGA

Across the three countries, the expected benefits of NGA are more diverse than those of NGN. While the Dutch foresee a majority of societal benefits as a result of increased competition, higher speeds and (unknown) new services, participants in the Swedish market expect more benefits for operators, such as lower costs and greater flexibility, and a better information society. In the UK, the benefits are all linked to better and more economical access for consumers. Figure 8-12 illustrates the underlying causal relationships.

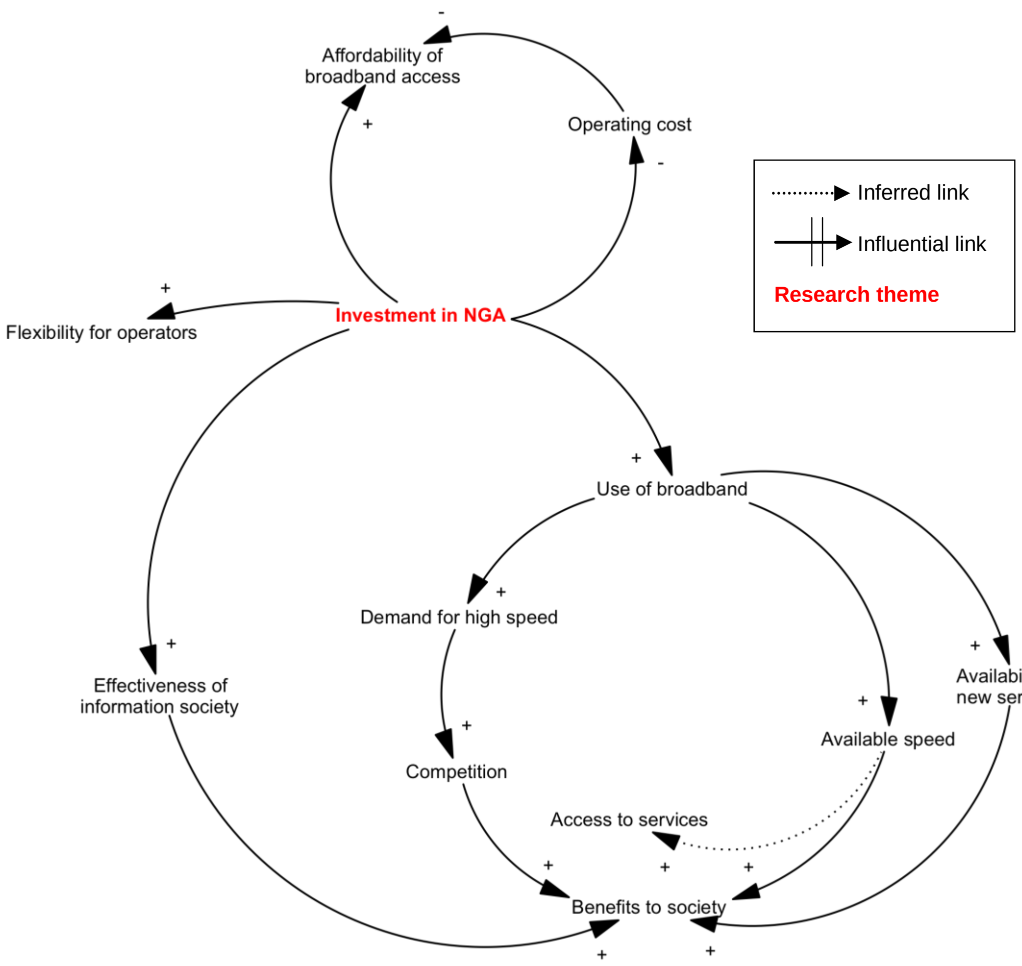


Figure 8-12: Causal relationships among market factors and benefits expected with NGA deployment

The focus of increased competition, higher speeds and new services in The Netherlands can be linked to the competitive nature of the market and the expectations and behaviour of users, which are key characteristics in the next-generation broadband discussion. These two factors have been driving investment in NGA in The Netherlands. In Sweden, the focus on an improved information society can be linked to its need to establish open NGA networks. It can also be inferred that the expectations of improved and more economical access in the UK are linked to the market conditions previously mentioned in Section 8.2 – the focus on speed as a defining attribute of NGA and the struggle to economically deploy NGA.

These comparisons highlight several points of interest. In the first instance, it is evident that market factors play a vital role in influencing stakeholders' perception of the benefits of NGA. The market conditions, in turn, determine the priorities for each country and, as a result, these emerged as important points in the discussions with the interviewees. Thus, the differences among the countries are linked to these different priorities for each country. Finally, it is also evident that some interviewees link the expected benefits to their own understanding of NGA. This is obvious in the UK where, for example, NGA is defined primarily in terms of speed and the main benefit is considered to be enhanced access to services.

A key similarity among the countries is that new services are not identified as a main benefit. While this can be linked to the lack of consumer demand for services in the UK, consumer demand plays an important role in both The Netherlands and Sweden, yet participants in these two markets also failed to identify services as a main benefit. Two conclusions can, therefore, be drawn. The first is that the profile of the interviewees was such that they collectively were not interested in selling services and this was, therefore, not a point of discussion. The second is that there is still a high degree of uncertainty with regard to the new services that can be delivered with NGA. This element of uncertainty has arisen several times throughout the discussions and, as the Dutch data shows, there is an expectation of new services but these are as yet unknown. There is a strong inclination, therefore, to surmise that the service benefit of NGA is still generally unknown and is not considered to be the most important benefit of NGA.

Based on this discussion, it can be concluded that, in general, the benefits of NGA are linked to two aspects of the market – market conditions and definitions. This finding highlights the interaction among the different market factors in the next-generation broadband discussion, which will be examined in Section 8.6.

In summary, there is a greater link between market conditions and the perceived benefits of NGA than between market conditions and the perceived benefits of NGN. This can be explained by the fact that NGN is a more standardized, technical upgrade to network infrastructure than is NGA. The uncertainty and differences with NGA stems from the different meanings to different individuals and in different markets – be it speed, technology or services, for example. The uncertainty also results from the differences in network access that is available within and across different countries, as is demonstrated in the three cases. For example, the average broadband speeds in The Netherlands, Sweden and the UK at the end of December 2010 were 7.0 Mbps, 5.1 Mbps and 4.3 Mbps respectively, with greater variations persisting locally within the countries (Akamai, 2010). Fifty-six percent of the Dutch broadband connections were capable of speeds over 5 Mbps; these figures were 29% and 22% for the Swedes and British respectively (Akamai, 2010).

