"Next Generation Networks" and Challenges for Future Competition and Regulatory Policy

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Zusammenfassung

Es gibt fundamentale Unterschiede zwischen traditionellen PSTN/ISDN Netzen und Next Generation Networks (NGNs). NGNs basieren auf einem paketvermittelnden Netz und verarbeiten Sprach-, Daten und Videoverkehr gleichzeitig. In solch einem Netz sind die Transport- und Kontrollfunktionen getrennt, die Netzfunktionen sind dezentral angesiedelt, die Intelligenz liegt mehr und mehr in Endgeräten und Standards sind offen. NGNs werden vermutlich auf einer Schichtenstruktur bestehend aus vier Schichten beruhen. Die starke Disaggregierung von NGNs ermöglicht eine weitgehende Spezialisierung von Marktteilnehmern auf verschiedene funktionale Bereiche der Bereitstellung von Diensten und Applikationen. Insbesondere kann ein Wettbewerber eigene Dienste und Applikationen unabhängig vom Transportnetz spezifizieren. Darüber hinaus können Dienste durch Endnutzer kreiert werden. Dies führt im Ergebnis zu einer Multi-Schichten, Multi-Netzbetreiber und Multi-Service Provider Welt.

NGNs werden zu einer Verwischung von traditionellen PSTN/ISDN Konzepten wie Funktionsherrschaft über Netz(bestandteil)e sowie das Betreiben eines Netzes führen. Die Kontrolle über ein Netz wird sich nicht länger direkt an physikalischen Netzbestandteilen festmachen lassen, sondern a-priori wird es ein breites Spektrum von zulässigen dienste- bzw. netzbezogenen Zusammenschaltungspunkten geben und Service Provider werden zumindest konzeptionell Zugang zu Funktionen der Kontroll- und Nutzerebene sowie zu Netzmanagementfunktionen benötigen. Aufgrund ihrer Dezentralisierung werden NGNs aller Wahrscheinlichkeit nach die Abgrenzung neuer TK-Märkte erfordern. Darüber hinaus können neue Möglichkeiten und Anreize für vertikale Integration eine viel differenziertere Art und Weise der Definition und Bewertung der missbräuchlichen Ausnutzung einer Marktstellung als heute sowie wirtschaftspolitische Maßnahmen gegen sie erfordern. Einmal abgesehen vom tatsächlichen Bestehen von "essential facilities", wird die Entbündelung in einer NGN-Umgebung eine Reihe von neuen Herausforderungen mit sich bringen. Die starke Disaggregierung von NGNs macht die Aufgabe der Sicherstellung der Netzintegrität sehr komplex. Darüber hinaus wird zumindest die Migration zu NGNs absehbar durch herstellerspezifische Dienste- und Netzarchitekturmerkmale charakterisiert werden. Zusammen mit der Dynamik des technischen Fortschritts und in der Folge viel kürzeren Produktlebenszyklen als in der PSTN Welt ist daher der Raum für regulatorische Eingriffsmöglichkeiten mit Blick auf Entbündelung in NGNs beschränkt, wenn Regulierung technologieneutral sein soll. Zusätzlich wird potenziell die Zahl der in einen regulatorischen Entbündelungsfall involvierten Wirtschaftseinheiten zunehmen.

Wenn keine marktbeherrschende Stellung vorliegt sehen wir keine Notwendigkeit für Zusammenschaltungsverpflichtungen bei internationalen oder nationalen (Ende-zu-Ende) IP-basierten Backbones von ISPs. Wettbewerbspolitische bzw. regulatorische Herausforderungen in Folge von Marktbeherrschung mögen sich jedoch ergeben mit Blick auf die Zusammenschaltung zwischen großen nationalen und kleinen regionalen oder lokalen ISPs. Mit Blick auf Interoperabilität sollte die Entwicklung von Normen und Standards zuallererst dem Markt überlassen werden. Regulierung wird jedoch eine bedeutende Aufgabe haben den Prozess der Standardisierung zu organisieren und zu überwachen sowie geeignete Konfliktlösungsmechanismen zu entwickeln.

Summary

There are fundamental differences between traditional PSTN/ISDN and Next Generation Networks (NGNs). NGNs, based on a packet switched network, are capable of handling voice, data and video traffic simultaneously. In this network transport and control functions are separated, the network functions are located decentrally, the intelligence is more and more located in terminal devices and standards are open. NGNs presumably will rest on a layered structure consisting of four layers. The disaggregated nature of NGNs enables increasing specialisation of market participants on distinct functional parts of the provision of services and applications. In particular, a competitor is able to specify own services and applications independent of the transportation network. Moreover, services can be created by the end user. Thus, NGNs will bring about a multi-layer, multi-operator, and multi-service provider environment.

NGNs will lead to a blurring of traditional PSTN/ISDN concepts of ownership and operation of a network. Functional control of a network will no longer be directly linked to physical terminal points of the network. Rather, NGNs will have reference points which not necessarily are physically determined. A-priori there will be a broad spectrum of feasible service-related and network-related points of interconnection. In a fully-fledged NGN environment service providers may at least conceptually need access to control plane functions, user plane functions and management functions.

The more decentralized nature of NGNs in all likelihood requires to define new telecommunications markets. Moreover, new possibilities and incentives for vertical integration might arise calling for a much more differentiated way to define, assess and find remedies against abuse of market power than today. Notwithstanding the actual existence of essential facilities, unbundling in an NGN environment will bring about several challenges. Due to the disaggregated nature of NGNs the issue of ensuring integrity of the network will become more complex. Moreover, (at least migration towards) NGNs foreseeably will be characterised by vendor specific service features and architectural features of the network. Together with the dynamic technological progress generating much shorter product life cycles than in the PSTN world the scope for regulatory intervention regarding unbundling of NGNs is therefore limited provided regulation aims at being technologically neutral. In addition, the number of entities potentially involved in regulatory unbundling cases will increase.

In the absence of a real market dominant position we basically see no need for mandated interconnection regarding international or national (end-to-end) IP-based backbone networks of ISPs. However, market dominance and, thus, competition policy or regulatory concerns might arise regarding IP interconnection between large national ISPs and small regional or local ISPs. Regarding interoperability, development of norms and standards first and foremost should be left to the market. Regulation, however, will have an important task to organise and monitor the process of standard setting and to develop appropriate conflict resolution mechanisms.

1   Introduction

Historically, telecommunications networks have been deployed to carry voice traffic, i.e. their architectures were optimised for handling the stochastic nature of PSTN traffic on a circuit switched basis. Since the cost pressure of competition takes place the networks developed towards digital transmission and switching and with this the networks became more universal. Since about a decade all carriers in the developed world can therefore observe a surge of data traffic conveyed by means of a packet switched technology. Today it is no longer that voice (or to put in more general terms narrowband bi-directional real-time transmission) determines the network infrastructures but data transmission resting increasingly on e.g. the IP protocol. Based on the volumes transported it is foreseeable that data traffic will become prevalent.

Up until today the regulatory policy and measures relating to providers of telecommunications services are virtually based on the architectural and topological characteristics of circuit switched networks. The provision of data transmission services resting on packet switched technologies, however, is not an issue of primary concern of regulatory policy. Due to technological developments the clear separation of circuit switched and packet switched networks and services provided via these networks becomes, however, more and more obsolete. It is fair to say that a shift of existing telecommunications networks towards "Next Generation Networks (NGNs)" is already underway.

Generally speaking, an NGN is to carry all traffic previously carried by original PSTN networks using digital and packet switched as the basic technology. At the same time, it is combined with broadband (e.g. IP) technology to add a number of multimedia services and innovative applications.

There are different objectives of the paper. We are aiming at analysing

- the essential building blocks of NGNs,

- the main implications of NGNs for business strategies in and the structure of the market for the provision of communications services, and

- the challenges for future competition policy and regulation, respectively, in (tele)communications markets thereby concentrating in particular on network access, interconnection and unbundling issues.

Some remarks concerning the methodological approach of this paper might be useful. Firstly, the analysis of this paper takes on a "long-term" perspective, however, no specific time horizon can be given. Secondly, the technical part of the paper can best be described as outlining a "scenario" of potential developments of communications network technologies. However, it is neither based on forecasts in a statistical sense nor on a scenario analysis as such. Rather, the basic information has been collected on

the one hand by desk research of relevant literature and web sites of manufacturers and operators. On the other hand a lot of personal interviews have been conducted with manufacturers, operators and experts from universities and research institutes etc. alike[1]. Thirdly, we are not focusing on actual long-term implementation plans of carriers, although we try to highlight observable technical developments currently underway regarding telecommunications networks. Fourthly, regarding the competition and regulatory policy issues the analysis is not aiming at providing definite answers. Rather, the main objective is to identify foreseeable potential items on the future agenda and to illuminate different approaches to deal with them.

The present paper is a substantially enlarged version of a paper presented at the EuroCPR 2003 Conference in Barcelona, see Elixmann and Schimmel (2003). The work on the topics of the present paper has benefited very much from research projects conducted by WIK on "The economics of IP backbone services" and on "Next Generation Networks" as well as from a workshop titled "Network access and interconnection in IP based networks" organized by WIK and RegTP in October 2002.

The paper is organised as follows. Chapter 2 contains an outline of characteristics of traditional voice telephony networks. In chapter 3 we are focusing on characteristic features of NGNs. Chapter 4 is devoted to illuminate actual solutions to get inter-operability of circuit-switched and packet-switched networks in NGNs. In chapter 5 we are dealing with NGNs and their implications for provision of services and applications. In Chapter 6 directions of current deployment of NGN architectures are presented. Chapter 7 contains an outline of current ITU work on issues regarding the actual implementation of NGNs. The technical details of our analysis are mainly contained in chapters 2.1, 3, 4, and 7. In order to understand the main economic implications of NGNs the reader is referred to chapters 2.2 and 5. Chapter 8 analyses challenges for telecommunications policy and regulation. This chapter rests both on technical and economic arguments. In Chapter 9 we present our conclusions.

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[1] Special thanks go to Reza Tardayoni who was the discussant of the paper and to the participants of the session at EuroCPR 2003. We have benefited very much from their comments and we have enjoyed the very stimulating discussions at the Conference. During the preparation of the present study a lot of people helped us in getting deeper into the subject and we would like to express our sincere gratitude to them. It is not possible to name them all. Special thanks go to Volker Gebauer from the Regulatory Agency for Telecommunications and Posts (RegTP) in Germany who has carefully read an earlier version of this paper and has made a lot of valuable comments and suggestions. Of course, the usual disclaimer applies.

2   Characteristics of traditional voice telephony networks

2.1   Technical details

To characterise voice telephony networks we are concentrating on ISDN networks. A basic rate ISDN access line (at least in Europe) offers two 64 Kbit/s transport channels (B-channels) which build the basis for the exchange of voice traffic[2]. The network is circuit switched, i.e. a connection between two subscribers is established as a permanent end-to-end channel the bandwidth of which can be used exclusively by the two subscribers during the entire period of utilisation. Of course, it is not a single physical wire establishing the circuit, rather, it is a virtual circuit running from the sender to the receiver[3].

A traditional telephony network mainly consists of a

- transport layer and a

- control or signalling layer.

The transport layer is responsible for the physical conveyance of voice between two subscribers encompassing essentially the switches and the links between the switches, i.e. the transmission lines. Regarding the ISDN control layer one can distinguish signalling in the local loop and signalling between switches. The exchange of signalling information between terminal equipment and the end office switch occurs via the so called D-channel (protocol) offering a bandwidth of 16 Kbit/s. The conveyance of signalling information as well as that of the actual voice information is digital[4]. Based on the ISDN technology, there are a multitude of service features like call forwarding, call waiting or call blocking which are (de)activated by the subscriber and which also require signalling processes. The exchange of signalling information between switches, i.e. within the core network, is based on the Signalling System No. 7 (SS7). Albeit also consisting of 64 Kbit/s per channel bandwidth the control functions of a SS7 network are conveyed on a network entirely different from that used to carry the actual voice calls.

SS7 plays a significant role with respect to the availability of all subscribers in the world who are hooked upon the telephony network. SS7 is a worldwide, industry-wide standard. Otherwise stated, worldwide public telephony via the national and international telephony networks of the different carriers in the world rests on linking

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[2] Needless to say that ISDN is capable of transporting not only voice traffic but also text, data and images.

[3] Roughly speaking, the dedicated circuit is opened by the operator serving the originating party and the circuit is used both for sending information to the recipient and for retrieval of the terminating customer's response.

[4] Signalling information conveyed via the D channel are e.g. subscriber A lifts the receiver, subscriber A dials the number of subscriber B, subscriber B lifts receiver or subscriber B hangs up.

both the channels in which the voice is conveyed and the channels in which signalling information is conveyed. In addition SS7 is important for Intelligent Network (IN) service offerings[5].

The SS7 network is a packet network that connects switches with so called Service Control Points (SCPs). These SCPs contain databases that contain programs that provide advanced telephony features like e.g call waiting, call forwarding, caller ID, 800 numbers etc. Each SCP can support calls from multiple end-office switches, i.e. the number of SCPs in the network is much lower than that of actual switches. Actual SS7 messages are switched through Signal Transfer Points (STPs) which are the packet switches (i.e. the routers) for the SS7 network[6].

Figure 2-1 gives a simplistic overview of the main network components of the transport and control layer of a traditional telephony network.

Two examples might help to understand the interworking of transport and control layer as well as the tasks of the STP, SCP and function manager.

The first example focuses on the provision of voice services without any further call feature. Let's assume that subscriber A is calling subscriber B. In this case there are virtually three steps to be performed: call setup, call connection and tearing down of the call[7]. Call setup means that subscriber A sends a terminal related name (i.e. the number of subscriber B)[8] to the network. The network is then looking for a link to connect the partners and reserves it. In the case that subscriber B's telephone line is not busy he or she is called, i.e. subscriber B's telephone is ringing. If subscriber B lifts the receiver the voice channel will be established, i.e. the actual conveyance of voice information can begin. Tearing down of the call can be initiated by each subscriber by hanging up. If subscriber B's telephone line is busy the end office switch from subscriber A sends a pre-defined acoustic sign to subscriber A. In this case only signalling operations and signalling transport have taken place, i.e. no physical channel to transport voice (payload) has been established.