8.6 Theme 5: Interaction of market factors

Sections 8.2 to 8.5 examined four themes of the research, presenting insight into the impact of market factors on various aspects of the development of next-generation broadband. In each of the theme discussions, some interplay among the market factors and, consequently, among the themes of the study, became evident. It is the objective now to examine this interaction, as a fifth theme of the study.

In order to illustrate and understand the interactions of the market factors, Figure 8-13 was developed from the casual maps produced for each theme in Sections 8.2-8.5. Figure 8-13, therefore, presents an overall picture of the interactions that exist among the market factors. Several key features can be identified, the underlying relationships of which are shown by the coloured arrows. Each of the key features is subsequently discussed.

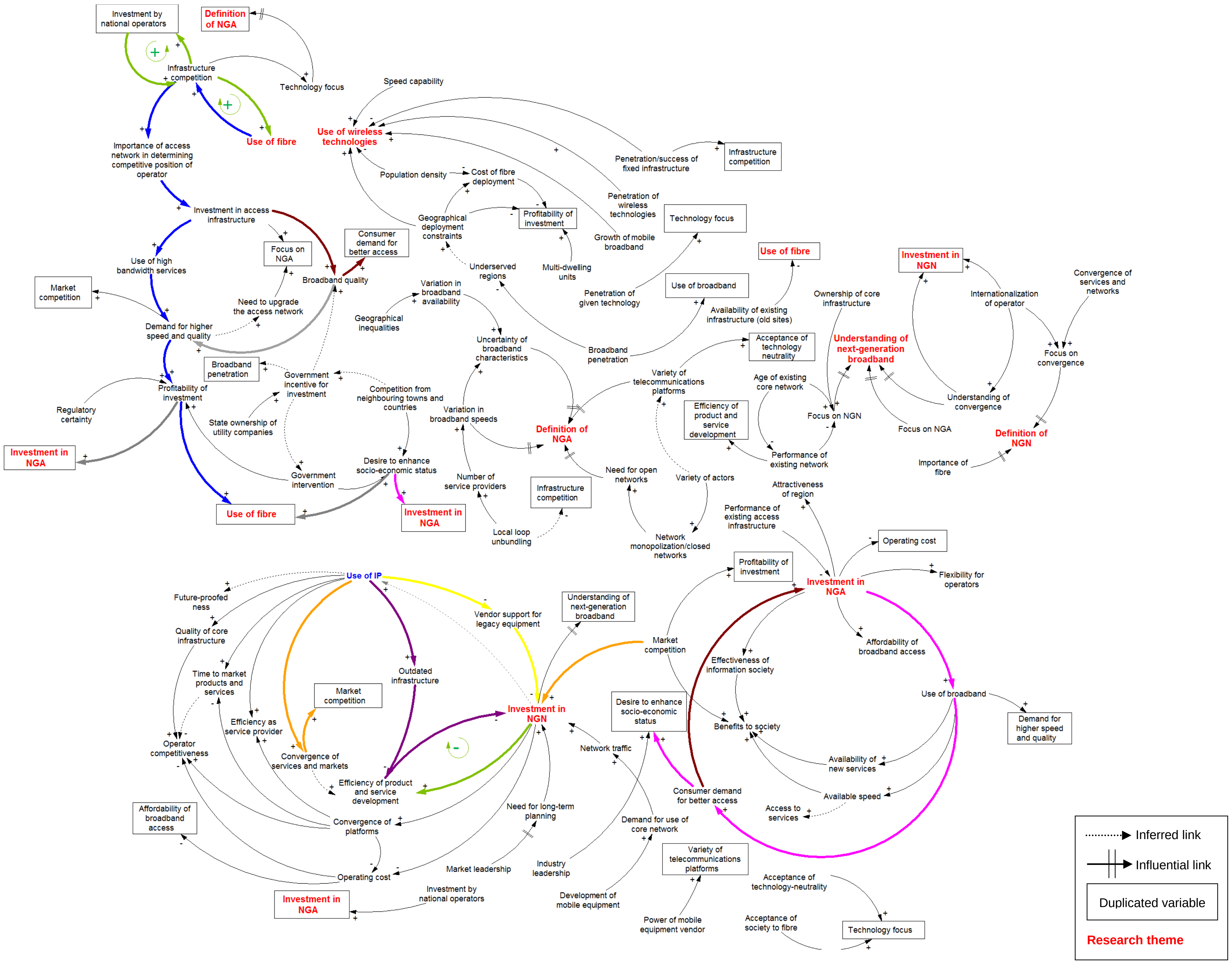


Figure 8-13: The interaction of market factors

8.6.1 Market complexity

Figure 8-13 draws attention to a high degree of complexity that exists within the telecommunications markets studied. A multiplicity of market factors and relationships has emerged. From a close inspection of the map and the relationships, it can be inferred that the driver of this complexity is the use of IP, or more generally, the advancement of technology. Developments in technology have led to an increase in the convergence of services (fixed and mobile), platforms and markets which has, in turn, increased the competitiveness of the telecommunications industry. Convergence has led to the removal of barriers to entry to some markets, enabling a new mix of players to enter otherwise "inaccessible" and unprofitable markets. Developments in technology have also affected the efficiency with which operators can deliver their products and services – core telecommunications network infrastructures using IP enable cheaper and faster development of products and services, surpassing the capabilities of infrastructure based on circuit-switching, frame relay and X.25. This revelation of the role of technology in promoting the complexity of the next-generation broadband market, based on empirical data, is in agreement with the conceptual framework proposed in Chapter 4.

8.6.2 Feedback loops

Several feedback loops have been distinguished on Figure 8-13 (shown by green arrows), re-captured in Figure 8-14. Two of the feedback loops are positive. According to Eden (2004), such a loop indicates that a 'reinforcing' dynamic exists. In such a cycle, rapid change and rapid growth is likely to occur (Giordano et al., 2007). The feedback loop depicted in Figure 8-14(a) shows this relationship between infrastructure competition and investment by national operators. Competition among network platforms is a major driver for investment in access infrastructure by private operators, in order to enhance their competitive position and to "survive". Competing infrastructures give consumers a choice of providers, thereby threatening the market position of operators if the competition is fierce enough. As investment in access networks increases, so does platform competition, be it among similar infrastructures or across different types of technologies.