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5 IN services are e.g. Freephone, Televoting, Calling Cards, Premium Rate services etc. A description of a great number of IN services can be found in Siegmund (1999b, pp. 147).

6 See Denton (1999).

7 We are concentrating here on a non-technical description. Actually the three steps consist of the exchange of a great deal of signalling information between the terminal devices involved and the network nodes as well as between the network nodes; see Haaß (1997, pp. 393) and Siegmund (1999, pp. 489).

8 In this paper we are not going into the very details of the terms numbers, names and addresses. Well known are telephone numbers (the e.164 numbering plan), the domain name service system and the IP addresses resting on the IPv4 protocol and consisting of a 32-bit code. Engineers usually are using the term address to focus on the act of physically approaching a target and the terms number and name, respectively, to focus on the actual target itself.

Figure 2-1:   Main network elements of a telephony network and their interaction
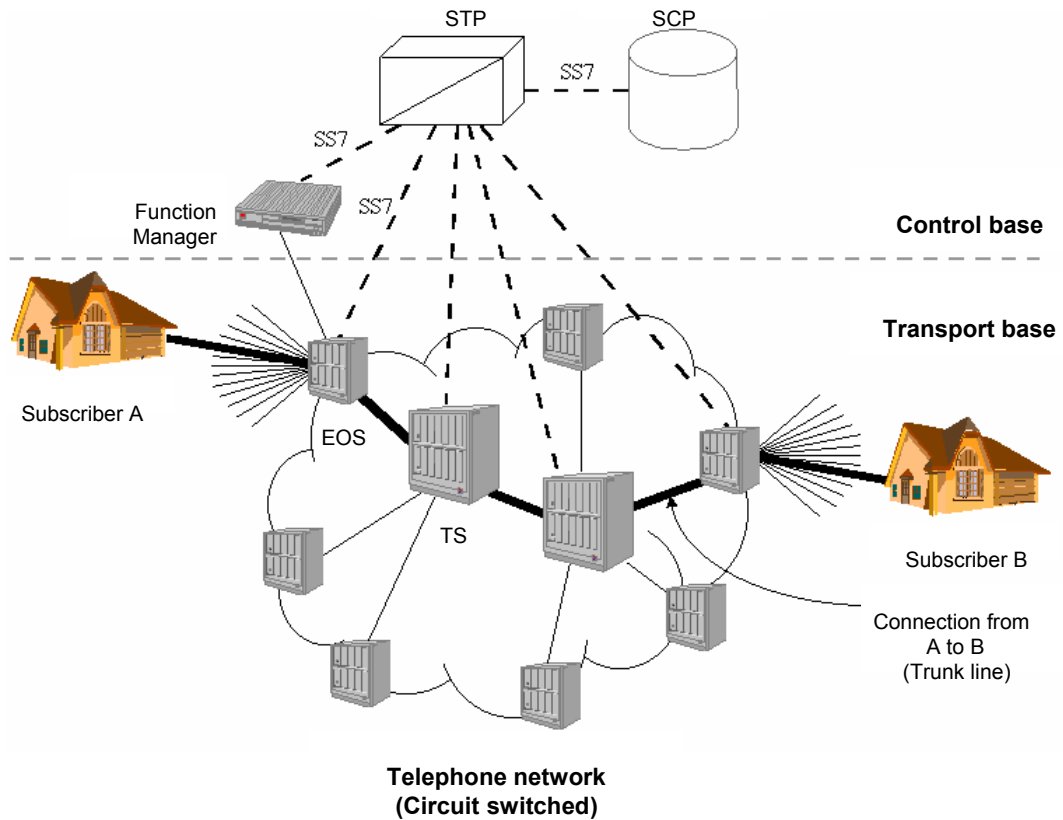
STP:	Signal Transfer Point	SCP:	Service Control Point
EOS:	Class 5 End Office Switch	TS:	Class 4 Tandem Switch

Source: based on Denton (1999, p. 11)

The second example is more complex in the sense that we take account of an additional service feature[9]. We assume that subscriber B is informed about each incoming call irrespective of whether his or her line is busy or not (call waiting). Thus, if subscriber B is calling and if he or she receives the respective information about another call waiting subscriber B can interrupt the call, hang up or can forward the incoming call to another access line. After subscriber A has lifted the receiver and he or she has dialled the number of subscriber B the call is processed at first as usual, i.e. as it has been described above. If subscriber B's access line is busy, the specific SSP supporting this connection receives a message that subscriber B is not available. The SSP in turn contacts the SCP, i.e. he initiates an IN-query. The respective SS7 messages are switched from the STPs to the SCP. The SCP then instructs the SSP to

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9 See Denton (1999, section 1.3) and Siegmund (1999a, p. 628-629).

convey a message "Call Waiting" to the end office switch of subscriber B which in turn is signalling subscriber B that there is a call waiting. Subscriber A now receives an acoustic signal like in an usual call if subscriber B were not busy. If subscriber B accepts the incoming call the respective connection (channel) is established. If he or she does not accept the call the end office switch of subscriber B sends a respective message to the SSP. After informing "his" SCP the latter could e.g. provide an alternative target, i.e. the number of a subscriber C to which the call is forwarded. However, if subscriber B does not answer after a pre-defined number of rings it could also be the case that via SS7 a Function Manager is activated starting an announcement like "The customer you have dialled does not answer. If you would like to leave a message please press 1"[10].

It is by no means necessary that each ISDN call feature requires the involvement of IN components, in particular of the SCP. The latter example, however, clarifies that there might be ISDN service features not contained as a basic feature, rather, priced as an add-on service, thus, requiring a query to the SCP.

2.2   Implications of circuit switched networks

We have seen so far that circuit switched ISDN communication rests on the transmission of bi-directional real-time communication and signalling information in different networks, however, characterised by a specific interplay of the transport and the control layer. The physical transport of the voice information, thus, is inevitably linked to the transport of signalling information. Moreover, the circuit switched telephone system is driven by intelligence *within* the network and not provided by the user's terminal devices[11].

This implies in particular that end users generally have no possibility to specify preferences regarding the handling of each distinct call. Rather, customers can only subscribe to call features at large, not on the basis of single calls[12].

Sinnreich and Johnston are summing up the most important architectural features of circuit switched networks as follows[13]:

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[10] Thus, the function manager is an intelligent peripheral that provides services such as computerised voice and voice mail.

[11] See Denton (1999, section 1.4) and Sinnreich and Johnston (2001, p. 34).

[12] The reason is that the terminal devices are not the location where intelligence is stored. A central storage and administration of user preferences would, however, generate severe scaling challenges. To quote Sinnreich und Johnston: "It is more difficult to store a page full of user preferences for millions of users in central servers of the IN in the PSTN and also have the data changed by users on a dynamic basis as compared to having such data and access to it be handled at the periphery of the network"; see Sinnreich and Johnston (2001, p. 103).

[13] See Sinnreich and Johnston (2001, pp. 33).

- Standards focusing on interfaces between user and network (user-to-network interface, UNI) and between different networks (network-to-network interface, NNI).

- Central control, i.e. control for setting up the paths across the different networks that might be involved in a communication link between two users is exerted centrally in each network[14]. Otherwise stated, the operation of the transport and signalling network is performed by a single entity and only this entity can define service features[15].

- The provision of services has to be supported by respective features across all interfaces (NNIs and UNIs) as well as in all central control units.

- The provision of new services requires the support of new standards in all interfaces (UNIs and NNIs) as well as in all central control units.

To cut a long story short one can quote Denton: "The functions that may be added to the network are

a) defined by the owners of the network and

b) limited by the nature of the network",

and further on: "...the telephone company's value proposition is governed by the simple idea that services are added to the network's repertoire *exclusively* (italics by Denton) by the telephone company"[16].

For end users this means that they virtually have no control over the selection of applications and services. Rather, they have to rely on the applications and services provided by their telecommunications operator[17]. Likewise, competitors of a network operator have only limited scope to define own services and introduce them to the market. The provision of a service always requires access to the signalling network controlling the access to the infrastructure. Otherwise stated, competitors can establish activities regarding development and provision of new services only in the frame set by the telephony network operator.

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14 This holds true e.g. with respect to the Intelligent Network capabilities in each network. Usually there are only a few SCPs installed in a network.
15 This is not totally correct with respect to IN services because in this case service providers to some extent can influence service specifications on the basis of specified interfaces.
16 See Denton (1999, section 1.4).
17 See Sinnreich and Johnston (2001, p. 34).

3   Characteristic features of NGNs

The present chapter firstly introduces the basic components of the architecture of NGNs and their functions. Secondly, we will highlight a layered model in which the elements of a NGN are interworking. Thirdly, the issue of the development of the local exchange network architecture in the next 15 years or so is addressed.

3.1   A NGN reference model

The term "Next Generation Network" does not define a unique future network architecture, rather there are several alternative approaches differing e.g. with respect to the time horizon, the organisation backing a specific approach and vendor specific solutions differing in one or the other component of a NGN[18]. Organisations currently working on NGNs are e.g. the European Institute for Research and Strategic Studies in Telecommunications (EURESCOM), the ITU and ETSI[19].

3.1.1   The EURESCOM approach

To give an overview of the main components defining an NGN we rely on EURESCOM (2001a,b). These studies analyze NGNs on a highly abstract level which allows a clear characterization of the essential elements of future networks and their functions (NGN reference architecture). Figure 3-1 gives an overview of the main building blocks of a NGN.

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18 Apart from the term "Next Generation Network" one can often find the term "Next Generation Internet (NGI)" and "Internet 2". Also NGI is used in different senses. On the one hand there are the NGI initiatives focusing mainly on providing high-speed network infrastructures to enable IP-based communication between universities, research institutes and the like, see e.g. Arlandis (2001) and Engebretson (2002b). These scientific networks also serve as testbeds for future technologies and applications like e.g. IPv6, multicast or QoS. Examples of these networks are G-WIN in Germany, GigaPort in the Netherlands, SWITCHng in Switzerland, Géant in Europe, Abilene in the U.S. and the Next Generation Internet initiative of the US Government. Relevant aspects on Geant, the Next Generation Internet initiative and Internet 2 can be found in Botterman et al. (2001). Schaffers and de Wit (2002) focus on initiatives in four countries (USA, Canada, Singapore, Netherlands) and concentrate their analysis in particular on the role of the government on stimulating innovation. On the other hand the term NGI is used in a much broader sense as "over the horizon Internet and related developments and directions", see Rutkowski (2000, p. 469) and the other articles in the special issue of Telecommunications Policy, vol. 24, No.6/7, July/August 2000.

19 As we are not focusing on actual standardization issues in this paper we concentrate on work done by EURESCOM and the ITU in this paper. Regarding ETSI's work on NGNs see www.etsi.org and search for "NGN". A good overview of NGN issues discussed from an ETSI perspective can be found in the papers presented at the recent NGN workshop held in Budapest in June 2003. These papers are available at the ETSI web site.

Figure 3-1:   Main building blocks of Next Generation Networks (NGN reference architecture)
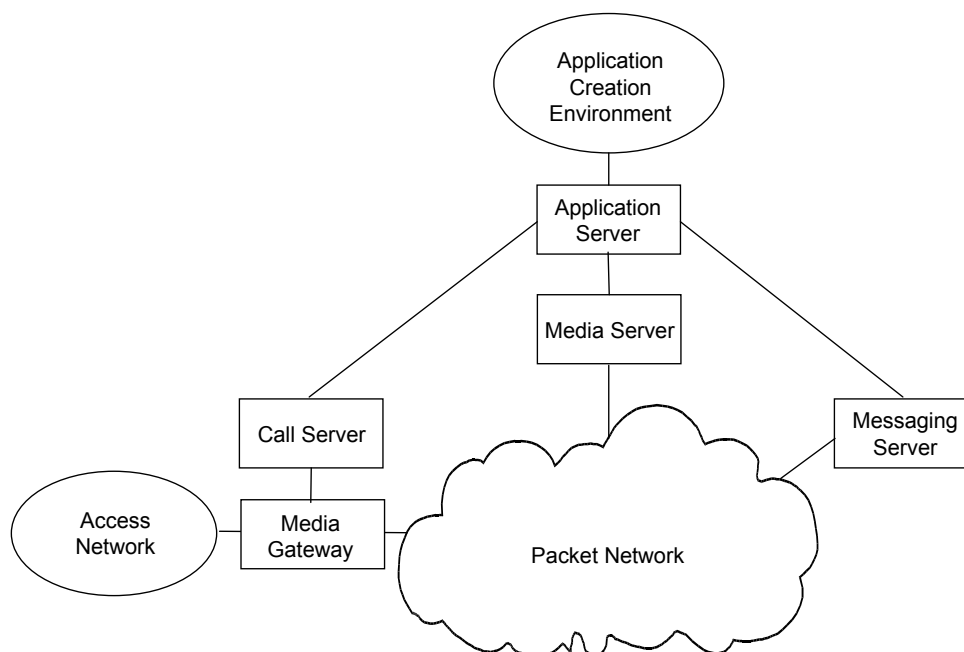
Source: WIK, based on EURESCOM (2001a, p. 17)

Broadly speaking, a NGN can be characterized as a packet network representing a common platform for the transport of voice, data and video. The main functions of the different building blocks will be described subsequently.

Packet network

The packet network contains mainly network elements for data transport and the routing of data packets. They virtually perform the basic functions of packet networks namely the transport of data packets from A to B as it is done today by the Internet. This part of a NGN is not further specified by EURESCOM.

Call Server

The key element of a NGN (apart from the transport function) is the call server which is responsible for signalling and the control of resources in the network. The control functions can be specified as follows:

- Call Control,

- Media Gateway Control and

- Service Control.