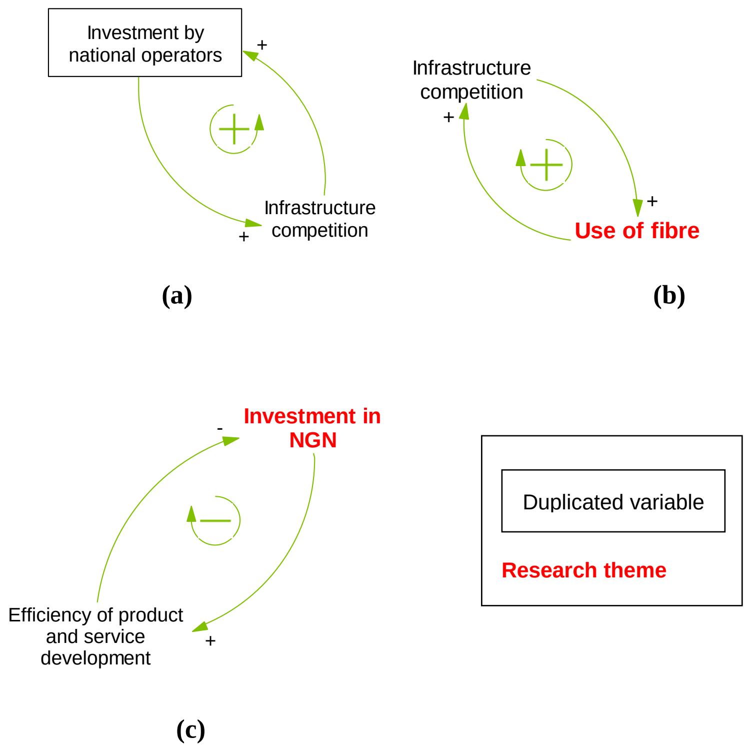


Figure 8-14: Reinforcing feedback loops among market factors

In Figure 8-14(b), a comparable link between infrastructure competition and the use of fibre can be seen. As competition among platforms increases, there is a greater drive among network operators for investment in fibre, as fibre is considered to be the "future-proof" technology with the greatest inherent competitive advantage. Investment in fibre furthers infrastructure-based competition.

The final example, reflected in Figure 8-14(c), highlights a negative relationship between investment in NGN and the efficiency of product and service development, in contrast to the previous two feedback links. Investment in NGN will enhance the cost and resource efficiency of operators in the development of products and services, but as their efficiency increases, the need for future investment in NGN will be reduced.

The emergence of these feedback loops indicates the importance of the respective variables in influencing market activities. The first two loops demonstrate that infrastructure competition is vital in encouraging and sustaining investment by national operators and investment in fibre. As a result of the reinforcing dynamic between these two variables, a continuous/unlimited loop of investment and competition can be established. Moreover, as the loops (relationships) persist with time, the changes become faster and greater. For example, as infrastructure competition continues to increase as a result of investment by national operators, the competition strengthens. In turn, operators invest more and in shorter increments of time. As the two reinforcing feedback loops represent dynamic behaviour that result in desirable outcomes (that is, increased investment by national operators or increased use of fibre), they can be cited as virtuous circles (Eden, 2004). The two positive feedback loops interact as shown in Figure 8-15 below, showing that, ultimately, investment by national operators can sustain the use of fibre by operators, and vice versa.

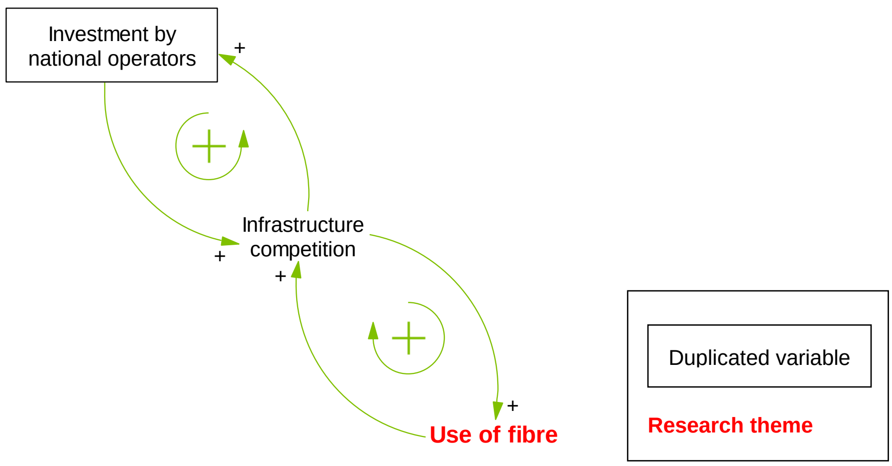
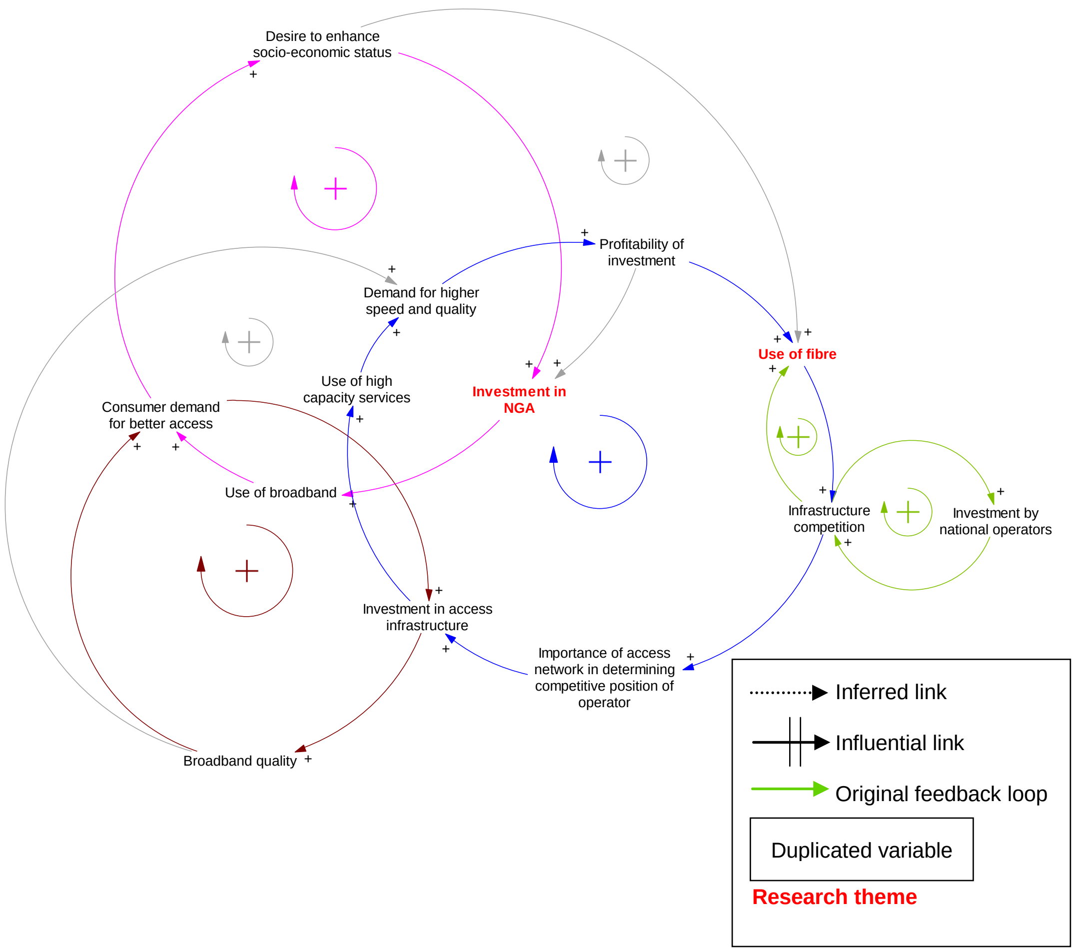