The call server is the essential element within a NGN to establish a telephone call. It is managing and controlling the call set-up by signalling protocols (call control). Moreover, the call server communicates with the media gateways to ensure the physical call set-up (media gateway control) and it controls functions being stored on media, message or application servers (service control).

Call control is a very complex task and encompasses according to EURESCOM the following functions:

- Call Routing,

- Call Signalling,

- Third Party Call Set-up,

- Third Party Call Control und CLASS Services.

Call routing means that the signalling information has to be conveyed across the network. To this end directories (addresses and routing tables) are used containing information to handle the steering of a connection. *Call signalling* enables the exchange of signalling information to set up a connection within the network on the basis of signalling protocols. In particular, the call server usually is to support a SS7 signalling gateway to enable the exchange of signalling information between PSTN and packet network. The signalling gateway function either can be an integral part of the call server or it is located on a dedicated signalling gateway platform[20]. Call server moreover can provide functions like e.g. *Third Party Call Control* and *Third Party Call Set-Up.* These functions enable the provision of a multitude of extended call services on the network like e.g. call centre services[21]. And call servers might support different *CLASS services (Custom Local Area Signalling Services)*, providing ISDN-like service features.

In chapter 4 we will present specific architectures like e.g. H.323-, SIP- and Softswitch based architectures. Thus, examples of a call server are the so called H.323 gatekeepers, SIP Proxy Servers and Softswitches (often also called Call Agents or Media Gateway Controller)[22].

Media Gateways

Media gateways physically are located at the interface between different networks. This can mean the interface between the PSTN/ISDN and the packet network or the interface between packet networks which are supported by different protocols. Media gateways are important because of the presence of access networks which are not

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[20] vgl. EURESCOM (2001, S. 38).
[21] See Sinnreich and Johnston (2001, p. 73 and p. 141).
[22] See Uebele and Verhoeyen (2001, p. 85). Obviously, ETSI prefers the term "Media Gateway Controller" and the IETF uses the term "Call Agent".

being based on packet-switched technology. Media gateways, thus, are converting media information flows of one network into those of the other network based on the specific requirements of the latter network. If for example a PSTN access line is connected to a NGN the media gateway provides for the conversion of frequencies into data packets (transcoding).

Media Server

Media servers provide functions enabling an interaction between a caller and an application through telephony devices. Examples are answering a call, playing announcements, or reading an e-mail by using speech synthesis. Media servers, thus, consist of software and hardware responsible for functions like speech recognition, speech synthesis, audio generation as well as conversion of speech to text and vice versa. These functions primarily are required if extended call services are to be provided.

Message Server

Message servers mainly are responsible for the storage of information and to make this information available to different terminal devices. Thus, message servers primarily contain storage capacities. Moreover, they provide functions like e.g. to govern the access of users to the information, to manage the data stored (e.g. a user is informed upon reception of a new message) and to transfer the information (e.g. between different message servers). As in the case of media servers also message server mainly are used to provide extended call services.

Application Server

Application servers primarily are capable of introducing, executing, controlling and managing applications. EURESCOM specifies several functionalities an application server should be able to provide examples of which are:

- Control of network elements performing authentication, authorisation and accounting capabilities for service provision,

- Support for registration,

- Security services (encryption, authentication and authorisation to ensure access to services),

- Support for developing services,

- Communication with other internal or external applications and external network resource control servers (like media server and message server),

- Data base support to store subscriber and service data.

Broadly speaking, application servers contain the intelligence for the provision, execution and management of applications.

Application Creation Environment

The application creation environment is to support the life cycle of an application which is composed of a series of phases. EURESCOM (2001, p. 48) in this context specifies:

- Needs analysis and conception,

- Application creation,

- Acceptance testing,

- Application deployment,

- Application provisioning and operation,

- Application removal.

The application creation environment should provide the tools for addressing the identified activities. The components allowing to create applications are to provide an integrated environment to develop and validate applications to run on an application server.

3.1.2   The ITU approach

The ITU has dealt with the standardization of new generation networks since the mid 1990's in the frame of its Global Information Infrastructure (GII) project, see e.g. ITU (1998, 2000, i.e. the "Y-series")[23].

It is worth to be noted, however, that implementation issues were not in the scope of the GII. The ITU has therefore recently initiated a new project on NGNs (the "NGN 2004 Project") aiming at completing GII recommendations by additional specifications and implementation guidelines, see ITU (2003)[24]. The major task of the project is to "ensure that all elements required for interoperability and network capabilities to support applications globally across NGNs are addressed by ITU-T standardization activities", see ITU (2003, p.1). The ITU, thus, sees its NGN 2004 Project as a realisation of the concepts adopted in the frame of GII, i.e. the guidelines and standards to be developed should be in keeping with existing GII Recommendations and based on GII concepts.

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23 ITU (2000, p. 6) defines the GII to be "a federation of classical telecommunications, broadcast and/or data networks enhanced by IP based capabilities providing additional possibilities to interconnect available communications resources."

24 The ITU has decided to launch this project in 2002. It aims at producing a first set of recommendations on NGNs by the end of the 2001-2004 study period, i.e. by mid-2004.

Characterising NGNs ITU (2003) is mainly focusing on the changes regarding service provision, see chapter 5.

Yet, the ITU has not yet defined its general framework model regarding NGN, rather, it has identified this as one of the main study areas of the NGN 2004 Project[25]. The general framework model is to provide both general architectural principles and models regarding the functional architecture of NGNs. The main objective is to describe a NGN "in terms of control functions that can be abstracted and represented separately from the major areas to be controlled (such as resources, services and transport)" (ITU (2003, p. 3).

3.2 The layered structure of NGNs

Communication in networks usually is described by specifying functions which are performed on different hierarchically ordered layers. The basic OSI-model specifies seven layers[26]. Usually the literature on NGNs as well as the vendor catalogues of NGN products distinguish a four layered model[27]. This is visualised in Figure 3-2.

Figure 3-2: The NGN layered structure
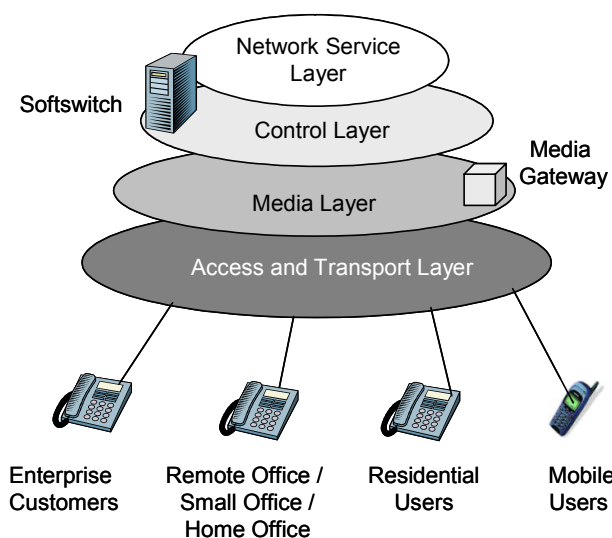
Source: Uebele and Verhoyen (2001)

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[25] See section 7.1 for more information on the NGN 2004 Project.

[26] OSI stands for Open Systems Interconnection and builds the basic frame for data communication, see e.g. Horak and Miller (1997) or Smith and Collins (2002).

[27] It has been pointed out to us that the ITU currently treats it as an open question worth to be discussed further if there is a necessity for a new OSI layer model in the frame of NGNs. Thus, it may very well be the case that according to a new ITU OSI scheme the number of layers of a NGN is greater than four.

The basic layer (Access and Transport Layer) comprises the copper and fiber transmission lines including the respective circuit switched and packet switched transmission devices.

The Media Layer is the layer where media gateways are located to adapt voice or other media from the PSTN/ISDN network to requirements of a packet switched network.

The two lower layers together (i.e. the Transport and Media Layer) enable end-to-end connectivity in the network, i.e. they represent the access to the network and the respective transmission of packets between the communication partners.

The main intelligence regarding control and signalling functions is located within a separate device, e.g. a softswitch, on the Control Layer.

The Network Service Layer, often also called Application Layer, contains devices like e.g. application servers[28], servers performing authentication and authorisation and data bases.

It should be noted that catalogues of vendors sometimes contain a slightly different allocation of functions performed on the two lower layers which carries over to the physical devices located on each layer[29]: In this case the lower layer is called the access layer containing narrowband or broadband IP access networks and particular access gateways. The second layer is called gateway layer and contains the packet core network and the trunking gateways as well as the signalling gateways[30].

Setting up a telephone connection in a NGN environment one basically needs only access to the transport network and the call server. The call server can be located at any location within the network provided there is a packet-based (e.g. IP) connection.

3.3   Development of the local exchange network architecture in a long term perspective

This section addresses the issue of how the local exchange network architecture might develop in a long–term perspective. We concentrate here on work carried out by Technology Futures, see Vanston (2001)[31]. Albeit this research focuses on the telecommunications network development in North America we believe that the basic

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28   Examples are e-commerce applications, education applications, entertainment applications, personal communications applications or teleworking applications.
29   See e.g. catalogues of ZTE and Harbour Networks (both from China but offering products on the world market).
30   With respect to the mentioned gateways the reader is also referred to section 4.4.
31   The report we refer to has been produced by Technology Futures (TFI) on behalf of the Telecommunications Technology Forecasting Group the members of which represent the North American carriers Verizon, SBC, Bell Canada, Bell South, Sprint, and Qwest.

patterns and arguments carry over also to European telecommunications networks. Vanston's analysis focuses on the time period until 2015[32].

Within the frame of the current paper Vanston's scenario of potential developments is mainly relevant regarding interconnection of networks and unbundling of network(s) (elements), see chapter 8.. The analysis of Vanston both focuses on how demand will evolve and on the technical characteristics of network development. Regarding the latter issue, the analysis describes the technical details how end users might be connected to the network in a long-term perspective, i.e. it identifies the basic building blocks of the future network infrastructure and it is outlining how the different network elements and facilities are interworking. The analysis, however, does not provide an institutional perspective by discussing which providers with which network elements are involved in the future provision of services.

We will first highlight the most important patterns regarding the demand side, thus, giving a better understanding of the frame for network evolution.

3.3.1 Demand features

Residential customers

According to Vanston 88 % of North American households are online at the end of 2015. Nearly all of them (82 %) are served on broadband systems and a household usually owns a home local area network connecting computers, TVs, telephones, utility management devices, and smart appliances. Regarding bandwidth more than half of all households have 24 Mb/s service and 28 % have already 50 Mb/s to 100 Mb/s service. Using streaming video to deliver targeted or specialized broadcast content has become common. About two-thirds of households have at least one high-definition television set. Regarding voice and low-speed-data applications wireless has displaced wireline to a large extent. It is estimated that in 2015 about 90 % of North Americans are wireless users. Almost 70 % of North American households no longer have a standard wireline telephone connection. Rather, they use wireless or at least occasionally computer telephony. Over 90 % of wireless subscribers are on third-generation (3G) systems.

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32 TFI has recently presented an update of previous findings regarding their work on the impact of technology change and competition on the network, see Vanston and Hodges (2003). This report provides a detailed empirical analysis regarding the migration path of different network switching and circuit equipment as well as metallic cable and non-metallic cable in the local exchange network between 2001 and 2020, however, it is not focusing on the architecture of the local exchange network as such. To some extent the more recent analysis has changed the findings of Vanston (2001) regarding the actual replacement status of old technology by new technology in the year 2015. However, since the focus in the present paper is not on the actual situation in a particular year, we take into account only the earlier analysis of Vanston (2001).

Business customers

As to business demand it is expected that most office computers are connected via local area networks operating at between 1 Gb/s and 10 Gb/s. Especially medium and large businesses use high-performance IP switches or gateways to provide intranet services but also access to the Internet and other data services. Several alternatives are used for up-stream connectivity. Most of the enterprises interface with the wide area network via fiber optics or on dedicated wavelengths. Some are operating their own wide area network using leased wavelengths or virtual circuits and others are using virtual private networks. Business customers are heavily using wireless LAN solutions and 3G wireless services. Almost all switching equipment on premise are based on packet switching technology. IP-PBXs are standard in most enterprises. Wired based telephones are connected to the switch via an Ethernet. In order to access the public voice network IP-based PBX/central office "trunks" are carried on the customers broadband channels.

3.3.2   Features of the network infrastructure

We will now concentrate on the main features of the long-term development of the local exchange network. Vanston's analysis primarily focuses on the lowest layer of a NGN, i.e. on the (physical) access and transport network (facilities). Only to a minor degree media layer issues are addressed (see section 3.2).

General architecture

Figure 3-3 illustrates the general architecture of the local exchange network in 2015. The figure contains three major types of nodes and edges which can be distinguished within the local loop:

- Central offices (CO) connected by the interoffice network,

- Remote nodes (RN) connected to central offices by the feeder network,

- End nodes (EN) connected to remote nodes by the distribution network.

Figure 3-3:   The Local Exchange Architecture - 2015
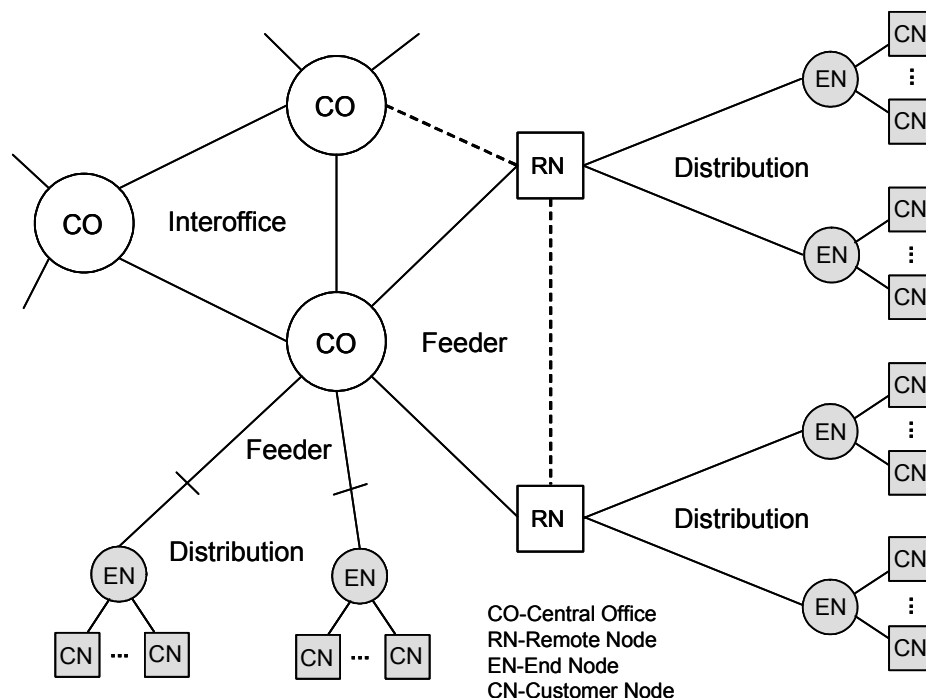
Source: Technology Futures, Inc.