Figure 8-15: Interaction between the positive feedback loops

On the other hand, the third loop shows that, from an operator efficiency perspective, investment in NGN will become stable at some point in time. As operators' efficiencies are increasingly improved with each investment, their efficiencies will be adequately developed after some time. Eden (2004) suggests that such behaviour can be possibly addressed by a change in policy.

8.6.3 NGN and NGA investment cycles

Two detailed cycles can also be identified from Figure 8-13 and it was interesting to note that these relate to NGA and NGN investment. The former is shown in Figure 8-16. The NGA cycle is a combination of several cycles, each of which can be represented as a positive feedback loop and contains variables that exhibit positive relationships among one another. This suggests that all the drivers of NGA investment, that is, factors that have a positive influence on NGA investment, are linked. Additionally, the reinforcing dynamics among the variables indicate that as the interaction continues, investment in NGA will grow and be sustainable. The key relationships are found to exist among investment by national operators, consumer demand and use, infrastructure competition, profitability, quality and socio-economic advancement.



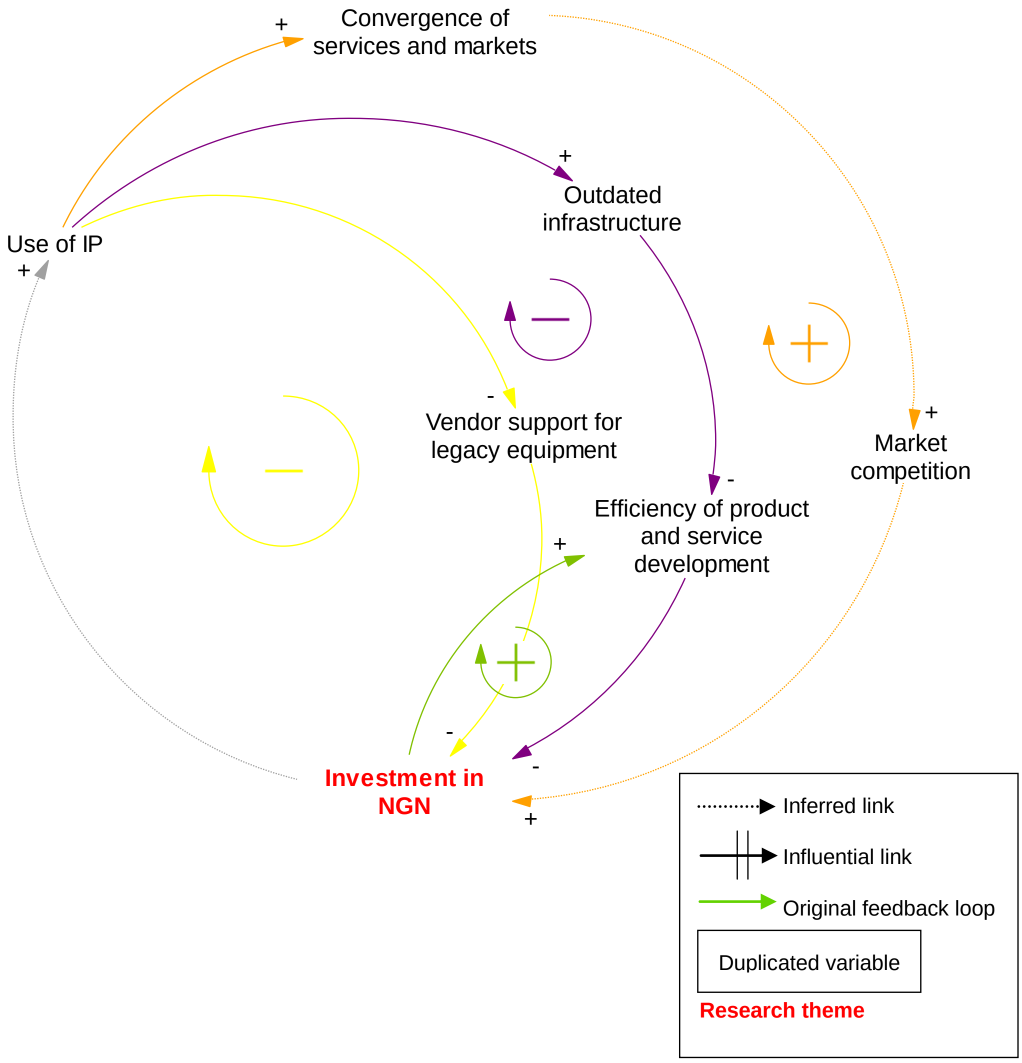
Note: The main cycles and feedback signs are colour-coded for easy association. The main cycles are shown in blue, pink and burgundy. The grey arrows are part of one or more of the main cycles.

Figure 8-16: Cycle of NGA investment

Figure 8-16 also illustrates a link between two themes of the research – investment in NGA and the use of fibre. This highlights an overlap of factors influencing investment in NGA and fibre and, consequently, the common association of next-generation access with optical fibre technology. Finally, the cycle of NGA investment demonstrates that it is difficult to identify a starting point for NGA investment or the use of fibre. This finding suggests that it is the overall influence of various aspects of a market that determine the investment made in NGA.