Central offices

According to Vanston central offices in 2015 are buildings where the major switches and network junction points are located. Moreover, points of presence for interconnection to long-haul facilities, competitors and content providers may be located here. Central offices may also contain servers and headend equipment.

Remote nodes

Remote nodes are located in special environmental enclosures, vaults, or buildings. An important use for remote nodes are passive and active optical multiplex equipment feeding end nodes or large enterprises. Remote nodes are generally within 12,000 feet of subscribers[33].

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33 In today's terms of the circuit switched world a Class 5 end office switch (the German analogue would be the "Ortsvermittlungsstelle") is connected to the jumper wire interface at the remote node (the German analogue would be the "Kabelverzweiger").

End nodes

End nodes are located at the telephone pedestal or similar locations within 1,000 feet of the customer[34]. The end node is connected to the customer node, i.e. to the end user via the drop wire.

By 2015 remote nodes are often connected to each other, and end nodes are often directly connected to central offices.

Interoffice network

According to Vanston, the interoffice network is entirely based on fiber in 2015. On most routes dense wavelength division multiplexing (DWDM) is used. The usual number of wavelengths simultaneously used by 2015 is 320 although Vanston mentions that some long-haul systems might even use 1,024 wavelengths. Each of the 320 wavelengths can carry up to 40 Gb/s. Thus, total capacity on a single fiber adds up to 12.8 Tb/s, see Figure 3-4.

Figure 3-4:   State of the Art Metro DWDM System - 2015

Source: Technology Futures, Inc.

Feeder network

The feeder network, today mainly based on copper, is expected to be nearly displaced by fiber in 2015. Vanston estimates that 97 % of all access lines are either served on fiber feeder or are too close to the central office to involve feeder facilities at all. It is expected that the last of copper feeder plant is replaced by fiber in 2020.

Distribution network

Regarding the distribution network, it is expected that essentially all medium and large business customers are served directly by fiber optics. Residential and small business customers are served by so called "deep fiber systems". This term encompasses several different systems like Very High-Speed Digital Subscriber Line (VDSL), Fiber-to-the-Premises (FTTP), or Advanced Hybrid Fiber Coax (AHFC) as can be seen from Figure 3-5.

Figure 3-5: Deep Fiber Systems in Common Use in 2015

Source: Technology Futures, Inc.
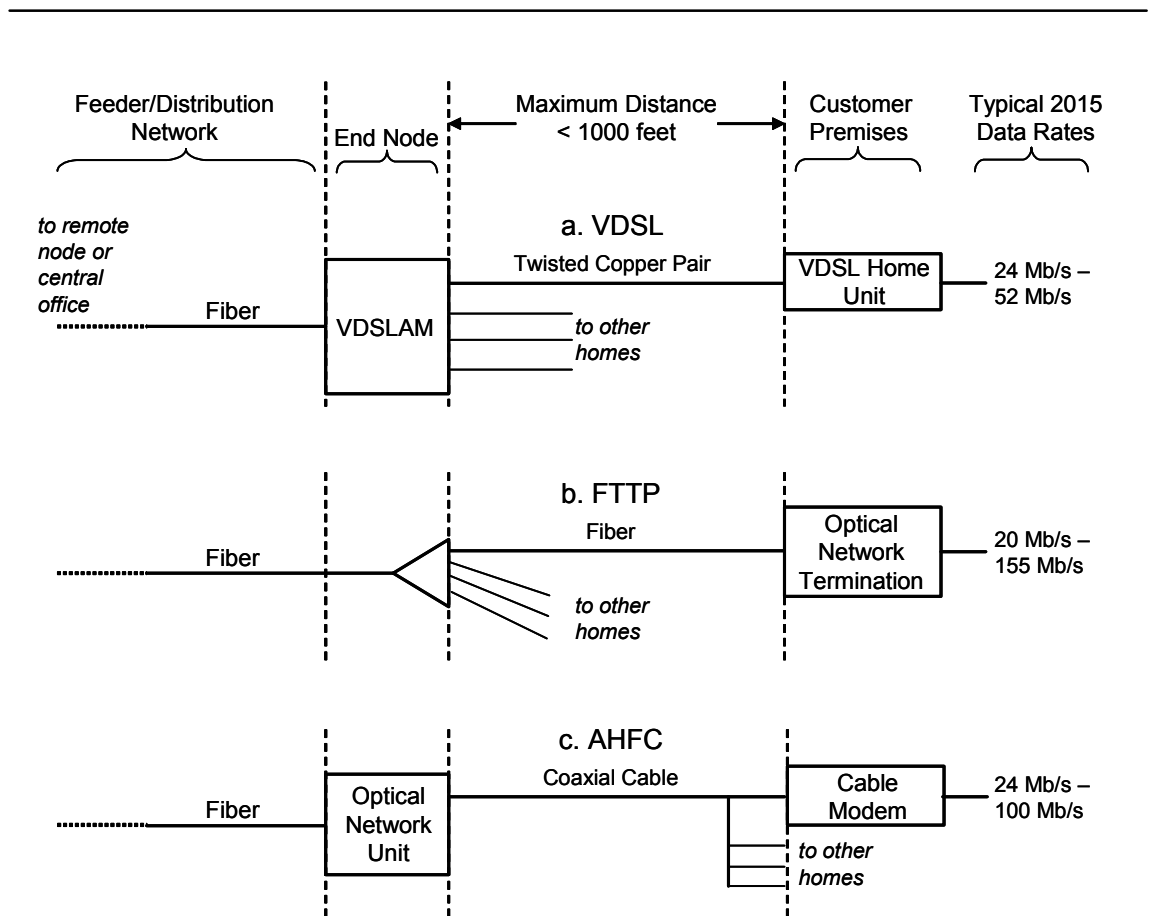
All deep fiber systems rest at least on fiber extending to an end node. According to Vanston most deep fiber systems use DWDM and/or passive optical network (PON) technology in the fiber systems supplying the end node.

Connections between the end node and the customer based on VDSL are still using copper. The VDSL solution rests on a VDSL home unit located at the customer's premises and a VDSL access module (a VDSLAM) located at the end node containing the active electronics that interface with the customer and provide for optical/electronic conversion.

If FTTP is used the connection from the end node to the customer is based on a dedicated fiber. At the end node the individual fibers are combined onto a single fiber back to the remote node or central office by a PON optical coupler. Vanston expects modern FTTP systems in 2015 to provide 155 Mb/s to 622 Mb/s bandwidth and that these systems combine DWDM and PON technology allowing wavelengths to be dedicated to customers, see Figure 3-6. He argues that a key advantage of FTTP systems is that active electronics are not required at the end node and, thus, allowing these nodes to be extremely small.

Figure 3-6:   Modern PON Systems with DWDM
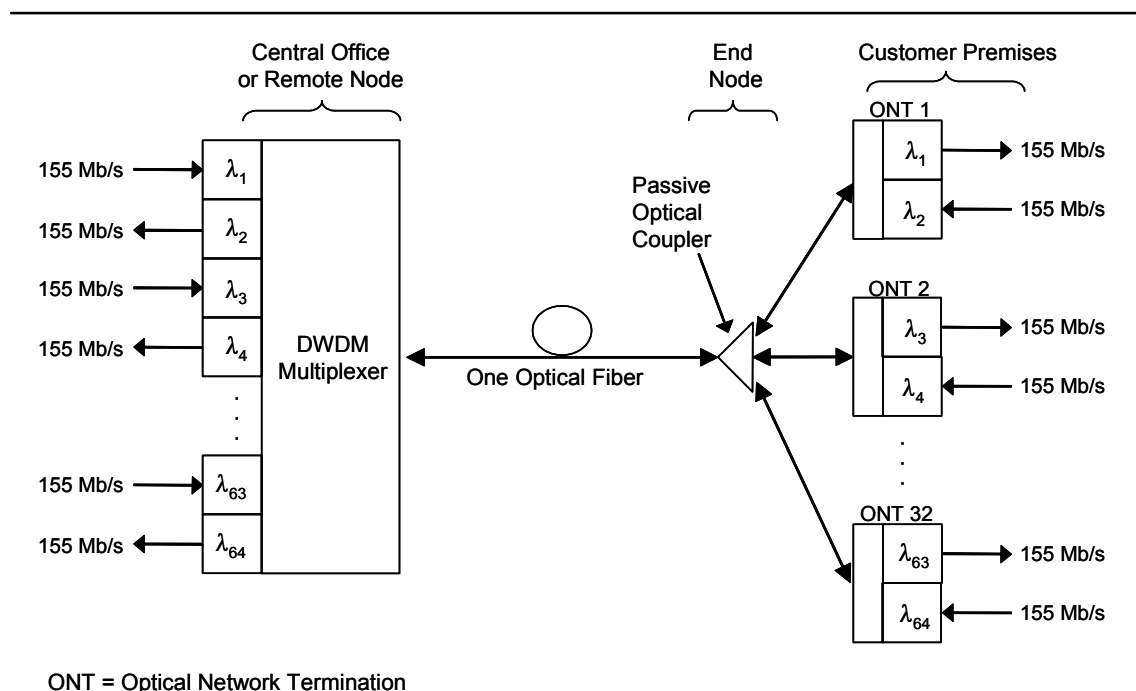
Source: Technology Futures, Inc.

As to the AHFC solution the connection from the end node to the customer is based on coaxial cable. Vanston expects most AHFC systems to provide a standard selection of broadcast television channels plus 24-100 Mb/s Internet access. Most AHFC systems are expected to combine DWDM and PON technology to maximize bandwidth per customer and to minimise fiber and electronics requirements.

Of course, Vanston acknowledges that the actual mix of deep fiber solutions in a given location of a country in 2015 hinges upon the actual development of the market power of traditional telecommunications carriers and of cable TV companies. Viewed from the perspective of today (2003) there are countries with a relative strong competition between telecommunications carriers and cable TV operators especially in the field of broadband access like e.g. the U.S. and Switzerland. However, there are also countries like Germany where the incumbent telecommunications carrier has a strong lead with its DSL broadband access technology and for various reasons cable TV operators are unable to establish a viable business case comprising TV distribution, interactive broadband services, let alone telephony services. These current differences in competitiveness might carry over even to the long-term future.

Circuit and switching equipment

Vanston focuses on a broad range of types of equipment and discusses their use in 2015. By circuit equipment Vanston comprises all kinds of facilities providing the communications channels being carried on fiber and switched by IP switches at network nodes, i.e. :

- WDM (Wavelength Division Multiplexing) switches,

- Optical multiplex equipment,

- SONET (Synchronous Optical Network) equipment,

- DSL and VDSL equipment,

- DLC (Digital loop carrier) equipment.

Switching equipment comprises the traditional narrowband circuit switching facilities and packet switching technologies.

According to Vanston in 2015 the (higher-level) IP networks will mainly be served by a (lower-level) optical transport network (OTN) encompassing WDM switches and WDM multiplexers. *WDM switches* are located at junction points in the fiber network. They crossconnect wavelengths carried on the different fibers attached to the respective switches and allow to set up an optical path between any two nodes of the fiber

network, thus, providing a high-speed communications path for the IP switches at those two nodes[35].

Optical multiplex equipment comprises equipment which on the one hand is combining individual wavelengths from different sources onto a single DWDM fiber and on the other hand decomposing the signal from a DWDM fiber into the individual wavelengths destined for the different users[36]. According to Vanston optical multiplex equipment is used at different locations in the network:

- At the interfaces between the optical transport network and switch nodes,

- at the interfaces between networks, and

- at the interface between customers and the network.

It is fair to say that *SONET*[37] today is the usual form to put information on a fiber optic wavelength. It is standardized, has an add/drop multiplexing ability, allows protection switching over rings and enables a carrier to manage bandwidth. Vanston expects however, that by 2015 the bulk of SONET equipment in place will be removed[38]. The reason is that SONET obviously will become obsolete. Vanston argues that SONET equipment is unnecessary once the following conditions prevail (see Vanston (2001, p. 18):

- DWDM have replaced single wavelength fibers in the local exchange network,

- WDM switching has become ubiquitous,

- wavelength have become the standard for IP/ATM switch interconnection,

- a robust and standardized optical network controller has been developed.

Vanston expects that by 2010 all conditions will have been fulfilled so that a process of accelerated removal of SONET equipment after 2010 is initiated.

Regarding *DSL and VDSL equipment* Vanston argues that most first-generation DSL access devices installed in central offices and remote nodes are no longer in use in 2015 because end users have migrated to higher-speed solutions. Thus, the VDSL

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35 Vanston argues that the "optical paths can be set up and torn down almost instantaneously in response to the demands of the IP networks served by the OTN. Optical network controllers maintain all the topology and resource availability information about the OTN and receive and act on the orders of higher levels." See Vanston (2001, p. 16).

36 Optical multiplex equipment includes the PON couplers in the distribution network if a FTTP solution is used. Vanston expects optical multiplex equipment to be not necessarily purely optical. Otherwise stated there are presumably types of equipment providing electrical instead of optical interfaces to individual sources or destinations.