Figure 8-17 presents the second cycle extracted from Figure 8-13. This cycle represents NGN investment. Similar to the NGA investment cycle, Figure 8-17 was developed from several individual cycles that overlapped in their link to investment in next-generation networks. However, unlike Figure 8-16, the NGN investment cycle is a mix of positive and negative feedback loops and indicates that there is a possibility for the culmination of NGN investment, as explained earlier of negative feedback loops. The variations in influence in NGN investment signify that investment will be determined by the combined impact of the market variables.

It is interesting to observe, however, that, like the case of NGA investment, competition can aid in sustaining investment in NGN. In the NGN scenario, market competition in general rather than infrastructure-based competition in particular, is the driving factor. Thus, although increased vendor support for legacy equipment and a peak of operators’ efficiencies have the potential to cease NGN investment, increased market competition can provide a sustaining motivation. Finally, it is clear from Figure 8-17 that the use of IP is the starting point of the cycle of NGN investment, as all three cycles commence with this activity.



Note: The main cycles and feedback signs are colour-coded for easy association. The main cycles are shown in yellow, purple and orange. The dashed, grey arrow is part of all three cycles.

Figure 8-17: Cycle of NGN investment

The identification of the two investment cycles as the only cycles within the market interactions presents an interesting insight. Firstly, the cyclical relationships imply that some degree of continuity exists within these two themes of the study, as compared to the other themes investigated, and the potential for self-sustenance of the cycles/investments exist. The cyclical relationships mean that points of intervention can be identified and modified in order to achieve the desired outcome (Eden, 2004). For example, as previously mentioned, the use of policies can be exploited to change the causality of negative feedback loops, such as those identified with NGN investment. Finally, the recursive feature of the cycles implies that a temporal effect on investment in NGN and NGA exists, while this is not the case with understanding, choice of technology and the expectation of benefits. In practice, the temporal impact means that investment in NGN and NGA today will influence future investments.

8.6.4 Interaction of market factors

Apart from the recognition of the two investment cycles from Figure 8-13, the majority of relationships emerging from the causal map are illustrative of another key feature of the interplay among the market factors – that a range of variables influence a given factor and, therefore, market factors cannot be considered in isolation. Figure 8-18 was randomly extracted from Figure 8-13 to illustrate and explain this feature. As Figure 8-18 shows with 'profitability of investment' and 'benefits to society', the influential variables have different impacts. In such a scenario, the overall impact must be considered. For example, profitability of investment is determined by a combination of government intervention, the existence of MDUs, regulation, demand, geographical constraints and competition, and the impact of a single factor cannot be used to indicate the level of profitability of the investment. Similarly, the benefit to society expected with the deployment of NGA is determined by a combination of the improvement of the information society, market competition, available speeds and new services.

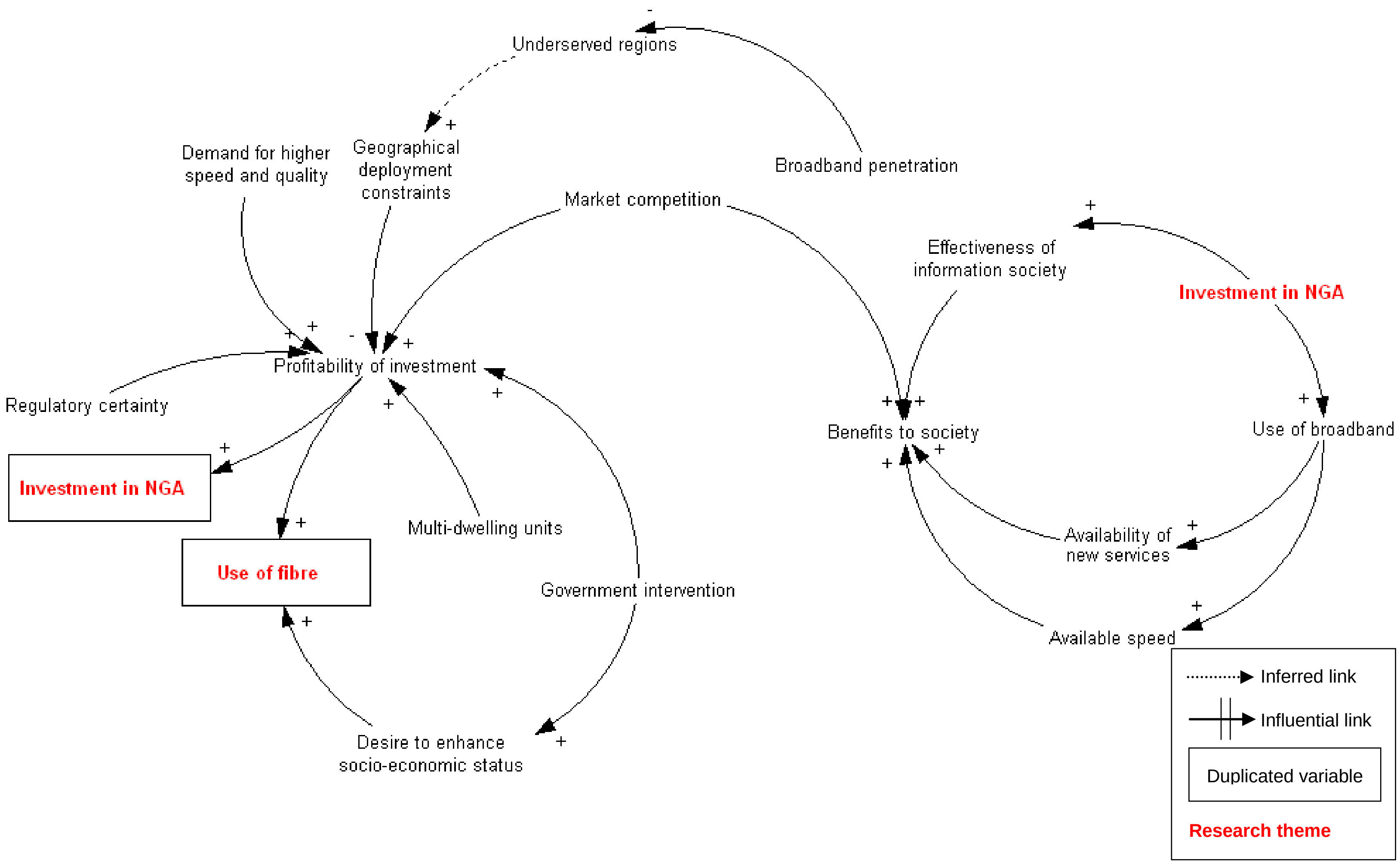


Figure 8-18: Examples of non-cyclic relationships among market factors

A higher-level perspective of the relationships within Figure 8-13 is presented in Figure 8-19. While the ‘value add’ of the links is more evident in Figure 8-13, Figure 8-19 emphasizes the interaction of the various aspects of a market – services, consumer demand, regulation, infrastructure, and so on - in the development of next-generation broadband. The diagram does not show causal relationships but rather an overview of how market variables and the themes of the study are linked. Figure 8-19 shows, for example, that geography is linked to broadband availability, which, in turn, is related to the understanding of next-generation broadband. As a second example, Figure 8-19 illustrates that the market position of an operator is linked to competition in that market, which is related to existing infrastructure. Therefore, activities in one market segment can have consequences in another, emphasizing the necessity to make investment decisions by considering the holistic impact of the various market factors.