37 The European analogue for SONET is SDH.

38 Vanston expects about 80 % of the SONET equipment in place in 2010 will be removed by 2015.

equipment in use in 2015 will consist of small VDSLAMS located at end nodes fed by fiber from the central offices or a remote node.

According to Vanston, the vast majority of analog and ISDN access lines used for narrowband services will have been replaced by broadband solutions by 2015 and, thus, traditional *DLC equipment* has nearly disappeared from the network or is severely under-utilized, respectively[39].

Vanston expects that traditional narrowband circuit switches are more or less completely removed from the network by 2015. Instead, voice signals are packetized either by customer equipment or at the edge of the network at remote terminals and then transported on IP. In keeping with the basic NGN architecture Vanston argues that the intelligence for call control and management signalling and processing via SS7 and network databases has migrated into outbound servers. Moreover, Vanston expects that IP switching will have become the dominant switching technology by 2015[40], i.e. virtually there is no longer a need for ATM. Rather, direct communication via DWDM channels will become the prevailing mode of communication. The reason is according to Vanston that the capabilities of DWDM regarding bandwidth together with MPLS will allow IP to provide the necessary QoS required for real-time communication.

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39 Vanston argues that with "the transition to IP switching, most households and small businesses retaining wireline services switched to voice over IP services carried on the customer's broadband channel, bypassing the analog local loop and any associated DLC equipment"; see Vanston (2001, p. 20). This is all the more true of medium and large businesses being served on fiber.
40 See the preceding discussion on WDM switching.

4   Actual solutions to get interoperability of circuit-switched and packet-switched networks in NGNs[41]

Adoption of NGNs in all likelihood will be not disruptive. Rather, traditional telephone networks (analog PSTN, ISDN) will be widely used for many years to come, in particular with respect to the access network. Thus, interoperability between the telephone network and networks following the NGN concept will continue to be a crucial issue.

Interoperability between circuit-switched and packet-switched networks is e.g. still a crucial issue regarding VoIP and other real-time services. VoIP providers need to connect with end-users through interconnecting with traditional PSTN operators in order for the former to obtain access to the PSTN's addressing system (i.e. telephone numbers), and to use the PSTN's SS7 signalling system. Thus, present VoIP providers are essentially providing long-distance / international bypass of the PSTN.

This section presents actual solutions which in particular are enabling interoperability of circuit switched and packet switched networks in NGNs.

When voice is delivered over IP it is still necessary to perform signalling and call control functions. To enable real-time multi-media communications across IP networks, two protocol standards are mainly in use:

- H.323, and

- Session Initiation Protocol (SIP, RFC 2543).

Thus, we first characterise the main features of these two approaches in sections 4.1 and 4.2. Evaluating the current vendor catalogues, however, one gets the impression that the NGNs virtually are going to be based on a softswitch approach. The latter will be highlighted in section 4-3.

4.1   The H.323 standard

The ITU recommendation H.323 "Packet based Multimedia Communications Systems" contains a set of standards required for establishing, monitoring and terminating end-to-end connections for multimedia services such as VoIP, video communication over IP and collaborative work for multimedia services[42].

H.323 not only specifies the signalling protocol but also a characteristic network architecture. As can be seen from Figure 4-1, the main components shaping an "H.323-zone" are:

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41   Sections 4.1 – 4.3 are drawing on Elixmann and Scanlan (2002).
42   H.323 has the official title "Packet-based Multimedia Communications Systems".

- H.323 compatible terminal devices,

- Gateways,

- Multipoint Control Unit(s) (MCUs), and

- Gatekeeper(s).

The primary objective of H.323 is to enable the exchange of media streams between these components. Typically, an H.323 terminal is an end-user communications device that enables real-time communications with other H.323 endpoints. A gateway provides the interconnection between a H.323 network and other types of networks such as the PSTN[43]. An MCU is an H.323 endpoint that manages the establishment and the tearing down of multi-point connections (e.g. conferences)[44]. The gatekeeper is responsible for controlling his H.323-zone, including the authorisation of network access from the endpoints of the H.323 zone. Moreover, the gatekeeper supports the bandwidth management of connections with particular QoS requirements. In addition it performs IP addressing tasks. The gatekeeper represents the key element of the H.323 network architecture and virtually corresponds to the call server presented in section 3.1.1.

Figure 4-1:   H.323 network architecture
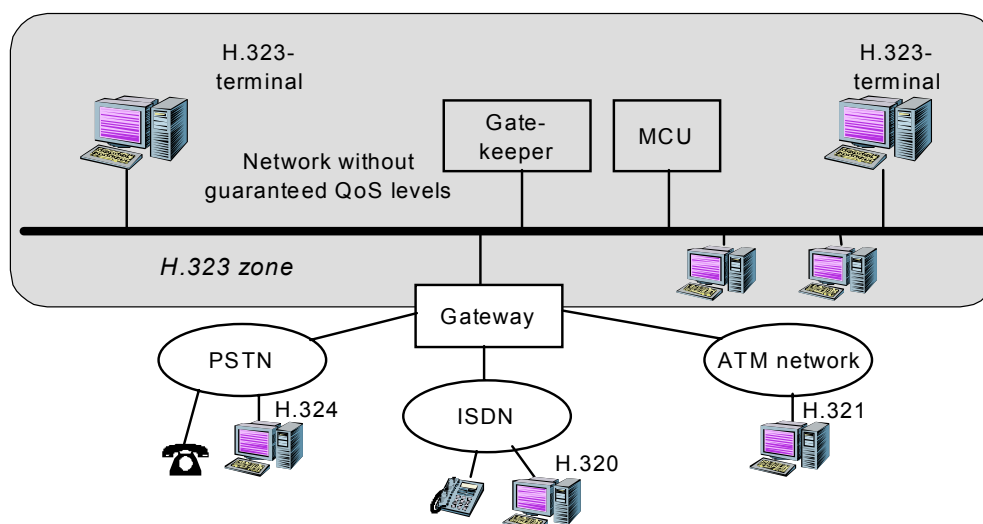
Source: Badach (2000).

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43 One side of the gateway mirrors the requirements of H.323, i.e. it provides H.323 signalling and conveys packet media. The other side fulfils the requirements of the circuit-switched network. Thus, from the perspective of the H.323 side a gateway has the characteristics of a H.323 terminal. From the perspective of the PSTN it has the characteristics of a PSTN (or ISDN) network node.

44 The MCU functionality can be contained in a separate device, although it can also be part of a gateway, a gatekeeper or a H.323 terminal. The task of an MCU is to establish the media that may be shared between entities by assigning a capability set to the participants of a multi-part session. The MCU may also change the capability set if other endpoints join or leave the session.

H.323 is not a single standard, rather it is a complex suite of standards each concerned with different tasks[45]. An overview of the main elements of the protocol-architecture enabling multi-service networking with IP are shown in Figure 4-2.

With respect to the exchange of the actual payload, Figure 4-2 shows that H.323 works on the basis of RTP (RTCP) using UDP for transport over IP, i.e. TCP is not used[46]. Additionally, the protocols H.225 and H.245 are used for control of the terminal equipment and applications[47]. H.225 is a two-part protocol. One part is responsible for setting up and tearing down connections between H.323 end-points (call signalling); the other part of H.225 is utilized by the gatekeeper for the management of endpoints in his zone and is usually called RAS (Registration, Admission, and Status) Signalling[48]. The main task of the H.245 control signalling is the management of the actual packet streams (media streams) between two or more participants of an H.323 session. To this end H.245 opens one or more logical channels with specific properties (such as bit rate) between H.323 endpoints, which are utilised for the transfer of the media streams.

Figure 4-2:   H.323 protocol layers

Audio	Video	Terminal Control and Management				Data Applications	
G.711	H.261	RTCP	H.225.0	H.225.0	H.245	HTTP	T.120
G.722	H.263						
G.723.1			RAS	Call Signalling	Control		
G.728			Channel	Channel	Channel		
G.729.A							
RTP			X.224 Class 0				
UDP			TCP				
Network Layer (IP)							
Link Layer (IEEE 802.3)							
Physical Layer (IEEE 802.3)							

Source: Schmidt (2000)

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[45] See Schmidt (2000) for a discussion of ITU Internet telephony related standards.

[46] The Real Time Transport Protocol document (RFC 1889) encompasses the actual RTP for media packet transport and the RTP Control Protocol (RTCP) monitoring the quality of service and generating reports to the network. More information can be found in Sinnreich and Johnston (2001, pp. 46). Contrary to TCP which specifies a virtual connection UDP (User Datagram Protocol) is a connectionless protocol.

[47] In the following we draw heavily from Smith and Collins (2002).

[48] RAS signalling is used for registration of an endpoint with a gatekeeper and it is utilised by the gatekeeper to allow or to deny access to the endpoint.

4.2   Session Initiation Protocol (SIP)[49]

SIP was developed by the IETF in 1999. It is a protocol for establishing, routing, modifying and terminating communications sessions over IP networks. It is based on elements from HTTP, which is used for Web browsing, and the Simple Mail Transport Protocol (SMTP), which is used for e-mail on the Internet. Even though SIP is used for peer-to-peer communications[50], it uses a client-server transaction model in which a SIP client generates a SIP request which is responded to by a SIP server. SIP mainly performs those functions in IP-based networks which in traditional networks are performed by signalling protocols.

To get a clearer picture of what SIP is, it is useful to outline what SIP is *not.* SIP is not:

- A protocol which controls network elements or terminal devices;

- A resource reservation protocol or prioritisation protocol;

- A transfer protocol designed to carry large amounts of data[51];

- Designed to manage interactive sessions once the sessions are set up;

- Aiming at mapping all known telephony features from circuit-switched networks into the SIP world[52].

Compared to H.323, SIP is considered simpler[53]. SIP can use both the connectionless UDP and TCP as transport protocol in layer 4.

The main building blocks of a SIP-enabled IP communications network are:

- SIP endpoints;

- SIP server, and

- Location server.

Broadly speaking, a SIP endpoint is a computer that understands the SIP protocol. SIP endpoints in particular are fully qualified Internet hosts. Two types of SIP-endpoints can be distinguished:

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49   This sections draws on Sinnreich and Johnston (2001).
50   Peer-to-peer means that both parties involved in a SIP based communication are considered equals.
51   Rather, it is designed to carry only those comparably small amounts of data required to set up interactive communications.
52   Although it is worth to be noted that SIP supports PSTN Intelligent Network services and mobile telephony features, see Sinnreich and Johnston (2001, p. 13).
53   To quote Sinnreich and Johnston: "SIP...makes no specification on media types, descriptions, services etc. This is in comparison to a VoIP umbrella protocol such as H.323, which specifies all aspects of signalling, media, features, services, and session control, similar to the other ISDN family of protocols from which it is derived". See Sinnreich and Johnston (2001, pp. 56-57).

- User devices such as (SIP-)phones and PCs[54], and

- Gateways to other networks, e.g. connecting to the PSTN, H.323 networks, or to softswitch-based networks using MGCP (RFC 2805) or Megaco (H.248, RFC 3015) protocols.

A SIP server is a computer that performs special functions at the request of SIP endpoints. There is no necessity that a SIP server is on the same network as the SIP endpoints that are associated to it, rather, the only requirement is that the server can be reached via an IP network[55]. The SIP server performs key functions of the SIP network architecture and corresponds to the call server presented in section 3.1.1. A Location Server is a database containing information about users (like URLs), IP addresses and routing information about a SIP enabled network.

SIP-addressing rests on a scheme similar to e-mail addressing[56]. SIP-addresses identify users rather than the devices they are using, i.e. there is no differentiation between voice and data, telephone or computer. SIP supports queries on DNS servers, ENUM[57] queries and queries at location servers.

4.3   H.323/SIP Interworking

We have seen that H.323 and SIP rest on very different principles and that they are backed by different organisations (ITU, IETF)[58]. We recognise, however, that there are developments in the manufacturing/software industry which actually are going to lead to a situation where the technical differences between the approaches disappear. In 2001, a company called SS8 Networks has patented what it refers to as a "Signalling Switch"

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54 The terminal devices in a SIP network are also called user agents. They originate SIP requests to set up media sessions and they send and receive media. A characteristic is that every user agent contains both a User Agent Client and a User Agent Server. The User Agent Client is the part of the user agent initiating requests and a User Agent Server is the part generating responses to requests. During a session usually both parts are used. See Sinnreich and Johnston (2001, p. 57).

55 To be more precise there are different types of SIP servers with specific tasks: SIP *proxy servers* receive SIP requests from an endpoint or another proxy server and forward them to another location. *Redirect servers* receive requests from endpoints or proxy servers and are responding by indicating where the request should be retried. *Registrar servers* receive SIP registration requests and are updating information received from endpoints into location servers.

56 The SIP address of the author of this study could be: sip:d.elixmann@wik.org. It is, however, possible, to use also a telephone number in the user part, like sip:+49-2224-922543@wik.org; user=phone.

57 ENUM first and foremost is a protocol defining a DNS-based architecture aiming at using an ordinary E.164 telephone number to identify IP-based addresses. ENUM has been standardised by the IETF in September 2000. E.164 is the name of the international telephone numbering plan administered by the ITU specifying the format, structure, and administrative hierarchy of telephone numbers. The ITU issues country codes to sovereign nations, however, national telecommunications organisations administer the telephone numbers within a country. A fully qualified E.164 number consists of a country code, an area or city code, and a phone number. The related IP-based addresses might e.g. be the mail address, an URL or an IP phone address.

58 To some extent it is fair to say that H.323 is oriented to the old circuit-switched telephony world, see Denton (1999), whereas SIP was developed with the Internet in mind. Both SIP and H.323 use the same mechanism for transport of media streams, namely RTP. However, their addressing schemes are different.

which is both a SIP proxy server and a H.323 Gatekeeper and which in addition provides H.323/SIP interworking[59]. Moreover, this solution is claimed to support ENUM. Today, we have the impression that the bulk of vendors offering softswitches support both the H.323 and SIP protocol[60].