The interactions illustrated by Figure 8-19 are representative of the greater complexity of the relationships among the themes of the study than proposed by the research question framework in Figure 3-1. The difference lies not only in the interaction of other market factors but also in the number of links between the themes. This emphasizes the value of an empirically-based study such as the current one.

Figure 8-19 also reveals that two entities – the regulator and the government - contribute to the development of next-generation broadband. In a direct relationship, regulation influences the profitability of NGA investment. The government, too, influences the profitability of NGA investment, but also impacts on the availability of broadband, societal development and investment in NGA. As these institutions can be exploited to accelerate the deployment of next-generation broadband, their link to investment is worth exploring. This importance of this finding will be outlined in Chapter 9.

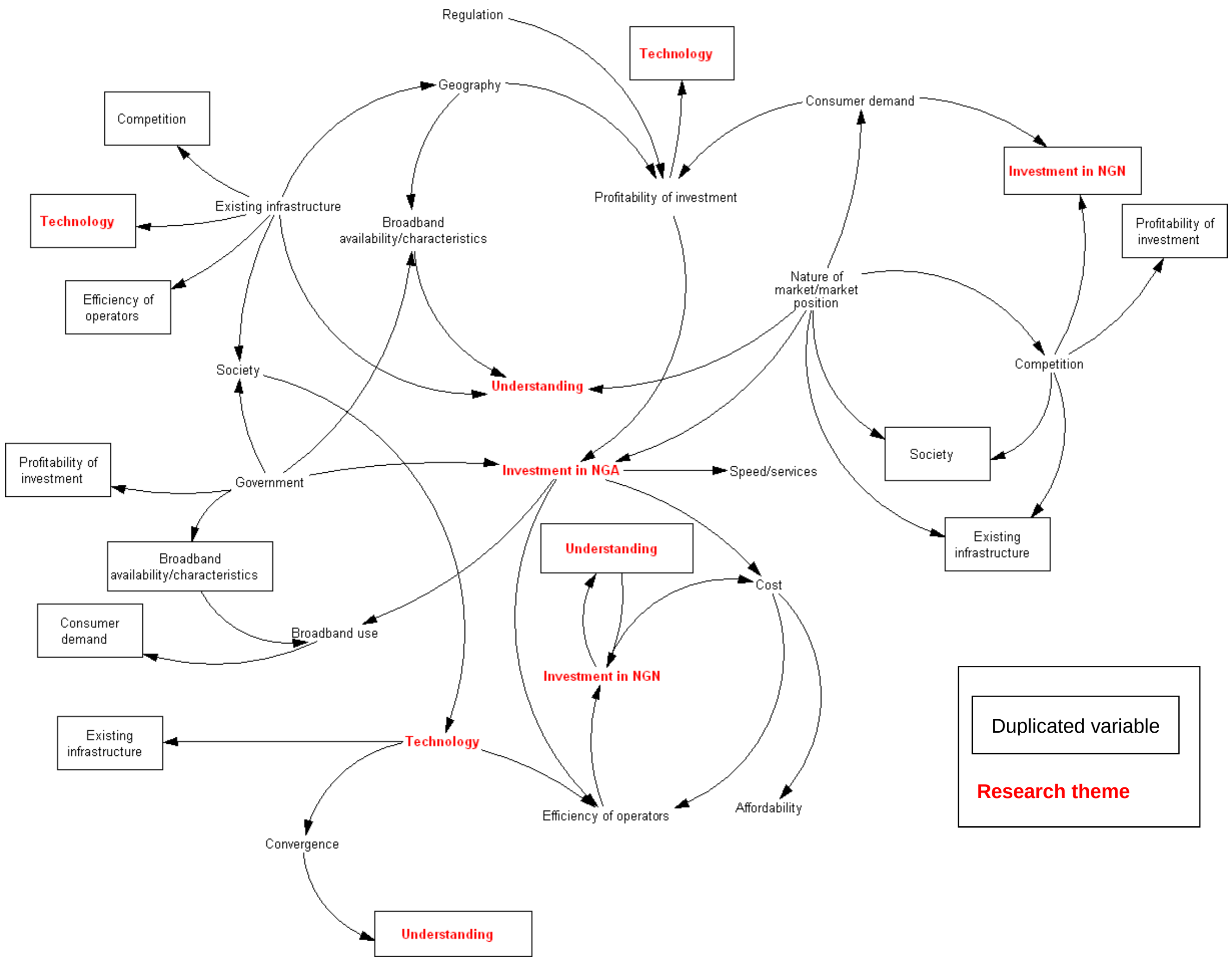


Figure 8-19: High-level relationships among market factors

8.7 Conclusion

The cross-case analysis presented in this chapter thoroughly explored the relationships between market factors and the development of next-generation broadband that emerged from the three case studies under the five themes targeted by the research. By examining the similarities and differences among the three countries and understanding the underlying factors, both detailed and high level representations of the influences towards next-generation broadband development were developed in the form of causal maps. These maps not only revealed the complexity of the next-generation broadband investment situation but were also valuable in disclosing substantial relationships and interactions among market variables and in highlighting areas of intervention in order to accelerate the development of next-generation networks.

Overall, a wealth of factors influences the considerations for the deployment of next-generation broadband, among which immense interactions exist and which creates, in turn, a very complex and intertwined next-generation broadband sector. The source of this complexity is advances in technology. As a result of the complexity of the relationships, the combined influence of a variety of factors must be considered when determining the impact of the market on the development of NGN and NGA.

The interactions also show that several reinforcing relationships exist – between infrastructure competition and investment by national operators and the use of fibre, and between investment in NGN and the efficiencies of operators. These relationships highlight the importance of infrastructure competition in sustaining investment in and use of NGA, but also reveal that policy enforcements may be required to sustain investment in NGN. The relationships also emphasize the need for national operators to invest in next-generation broadband infrastructure.

Two investment cycles, for NGN and NGA, were also identified and examined. The cycles show that the main driver for NGN is an advancement of technology or the use of IP while that for NGA is difficult to pinpoint, as a wider variety of market factors influence NGA investment. The cycles also reveal that investment in NGA is sustainable through increased use, demand, higher quality and profitability, for example. On the other hand, NGN investment is primarily unsustainable, constrained by operators' efficiency and lack of support for legacy network equipment. Market competition, however, can possibly counter these influences. As a result of the cyclic relationships, both NGN and NGA investment are considered to be temporal in nature. Finally, it was observed that institutional influences are important. In particular, governments and regulators can accelerate next-generation broadband development.

A micro-examination of the market influences on the development of next-generation broadband was also conducted. In relation to the first theme of the study, market factors play an important role in directing the focus and understanding of next-generation broadband within the telecommunications sector. In general, factors such as existing infrastructure, the nature of the market players and market activities such as convergence, competition and broadband availability were influential in defining NGN and NGA. However, the definition of NGN, from a technical perspective, was standard across all three markets. While a greater understanding of NGN was evident in the UK than in the other two countries, influenced by BT's old network and international operations, this market was also the most uncertain in the definition of NGA because of diverse broadband availability across the country.

Investment, too, was very much shaped by market factors. NGN investment was primarily supply-driven in the three countries but the underlying factors varied. Generally, as a result of the condition of their existing core infrastructures, the Dutch and Swedish operators adopted a more reactive approach to NGN investment while the British operators were proactive in this regard. In the NGA domain, an overlap of influential factors was evident – competition, the desire to enhance the socio-economic status of the country, consumer demand, regulation and geography, for example – but the details and conditions were different. For example, geographical features facilitated investment in The Netherlands but deterred investment in the UK. The crucial role of infrastructure competition became evident in the NGA investment discussion. Such competition proved to be important in encouraging sustaining investment by national operators. Additionally, regulation was identified as a facilitator but not a primary driver of investment.

In the technological domain, a relation between the factors influencing investment in NGA and the choice of optical fibre was noticed. Fibre was the preferred choice for NGA deployment in the three countries, mainly because of competition and its technical advantages. Notwithstanding, the question of profitability always underlay the investment decision for fibre. As a result of other driving factors in The Netherlands and Sweden (such as competition, consumer demand and government intervention), however, profitability was less of an issue for operators in these two markets than it was for the British. Across all three markets, consumer services were not drivers for fibre investment, highlighting the continued uncertainty that exists in this domain. The factors influencing the use of wireless technologies were standard – geographical terrain, cost of deployment, population density, and so on – and these technologies, therefore, are used in specific, geographically targeted areas.

In terms of benefits, NGN was largely expected to benefit the network operator, with the poor quality and performance of existing core infrastructure driving this expectation. The benefits expected with NGA are linked to market conditions and the perception of NGA in the given market. For example, with the strong infrastructure competition in The Netherlands, the broadband market players expect that competition will continue to drive the market, among other societal benefits. There was still, however, an uncertain link between investment and service benefits.

As an overview, the discussions demonstrate that, in general, priorities and activities in the development of next-generation broadband are, indeed, linked to market factors. However, market factors have a greater impact on the development of NGA than it does on the development of NGN. As a result of the interactions among them, the market conditions and variables cannot be considered in isolation. It is possible, for example, that two countries with similar consumer demand can have different investments in/approaches to NGA roll-out, as other variations can contribute to the decision and create different results. Therefore, an overall understanding of how the variety of variables in a market together influence the deployment of next-generation broadband deployment is more important than understanding the individual impacts of the market factors.

9 Conclusion

9.1 Introduction

Recognizing a lack of published empirical evidence identifying market variables and their influence on the development of next-generation broadband, this research provides a comparative analysis of the supply-side development of these networks. The study set out to answer the more specific research question of 'how do market factors influence the development of next-generation broadband?', guided by the decisions of investment and the choice of access technology. In doing so, four key themes related to deployment - understanding, benefits, investment and technological choice - were addressed.

By undertaking a case study strategy that investigated and compared the market conditions and development trends in The Netherlands, Sweden and the UK, several key relationships were identified. These are summarized in Section 9.2. Section 9.3 highlights the value added by the key findings, both theoretically and practically. In Section 9.4, the limitations of the study are described. Based on these constraints and other emergent theories, Section 9.5 discusses further research to build on this study. Section 9.5 concludes with a brief summary.

9.2 Key findings

Five research questions were explored in this study. The first examined the relationship between market factors and stakeholders' definition of next-generation broadband. This investigation revealed that market conditions dictate the focus for operators, that is NGN or NGA, and that market factors influence the perception of NGA more than that of NGN. Technically, NGN was defined in the same way across all three countries. The second research question focused on investment. While NGN investment was, in most part, supply-driven in the three markets, a mix of supply and demand factors was observed to influence NGA investment, many of which (such as geography) can influence the decision either positively or negatively depending on the status quo of the market factor. The role of infrastructure competition was found to be significant in the investment decision. Additionally, regulation was identified as a facilitator of investment but not a primary driver.

The third research question examined the impact of market factors on technological choice. The view that NGA and optical fibre were synonymous was common. Profitability, and not end-user services, was the key factor in the technology decision. The fourth research question, which investigated the link between market factors and perceived benefits, revealed that NGN benefits were generally associated with the network operator while NGA benefits were more varied and closely dependent on market conditions. Though many societal benefits were expected with NGA, service benefits were uncertain.

The final research question analyzed the interaction of market factors and showed that market influences cannot be considered in isolation when making an investment decision. Several key relationships, highlighting the importance of infrastructure competition and investment by national operators in NGA development in the first instance and policy requirements in creating a sustainable competitive NGN market in the second, were identified. While the main driver for NGN was identified as technological advancements, that for NGA was more challenging to specify. The relationships also disclosed that NGN investment can be leveled because of its link to operators' efficiencies and vendor support, while NGA investment can persist due to factors such as competition and demand. Finally, the role of institutions such as governments and regulators was seen to be important in developing next-generation broadband.