4.4 Softswitch based architectures

According to the International Softswitch Consortium (ISC) a softswitch can be defined as follows:

Softswitch is "*an all-encompassing term for next generation communications systems that employ open standards to create integrated networks with a decoupled service intelligence capable of carrying voice, video and data traffic more efficiently and with far greater value-added service potential than is possible with existing circuit switched networks. .....The migration from circuit switching to packet/frame/cell-switched networks controlled by softswitches will transition the industry from a closed environment to open standards-based systems, achieving the openness started years ago with Intelligent Networking (IN) initiatives*[61].

The concept of softswitch was initiated by the Bell Laboratory in 1997. A softswitch based architecture separates the service and call control layer which is integrated in a PSTN world and allocates these functions to different platforms, see Figure 4-3.

Figure 4-3:   Concept of the softswitch approach
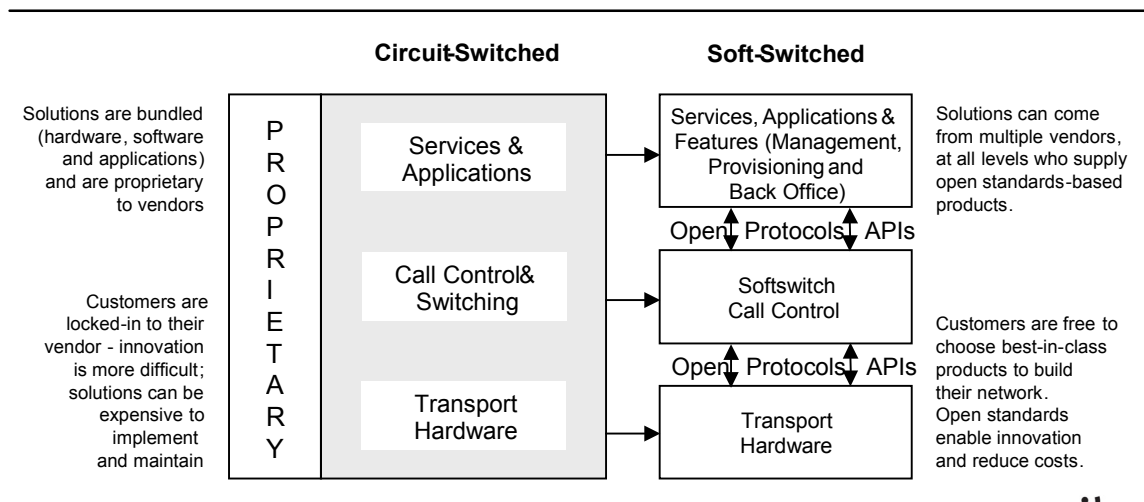
Source: ISC (2002, p. 3)

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59 For more details on SIP and H.323 see SS8 Networks (2001).
60 See also Tanner (2002).
61 See ISC (2002, p. 3).

Gateways are playing a prominent role within a softswitch-based architecture which can be seen from Figure 4-4. The different types of (media) gateways perform different functions and are located decentrally at different locations[62]. They provide interfaces to the packet network on the transport layer.

Residential Gateways (RGW) perform the conversion directly within the customer's building or at the customer's premises. They are located e.g. between a circuit switched terminal device and a packet switched access network. Regarding business customers specific "business gateways" can be located between PBX systems and the packet network.

Figure 4-4:   Access alternatives to a softswitch based NGN architecture
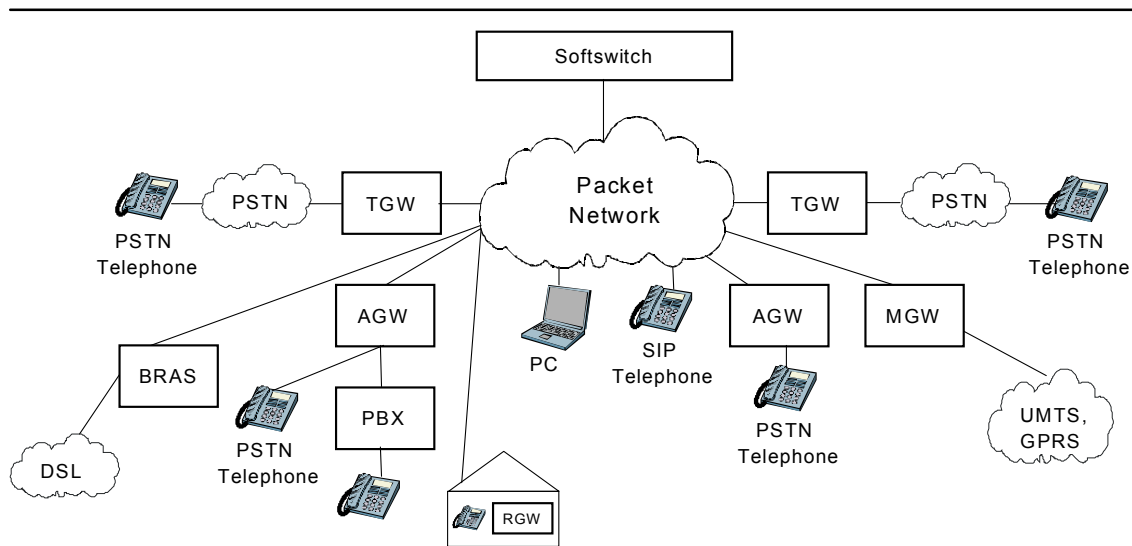
Source: WIK, based on interviews with vendors

Access Gateways (AGW) represent the interface to the packet network at a local level of the PSTN network and usually are provided by the access network operator. The location for an AGW can e.g. be the local exchange, however it might be located even "nearer" to the end-user within the local loop[63]. Location of the gateway at a point between the class 5 end office switch and the end user of course requires that there is access to a packet network (e.g. IP-network). This is hardly the case within the bulk of the PSTN networks. Moreover, if access gateways are provided by third parties collocation issues arise.

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62   See Anquetil et. al (1999, p. 152).
63   See section 3.3.

Trunking Gateways (TGW) provide for conversion of media streams at a regional level. Potential locations for TGWs are the trunk exchanges of the network operator. Termination of voice traffic from a NGN into the PSTN on a regional level may have implications with regard to existing interconnection regimes. Based on the current rules in Germany DTAG is e.g. pointing out that the exchange of traffic has to take place at the POIs of DTAG. However, trunking gateways need not be placed at each POI. Rather, a centralized approach with regard to the installation of a TGW in this case would require to convey traffic via leased lines from the location of the TGW to the different POIs.

A *Mobile Gateway (MGW)* is responsible for the access of mobile traffic. Mobile gateway functions are in particular needed in the case that the format of data packets in the access network are different from the format of the data packets required in the core network. For example, in the case of GPRS data packets are conveyed via TDM.

A *Broadband Remote Access Server (BRAS)* providing access for example for DSL traffic can be directly linked to the packet network.

Media gateways are not needed if the technologies being used in the access network and those in the core network are the same. This is e.g. the case if IP capable terminal devices (e.g. SIP telephones, SIP PCs) are linked to a core IP network.

Capabilities of softswitches still are vendor specific. Moreover, softswitches are implemented into a network with different purposes, see chapter 6.

Gateways and softswitches need not necessarily be at different geographical locations. Vendor product information suggests that e.g. signalling gateway functions and trunking gateway functions can be integrated within a softswitch (through respective service cards)[64].

To sum up, in practice softswitches virtually can encompass the functions of a Signalling Gateway, a Call Controller, a SIP and a H.323 Server[65]. A softswitch usually has an interface to application servers and media servers in the network and it controls the media gateways. A softswitch, thus, aims at offering a high degree of interoperability between heterogeneous networks which can be based on several different protocols (e.g. SS7, H.323, SIP)[66].

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[64] See e.g. product information of Harbour Networks (www.harbournetworks.com).
[65] There are differences e.g. between the softswitch based approach and a SIP based approach regarding control of the network, see Smith and Collins (2002, p.349). These details are not imporatnat for the present paper.
[66] Lucent Technologies (2001).

5   NGNs and their implications for provision of services and applications

This chapter will be focusing on an analysis of potential implications of NGNs for the basic economics of telecommunications service provision and future business strategies of players in the market.

General implications of NGNs

The preceding chapters have shown that NGNs will have very different features compared to traditional PSTN/ISDN networks:

- NGNs are using a common platform for the provision of voice, data and video services. The different services and applications are based on a common "bearer protocol" like e.g. IP[67].

- The structure of NGNs is based on a distributed functional structure, i.e. different functions are provided by distinct network elements geographically distributed at different locations.

- Within NGNs the transport function is separated from the control and signalling functions. In particular these tasks are performed in separate network elements.

- The bearer protocol can terminate directly on a user device like e.g. a PC, server or telephone and, thus, defines a " terminal point". Access to this terminal point therefore takes place directly at the user premise or with a service provider[68].

- To enable the provision of services and applications within a NGN there are a multitude of protocols. Voice services are supported e.g. by SIP and H.323.

In particular, the NGN paradigm rests on a clear separation of service and transport. Regarding the provision of services and applications in a NGN environment the features mentioned have severe implications compared to service provision in the traditional PSTN/ISDN world. It is highly likely that NGN architectures provide for a substantially altered mode of service provision in the telecommunications market.

NGNs entail a far reaching decentralization, i.e. intelligence at the edges of networks is replacing hierarchical control from the core[69]. Due to the distributed structure of functions there are opportunities for market players to separately operate specific network elements (e.g. gateways, call servers, application servers) and related functions they need to provide services (provided this is economically sensible and the respective open interfaces are there).

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[67]   Additionally, gateways are required if a NGN is established via Frame relay or ATM.
[68]   See Denton (1999, p. 16).
[69]   See also the "Supernova Report" on the pulver.com website;
       http://pulver.com/supernova/subscribe.html.

The separation of the control and the transport layer opens up opportunities for competitors to carry out control functions they need to provide services on their own. Thus, services can be introduced into the market independent from the operator of the transport network. Moreover, due to the "bearer protocol" services can be created at the edge of the network, i.e. directly at end user premises or with a service provider. In a NGN environment the intelligence, thus, can be shifted more and more towards the terminal points fixed by the bearer protocol. Entities offering services will have choice between different architectures capable to support their specific service offerings.

ITU (2003) defines NGNs by the following fundamental characteristics:

- packet-based transfer,

- separation of control functions among bearer capabilities, call/session, and application/service,

- decoupling of service provision from network[70] and provision of open interfaces[71],

- support for a wide range of services including real time, streaming, non-real time services and multi-media[72],

- interworking with legacy networks,

- unfettered access from users to competing service providers and/or services of their choice.

The ÍTU, thus, is more or less in keeping with what has been presented so far as general implications of NGNs. In addition to the preceding features, however, ITU (2003) underlines that

- broadband capabilities with end to end transparency, including access network utilization considerations, and in particular

- generalized mobility

should be viewed as defining characteristics of NGNs.

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[70] ITU (2003) stresses that there is a clear separation between the functions for the services and the functions for the transport in the NGN architectures.

[71] According to ITU (2003) NGNs should provide for service related APIs (Application Programming Interfaces) in order to support the creation, provisioning and management of services.

[72] ITU (2003) emphasizes that the term "services" is to be understood in a broad sense. Services can use all kinds of media (audio, visual, audiovisual), with all kinds of encoding schemes and data services. In particular, they are comprising conversational, unicast, multicast and broadcast, messaging, simple data transfer services, real time and non-real time, delay sensitive and delay tolerant services.

Service provision and service providers in a NGN environment: examples

It has become clear that a NGN has a much more disintegrated structure compared to the PSTN/ISDN. A-priori this structure therefore opens up huge opportunities for market entry along the process of value creation. This means, that the provision of services can consist of inputs of a multitude of different providers. The prerequisite is, however, that NGNs preserve an open architecture with respect to the communication between network elements.

Open interfaces of this new architecture on the one hand allow a rapid introduction of new services into the market. On the other hand they enable new business models by breaking up the traditional value chain into a multitude of services and applications which at least in principle might be provided by different entities[73]. Thus, in a NGN environment, there will be in particular room for non-facilities based service providers, i.e. those developing services on top of an existing network[74].

Two examples might clarify this.

The first example focuses on the case of e-mail. In a future world it can be the case that

- Service provider 1 is responsible for the transport from sender to receiver (perhaps with specific attributes like real time service, including bandwidth guarantee and transport of billing information).

- Service provider 2 additionally carries out an error correction.

- Service provider 3 puts an e-mail application on top of this (including e.g. an authentication).

- Service provider 4 sets up e.g. mailing lists or enables setting up working groups.

From this disaggregated perspective further activities could be e.g. provision of routing and billing services or broking of backbone transmission capacities. The main message of this example is that in a future world each service provider is setting up a new application on top of the underlying network. In order to be able to do this pre-defined

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[73] We do not want to go into technical details regarding the difference between a (network) service and an application. Broadly speaking, network services are support functions of the network consisting of particular modules which are necessary to provide an application. An example is the application e-mail. The related network services are e.g. uni-directional transmission, creation of a point-to-point link and messaging. The WWW is an application of the underlying transport network. Each network service has particular quality attributes (e.g. delivering real-time service quality).

[74] Denton defines a non-facilities based telecommunications provider to be "one who offers services made possible by the unbundling of the network and the data link layers the purpose of which is to redefine the characteristics of the underlying network." See Denton (1999, p.16).

interfaces are necessary. Each additional application, in turn, increases the "value" of the product (application)[75].

The second example focuses on personalized (electronic) services tailored to the specific needs of a particular (type of) user currently under development by the Fraunhofer Gesellschaft in Germany[76]. The concept of this new service (creation) world encompasses the following main building blocks:

- Services and a service space. The latter comprises primitive (generic) services on the basis of which enhanced (generic) services may be constructed. The latter, in turn, may allow the construction of customized services.

- Service points, hosted on a portal (i.e. a server), making accessible specific classified services and providing for the connection of terminal devices of end-users to the service portal.