9.3 Research contributions

This research provides a valuable contribution for both theoretical researchers and academics and telecommunications practitioners. In the theoretical realm, several unique contributions can be identified. On a very basic level, the research adds to the existing literature on next-generation broadband. This is evident in three forms. Firstly, the study supports and augments the existing literature that proclaims a relationship between market factors and investment in NGN and NGA, such as those propounded by Cave et al. (2006), Alleman and Rappoport (2007), Soria and

Hernández-Gil (2010) and Ruhle and Reichl (2009). It builds on this literature via empirical substantiation.

Secondly, and a more novel contribution, the research addresses a gap in the literature with specific reference to the empirical relationships between market conditions and investment. This addresses the concern raised in Chapter 3, namely that existing literature focuses on the relationship between regulation and investment. This research highlights and details the causalities that exist between, firstly, market factors and the decision to invest in next-generation broadband networks and, secondly, between market factors and the choice of technology. The study also identifies and explains the link between markets conditions and stakeholders' perceptions of the meaning and benefits of next-generation broadband. These specific relationships, based on empirical data, are currently lacking in next-generation broadband literature.

Thirdly, the research adopts a systematic methodology in arriving at its conclusions. The research methodology, described in Chapter 4, is a robust, structured and formal approach to answering the research questions. The methodology includes the adoption of qualitative analysis software to strengthen the quality of the analysis and hence the results, the use of cognitive maps to identify key themes and the use of causal maps to collate the relationships between and interactions of the various market factors. This approach is unique in this particular area of study.

Finally, the research raises questions regarding the incentives for investment in next-generation broadband networks. By further exploring these issues, the theory produced by this research, as well as more generic next-generation broadband theory, can be further enhanced. This is explained in Section 9.5.

On a practical level, the relationships identified are a means by which network operators, policymakers and other investors can inform their own investment decisions. The causal relations reveal the factors that can promote, deter and otherwise influence the investment in NGN and NGA and the choice of technology. As these findings are based on empirical data, practitioners can be confident of their viability in real-world situations and environments. While it is true that the findings are not meant to be generalized, they do aim to provide guidelines by which investment decisions can be made. Given the timely nature of this topic, these findings are expected to be of particularly valuable use within the telecommunications industry.

In all the contributions, it is important to bear in mind that a temporal element exists, due to the dynamic nature of the next-generation broadband industry, as explained in Section 1.2. The study was conducted between 2008 and 2010 and, therefore, by the time of publication, several changes may have occurred within the three countries. Although the adverse impact of this was lessened by abstractly examining the underlying relationships, it is still suggested that the status of the markets at the time of data collection be taken into account when considering the research findings. The transient characteristic of the industry and the nature of the research make this temporal link an inevitable one.

9.4 Limitations

Despite the value of the research contributions described in the previous section, several limitations of the study must be acknowledged. The first of these is that the quantity of case studies is limited. As the study was a time-constrained one, required the case studies to be examined in sufficient detail and based on face-to-face interviews, a constraint was placed on the number of countries that could be included. The number of countries was further limited by the requirement for an adequately advanced status of NGN and/or NGA deployment, so that data would be available and effective comparisons drawn. Since next-generation broadband is a fairly recent development in telecommunications, the number of (feasible) countries that satisfied this criterion was small. The implication of this limitation is that the results are not generalizable but, instead, geographically limited to the cases examined herein and to countries of similar characteristics, such as other European states.

The recent nature of next-generation broadband also limited the data that could be collected to qualitative data. Quantitative data such as complete penetration rates of next-generation access technologies would be useful to compare the influence of markets on the deployment of technology, for example. However, such data was unavailable.

Finally, data constraints were also imposed by the inability to gain access to several key members of the telecommunications markets being examined. This was particularly applicable to Sweden, where the incumbent and alternative operators were unwilling to participate in the study. While this may have resulted, to some extent, in an incomplete picture of the development of NGN and NGA, the collected data and results were corroborated with other participants and published work to ensure that the insights acquired were generally representative of the Swedish market.

9.5 Further research

This research can be deemed successful in meeting its objectives and, more importantly, valuable in its theoretical and practical results. However, in addition to the limitations described above, several areas in which the value of the study can be extended have emerged during the research process. The recommendations for further work in these areas are described below.

The current study focused on examining the influence of market factors on the development of next-generation broadband from a holistic perspective. Conducting this research using an embedded case study approach, based on different types of stakeholders, might provide another dimension of insight to the findings obtained. For example, the influence of market factors can be dependent on the market position of the investor – incumbent, alternative operator or new entrant.

Linked to an embedded case study is the consideration that a greater coverage of the market-investment analysis can be achieved by including a wider portfolio of participants in the study. For example, input from equipment vendors and operators, particularly in cases where their input was unavailable in this study, can be useful. As next-generation broadband markets have changed over time, this inclusion of a wider range of participants can be valuable to gaining new insight.

Secondly, a quantitative element can be added to a future study, the merit of which was explained in Section 9.4. This will complement the findings of the current study. Thirdly, the number of case studies can be expanded. For example, other European countries can analyzed in order to examine the generalizability of the results or, alternatively, a selection of case studies from a different region can be assessed and compared to the European case.

Finally, this research provides a foundation that can be built on to complement other existing and upcoming research. Primarily policy discussions, such research areas include the debate on public intervention as presented by Given (2010), Nucciarelli et al. (2010) and Gómez-Barroso and Perez-Martinez (2005), the relevance and extension of the public-private interplay within NGA and the notion of agenda-setting as examined by Kingdon (1995). The discussion of public intervention by Given (2010) and others is linked to the current study through the mutual examination of the barriers and incentives for next-generation broadband investment in markets. By carefully examining the obstacles and drivers for investment and conducting a cross-case analysis, the need for intervention and the suitability of various incentives can be determined. This has been done to some extent in Ragoobar et al. (2011b).

The idea of agenda-setting is based on the involvement of the regulator and the government in the development of next-generation broadband as highlighted in Chapter 8. That chapter revealed that the regulator and the government play a key role in encouraging infrastructure investment. As such, the variations in investment observed across the markets can be linked to the different priorities of these policymakers. Following Kingdon's theory, it is evident that the influences of the market would have determined the main concerns for the policymakers (Kingdon, 1995). Therefore, by applying Kingdon's framework of agenda-setting to the three case studies in this research, an understanding of the issues and policies that are likely to evolve for the government and regulator, and how these can evolve, can be gained. By doing so, a constructive attempt at removing the barriers for investment in next-generation broadband in slower markets and, consequently, leveling the global broadband status can be made.

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Appendices

An accompanying CD contains the Appendices for this thesis. Below is the Table of Contents, for reference purposes.

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