- Service providers are operators of service portals on which the service points are hosted.

- Service hubs providing for collections of service points of some commonality, i.e. representing collections of services offered by different service providers.

Users enter into a service hub in order to select relevant service points. The idea is that this logical infrastructure is capable of learning. For example, the service points are to cope with changing requirements of users by providing different collections of services for different situations without user interference.

Of course communications infrastructures are needed that allow the connection of terminal devices to the portals, between the portals and between service hubs and portals. A-priori a multitude of service providers is involved in such a paradigm each providing different services and portals. And it may very well be the case that there is a kind of "cascade" regarding service provision, i.e. the output of one service provider (providing e.g. elementary services) is an input to another service provider (providing enhanced services).

It is important to state that following the ideas of the Fraunhofer approach the service providers are only working "above" the transport layer, yet, they need operators on the transport layer in order to communicate with one another[77].

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75   Usually the end user will be not aware of the "additional value" a service provider is offering. Rather, the additional value may be mainly relevant for another service provider.
76   We refer to research and development currently carried out by the Fraunhofer Institut Software- und Systemtechnik (ISST), see Weber (2003). I'm indebted to Prof. Weber for spending his time with me to explain the basic ideas of the Fraunhofer approach.
77   An example of the services ISST has in mind are personalized e-government services.

Resumé

The two examples underline the opportunities of NGNs. In particular, it is obvious that NGNs are likely to have severe implications for the future market structure. In this context Denton points out that in an all-IP network the network becomes the transport device for customers' services. In particular, terminal points are no longer owned and controlled by the network operator. This means that new services, new value, can be created without the permission, control or involvement of the network owner. And it is concluded, "when network ownership is decoupled from value creation, traditional telco operators derive no benefit from this new value beyond the traffic it spawns"[78].

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[78] See Denton (1999, p. 16).

6   Directions of deployment of NGN architectures

It can be taken for granted that the development towards NGNs will not be disruptive, rather, there will be a gradual migration of networks. Thus, for a foreseeable future we will witness a coexistence of circuit switched and packet switched networks. The present chapter aims at highlighting some patterns of current deployment of NGN elements by network operators.

In the past ten years or so there has not been a lack of advances to carry voice service over packet switched IP network technology. However, despite this nearly decade long history it is fair to say that IP telephony still is not a mass market. Virtually there is no IP telephony available enabling end-to-end packet based voice services on the public network.

The early implementation of IP telephony was based on the H.323 architecture described above[79]. Meanwhile there is a growing list of vendors offering SIP products[80]. Likewise Sinnreich and Johnston (2001, p. 28) give at least a short list of service providers using SIP technology within (parts of) their networks[81]. On the basis of our interviews we have the impression that SIP will become the dominant standard in the future.

Talking to German operators we can observe that there is a tendency to transmit fixed-link voice telephony at least in the backbone more and more on the basis of packet switched technologies.

Deployment of softswitches into carrier networks up until now is more the exception than the rule. Regarding the manufacturing side, however, at least all the big manufacturers of the world today have softswitch solutions as part of their product portfolio. In addition, it seams that there is a growing number of small companies and start-ups that are working on softswitch gear.

If carriers are deploying softswitches into their network they still address a very specific and limited set of tasks[82]. An overview of the different application areas of softswitches so far implemented is given by a survey recently conducted in the USA among 59 network operators[83]. This survey showed that RBOCs and IXCs were most likely to

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[79]   See Kulenkampff (2000, p. 9).
[80]   See e.g. http://www.pulver.com/products/sip/
[81]   Companies mentioned are AT&T, Telia, Level 3 and Worldcom. From different sources we know that BT, DTAG and Qwest have implemented SIP or are planning to do so. Likewise a German ISP, mediaways, has announced in October 2002 to use SIP.
[82]   See Sweeney (2001, p. 34).
[83]   See Engebretson (2002a).

have deployed softswitches[84]. Other incumbent telcos and national wireless carriers were more likely to be in an evaluation or "monitoring and watching" phase.

Among those who have deployed softswitches the most popular applications cited were

- Internet offload,

- as a replacement of Class 4 trunk switches[85] and

- to expand revenue by offering specific services and applications[86].

In the USA a potential for the deployment of softswitches is seen with regard to cable operators as a Class 5 replacement product. Some telecommunications carriers also are thinking about replacing Class 5 switching technology. For example, in 2001 it was reported that Sprint is planning to replace Class 5 switches by softswitches in a mid- to long-term perspective. Sprint's key drivers were reported to be lower costs to deploy and maintain softswitches and in particular to be able to quickly provide ATM, Frame Relay and ADSL[87].

In Germany we are not yet aware of any major pushes to replace end user switches by softswitches[88].

The main "pro" argument of softswitch advocates rests on flexibility and costs. Obviously, softswitches allow easier provisioning of individual customers and easier service creation and they are much cheaper than traditional circuit switches. Sweeney (2001, p.36) reports a cost advantage of softswitches of five to one. A European manufacturer has shown us internal calculations showing that a complete transition of a given PSTN network to a softswitch based NGN architecture will lead to a reduction of investment costs by 50-60 % and to a reduction of operating costs by 80 %. According to internal information from at least one Canadian carrier we know that it also is

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[84] 43 % of IXC respondents said they had deployed softswitches with live customers in at least one office – and 50% of all IXCs said they had committed plans to deploy softswitches. 66.7% of RBOC respondents said they had done major deployments – and 100 % said they had committed plans for future deployments. None of the other ILECs or national wireless carriers surveyed said they had done major deployments, but larger ILECs may be the next adopters. 40% of large independent operating companies (e.g. Sprint, Alltel) said they had committed plans to deploy softswitches – and 66.6% of IOCs with 20,000 to 100,000 lines said they had committed deployment plans.

[85] The main idea behind this is to save costs by moving long-haul traffic destined for the Internet off more expensive circuit connections. Thus, this makes sense for carriers relying on IP transport of voice in the long haul. See Sweeney (2001).

[86] We have learned from discussions with manufacturers that softswitches are deployed mainly to provide VPN solutions, IP Centrex solutions or call centre applications. Alcatel e.g. is offering softswitch based PBX applications in the context of VPNs, see Uebele and Verhoeyen (2001, p. 89). In the USA one can find shop assistant solutions based on softswitches. These applications are offering e-commerce customers to get telephony-based information support by a click of a button.

[87] See Sweeney (2001, p. 38).

[88] Some City Carriers in Germany like the one in Magdeburg and Cologne are using a (two-way) cable-TV (hybrid fiber coax) infrastructure not only for offering television services but also telephony and Internet access. The City Carrier in Magdeburg e.g. uses the H.323 protocol to provide VoIP.

planning a migration to Softswitch based NGN network architectures. One of the main arguments in favour of NGN deployment with this carrier is that NGN "enables lowering capex to less than 20 % of sales in future"[89].

There are several "cons" against (an immediate deployment of) softswitches. Firstly, traditional network operators often underline that there is no urgent necessity to invest in softswitching products. Moreover, they use the argument that investments made so far in "old" technology is not fully depreciated by now. Secondly, we have heard doubts that today's softswitches are capable of meeting specific regulatory requirements like guaranteeing interception[90] and emergency calling. Thirdly, it is foreseeable that softswitches never will be able to replace all the functions (i.e. the entire feature set) of a traditional circuit switch (numbering in the thousands). Softswitches today support a feature set of below hundred[91]. Fourthly, deployment of softswitch technology has been hampered in the past two years by the burst of the telecom bubble at the stock exchange. This is destroying incentives to move to new technology platforms not the least because demand for next generation (broadband) services still is not there[92].

Recently, two new studies were, however, reporting a rise of the softswitch market in the coming years where the USA remains the focus of softswitch developments[93].

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[89] Proprietary information by a Canadian carrier which likes not to be identified.

[90] This means tapping of lines backed by law and ordered by judges.

[91] According to manufacturers only a small portion of these features is "essential". Thus, the argument goes that there is a rather limited set of necessary supplementary features which have to be supported by a NGN solution. Following these views the development and supply of call features will be much more market (demand) driven in the future than in the past.

[92] See Wilson (2003).

[93] See www.pnewire.com, December 2002/January 2003. One study cited is estimating the worldwide softswitch market to reach US$ 1.3 bn in 2006. The other study cited is more ambitious and is expecting softswitch shipments standing at US $ 450 m in 2001 to reach US$ 4.4 bn by 2007.

7 Current ITU work on issues regarding the actual implementation of NGNs

Chapter 3 has presented the basic building blocks which in all likelihood will characterize NGNs. However, the NGN outlined so far first and foremost should be understood as a concept. There are still a lot of open issues to be sorted out regarding the actual implementation of NGNs, the interworking of NGNs and the interworking of NGNs with traditional telecommunications networks. Thus, we will see that there is still a necessity to develop further definitions and concepts as well as a requirement for standardization. We focus on work the ITU currently is undertaking in the frame of its NGN 2004 Project, see ITU (2003).

The ITU deals with NGN issues in a frame characterised by the following objectives:

- Promote fair competition,

- encourage private investment,

- define a framework for architecture and capabilities to be able to meet various regulatory requirements,

- provide open access to networks,

while

- ensuring universal provision of and access to services,

- promoting equality of opportunity to the citizen,

- promoting diversity of content, including cultural and linguistic diversity,

- recognizing the necessity of worldwide cooperation with particular attention to less developed countries.

Apart from the objective to define a general framework model (see chapter 3.1) ITU (2003) has defined several additional study areas regarding NGN:

- Functional architecture models for the NGN,

- End-to-end Quality of Service (QoS),

- Service platforms (APIs),

- Network Management,

- Security, and

- Generalized mobility.

Functional architecture models for the NGN are to concentrate on architectures and protocols. The ITU emphasizes that issues to be dealt with are

- generic reference modelling techniques the use of which should help to identify additional standards needed to support NGN compliant communication establishment services either within an operator domain or in between operator domains,

- interworking functions supporting the use of "old" (i.e. non-NGN) terminal equipment,

- functionalities of NGN capable terminal equipment,

- support of end-to-end service, call control and user mobility across heterogeneous networks.

End-to-end Quality of Service

The ITU argues there should be a distinction between telephony QoS aspects and those related to multimedia services. Obviously, as to telephony already today the work is almost complete. Regarding multimedia services, however, work is needed with respect both to a framework and the individual media streams (like e.g. video). Thus, according to the ITU work on end-to-end QoS should focus on:

- an end-to-end QoS class definition for telephony including voice over packet networks where the already existing body of standardization has to be completed,

- a new end-to-end multimedia QoS class definition framework and a method of registering QoS classes of individual media components,

- the use of lower layer QoS mechanisms to achieve upper layer QoS within the network,

- inter-domain lower layer QoS control, and

- end-user perception of QoS.

Service platforms (APIs)

Chapter 5 has made clear that NGNs entail a fundamental change regarding service development and provision in communications networks. It is obvious that it is in the best interest of users (end-users and service providers alike) that the required service platforms have open interfaces. Moreover, it seams reasonable to claim that the services should be accessible to end users while they are roaming between different networks. Likewise, end-to-end services should be available to end users independent of the networks and the service providers, respectively, to which the users are connected.

According to the ITU work on service platforms therefore should in particular concentrate on:

- service control architectures,

- mechanisms to support provision of services across multiple networks covering both roaming and interconnectivity of services,

- mechanisms to support user presence and user control of service customization and profiles,

- service platforms and user mobility.

Network Management

NGN in all likelihood will bring about the requirement to enable the interworking of a multitude of different network types (e.g. fixed and mobile; packet-switched and circuit-switched) entailing increasing complexities regarding the management of these networks.

According to the ITU work on network management should therefore in particular cope with

- enhancement of the overall core network management architecture,

- basic network management services and interfaces to meet NGN requirements regarding e.g. fault, performance, customer administration, accounting and charging as well as traffic and routing management.

Security

Network security in a NGN environment has several dimensions and it is foreseeable that it interrelates with network architecture, QoS, network management, billing and payment, and mobility.

According to the ITU NGNs should provide the security mechanisms to protect the exchange of sensitive information over their infrastructure, to protect against the fraudulent use of the services provided by Service Providers, and to protect their own infrastructure from outside attacks. Work on security should therefore especially focus on:

- the development of a comprehensive security architecture,

- the design of operational security guidelines,

- the development of NGN specific security protocols and Application Programming Interfaces (APIs).

Generalized mobility

It is worth to be noted that, unlike EURESCOM in its NGN Reference Model presented in chapter 3, the ITU has defined "mobility" as one of the additional key characteristics of NGNs. "Mobility" in this context means that users are allowed "to use and manage consistently their services across existing network boundaries", ITU (2003, p.5). In personal communication with ITU experts we have learnt that the ITU uses mobility as a general and broad concept, i.e. it is to encompass situations where the terminal device is physically mobile, the user is mobile with respect to the terminal device, and the terminal device is mobile with respect to network access.

The ITU therefore calls for the following requirements for mobility: users

- should be able to change access points or terminals,

- can be marked as mobile ("nomadic users")[94],

- get access from each network access point independent of the specific access technology used,

- get their services in a consistent manner (however, depending on the constraints they experience in an actual situation), and

- the users' availability and reachability should be known to network functions and possibly also to services and applications, including those provided by a third party.

It is foreseeable that securing general mobility globally several new network functions have to be developed at the control layer. ITU (2003) specifies in particular

- identification and authentication mechanisms,

- access control and authorisation functions,

- location management,

- terminal and/or session address allocation and management,

- user profile management, and

- access to user data.

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94 This implies that the mobility management functions are applied only to users marked as mobile.

8   Challenges for competition policy and regulation

Chapter 8 aims at addressing issues generated by (the migration to) NGNs which in our view are important items on the future agenda of competition policy and regulation, respectively, in the telecommunications market. This chapter focuses on:

- An appropriate frame to assess access to and interconnection of networks and network functions in a NGN,

- market definition and vertical integration,

- essential facilities,

- a frame of an unbundling policy,

- interconnection issues in IP-based networks, and

- interoperability of networks, services and applications.

Apparently, we are mainly concentrating on two topics in this chapter: unbundling and interconnection. Unbundling and interconnection policies have been crucial for the development of competition in today's telecommunications markets. In our view, it seems therefore important to focus on the relevance of these two issues in a NGN environment and challenges for policy to deal with them appropriately.

Of course the selection of topics discussed in this chapter and identified to be relevant for future competition policy and regulation, respectively, is not meant to be exhaustive. It is for example obvious that at least some of the topics presented in section 7 will also be of crucial relevance for making competition working and securing user benefits regarding NGNs even if the primary technical work currently being on the agenda of the ITU has been finished successfully. This holds true e.g. of end-to end Quality of Service. The role of policy in this respect might be to monitor the respective standards and to prevent quality of service degradation of "big" players against "small" players.

8.1   Access to and interconnection of networks and network functions in a NGN: general concepts

Generally speaking, we have seen so far that the future of telecommunications will take place in a multi-operator, multi-service provider and multi-vendor environment of communications networks, information processing equipment, databases and terminals. All of these components have to work together and, thus, interconnection and access to interfaces and protocols of the network infrastructure plays a crucial role.

In this sub-section we tackle these issues from a rather abstract perspective. We present here an overview of the guidelines the standardisation entity of ITU (ITU-T) so far has passed. The ITU's recommendations in this respect are focusing on so called Reference Points for Interconnection (RPIs) in a GII environment[95].

Figure 8-1 gives an illustration of potential RPIs in NGNs. These RPIs need not necessarily be already available today. Moreover, interconnection in this context shall be understood in a purely technical sense with no actual regulatory background. Thus, tacitly ITU's term interconnection encompasses also possibilities of unbundling.

The left hand side of the figure is to describe a world in which all parts of the telecommunications network are operated by an highly integrated entity (single player, multiple role). On the right hand side of the figure a situation is depicted in which several operators provide a telecommunications network each with a specific role (multiple players, single role).

At the bottom of the left-hand side there are terminal devices of end users linked to the local network comprising the access network and the local switch. The local network is connected to the long distance network, especially to a transit node. Local and long distance network are connected by physical transmission facilities and they have a common management system.

In the disaggregated world on the right hand side we have a customer network at the bottom connected to another access network which in turn is connected to another local network and finally to another long distance network[96]. Apart from this physical (inter)connection the figure illustrates in addition types of connections to the network by specific service providers or brokers (see the far right hand side of the figure). ITU distinguishes at least three types of service providers or brokers[97] (SP):

- SP Class 1 denotes providers connected to the network like a "normal" end-user, but offering a service to the public (e.g. video on demand). The main characteristic of this SP is that he buys network transport functions as in the case of usual telephone calls and uses the basic network product to add own services or service features independently of the network operator. However, it is assumed that billing and service control functions will be handled directly by the terminal equipment after the call (i.e. the transmission path or "route") has been established.

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95 Reference Points for Interconnection first and foremost are physically and logically feasible points of interconnection. This does, however, not necessarily imply that they are also feasible and reasonable from a business point of view. See chapter 3 for further information on the work of the ITU regarding NGNs

96 Actually from a theoretical perspective there can be several other access networks as well as other local networks as well as other long distance networks.

97 Brokers can have e.g. the function to provide for handling traffic peaks in the network by broking with backbone network capacities.

Figure 8-1: Reference Points of Interconnection

Multiple Role, Single Player

Single Role, Multiple Players

LDN Management

Other Long Distance Networks

SP / Class 3

SP / Class 3

Transit Node (Note 2)

Long Distance Network

LN Management

Common LDN and LN Mgmt.

Other Local Networks (Note 1)

SP / Class 1

SP / Class 2

SP / Class 3

Local Network

Local Node (Note 3)

AN Management

Other Access Networks (Note 1)

SP / Class 2

SP / Class 1

Access Network

CN Management

SP / Class 1

Customer Network

——— carry user plane and control plane information   ············ carry management plane information

(◎) Conceptual Reference Point for Interconnection cRPI

Note 1 This could use, e.g. twisted pair, coaxial cable, wireless and support ATM, FR, IP, etc.
Note 2 Transit Switch and/or Router
Note 3 Initial point of attachment (Service Node/ Local Switch)

cRPI a Point of connection of a customer to a public network
cRPI b Initial point of connection to a switched network, i.e. to gain access to switched services
cRPI c Point to connect a SN to other SNs or to services of the Transit Network
cRPI d Point of interconnecting Transit Nodes
cRPI e Point to connect an SP/broker class 2 to a (transport) network
cRPI q Point to connect a network to its management system/TMN
cRPI x Point to interconnect Management Systems/TMNs

Source: ITU (2000)

LDN = Long Distance Network, LN = Local Network, SN = Service Node, AN = Access Network, CN = Customer Network

- SP/Broker Class 2 comprises providers using a "special access", i.e. using at least some control functions of the network. The service could also be video on demand but additionally the SP has access to some network functions e.g. reservation of transport capacity or billing via the original network provider (the facilities based operator).

- SP/Broker Class 3 is defined by SPs which have only access to some network internal functions. To interact with a user this SP does not necessarily make use of the transport facilities. Rather, he is offering only a service like e.g. for third party billing or directory answers. Another example is a content provider who needs direct access to parts of the network management of a network operator in order to be able to put his product on the network and to handle bandwidth reservations for and interactive requirements of their customers. In order to be able to perform these tasks he may, thus, need access to internal network data or functions, yet, there is no need using the "normal" transport facilities of the network.

The main messages of this figure are as follows:

- Firstly, in the NGN world there are a multitude of interconnection points which are at least conceptually feasible. Interfaces can exist both within the core network(s) and close to the user or even within the user's terminal equipment[98].

- Secondly, in both worlds there are interconnection points between terminal equipment/customer networks and access network(s), local network(s) and long distance network(s) as well as between different long distance networks, see RPIs a, b, c, d. RPIs c and d are known already today as interconnection points in a PSTN world. Viewed from a PSTN perspective RPI b could mean e.g. interconnection at the level of Class 5 end office switches. RPI a denotes an interconnection point located at the customer premises[99].

- Thirdly, in a NGN the main new RPIs are RPI e, q and x. These RPIs are required if SPs from the disaggregated world focusing only on specific roles are in the market. RPIe denotes a point where a class 2 SP is connected to a transport network. RPIs q and x come into play if access to the management system of the network is relevant. RPI q denotes a point where the transmission network is connected to the management system of the network. RPI x denotes points where two management systems are interconnecting.

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98 An example is if a terminal device gets additional software defined functionalities which it can exchange with the network.

99 Regarding the access network, the local node and RPIs a, b the reader is also referred to section 3.3. One can identify Vanston's customer node with ITU's RPI a and Vanston's central office with ITU's local node. Apparently, ITU's RPI b may denote both what Vanston calls end node and what he calls remote node.

ITU-T's objective is the standardisation of interfaces at these RPIs. ITU differentiates on the one hand between User-Network Interfaces (UNIs) and Network–(Network) Node Interfaces (NNIs). The first are located at the boundary of the network and the latter denote interfaces within the telecommunications domain. On the other hand in a NGN interconnection interfaces at a RPI have to take account of the layered structure of communication. This is illustrated in Figure 8-2.

Figure 8-2:   Lower and higher layers of the protocol stack associated with an interconnection interface at a RPI
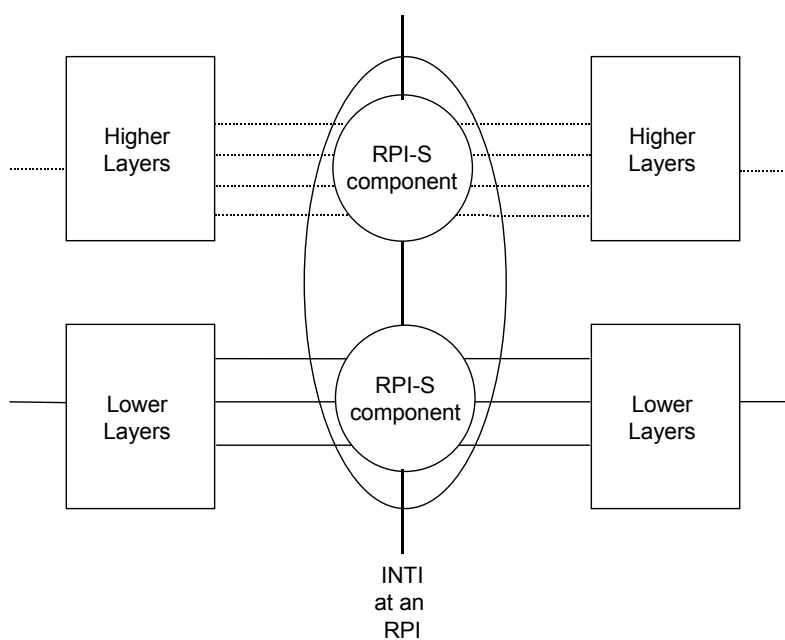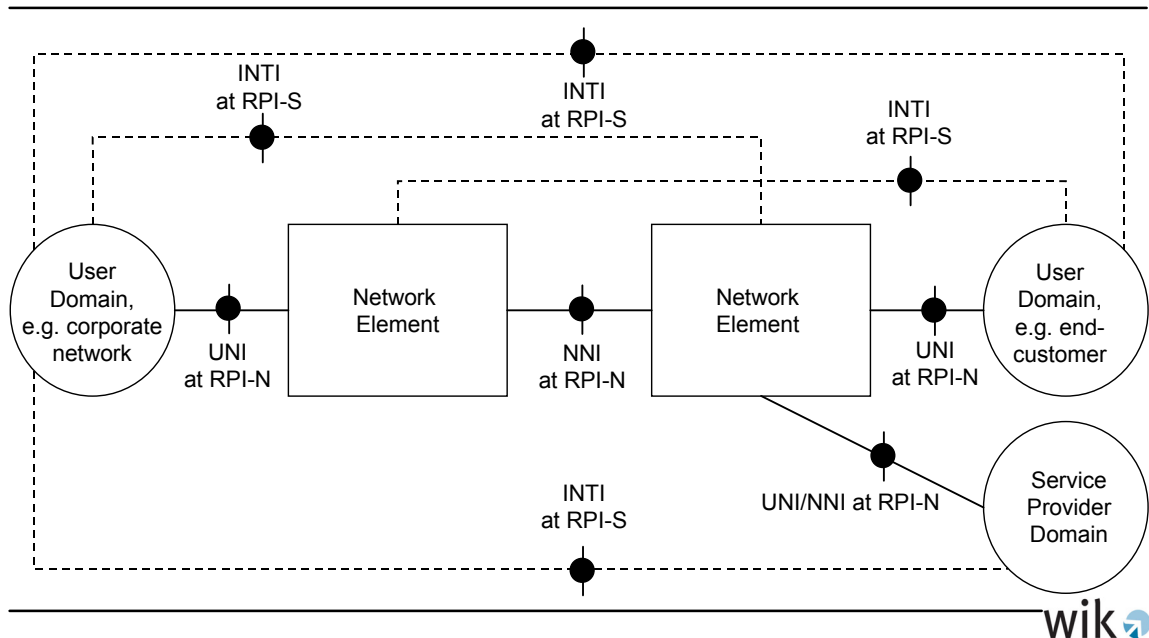

Source: ITU (2000)

Figure 8-2 is to give a general reference configuration for a multi-layer RPI. The figure shows that basically an interconnection interface (INTI) at a RPI may consist of two components: a network related RPI component (RPI-N) based on lower layers and a service related RPI component (RPI-S) related to higher layers. Otherwise stated, it is assumed that a given interconnection interface has its own inherent network component and its service component and the lower layers of the RPI are to transfer transparently interconnection information on higher layers.

The challenge then will be to provide for multi-player independence in this multi-layer service provision environment. This requirement may lead to a situation visualised in Figure 8-3.

Figure 8-3:   Network and service related interfaces to enable interconnection in
                         a NGN

Source: ITU (2000)

The figure has two main messages.

Firstly, the figure makes clear that one can functionally distinguish if an interconnection interface is related to the network (INTI at RPI-N) or related to the service component (INTI at RPI-S)[100]. Thus, one can see that e.g. there are network related interfaces between the user domain on the right and on the left hand side and the respective adjacent network elements (UNI at RPI-N). Likewise there is a network related interface between the service provider domain and the network element on the right hand side (UNI/NNI at RPI-N) as well as between the two network elements (NNI at RPI-N). Service related interfaces can be between the two user domains (i.e. end customer, corporate network), between the service provider domain and the user domain (corporate network) as well as between the user domain (end customer and corporate network) and a (non-adjacent) network element. ITU concludes that this functional differentiation has a crucial implication viewed from an institutional perspective. Provided a RPI-N has a real standardised interconnection interface associated with it carrying higher layer interface protocols for a RPI-S, the provider of the interface associated with the RPI-N is not necessarily responsible for the corresponding interface associated with the RPI-S.

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100 In the latter case it is a-priori not clear where the interface is exactly located, rather, the higher layer protocols may be observed at any intermediate lower layer interface which is used to carry the protocols transparently. ITU suggests, that conceptually one might relate the service related interface to the two end-points of such higher layer protocols.

Secondly, with respect to the parties involved the figure makes clear that there might be several different interconnection types:

- Interconnection between the networks of two public network operators,

- Access and/or interconnection of a service provider to a public network operator,

- Access and/or interconnection of a private corporate network to a public network operator,

- Access and/or interconnection of an end user to a network and/or service.

ITU (2000) underlines that from a technical point of view interconnection can take place vertically or horizontally. Especially with respect to securing Quality of Service (QoS) this will have crucial impacts on the players on both sides of the interface. In this context "vertical" protocols are to link the upper and lower layer QoS mechanisms and a "horizontal" mechanism is to link the lower layer QoS control between different domains and networks, see ITU (2003, p. 4).

To sum up, firstly, in the NGN there will be a far greater number of at least technically feasible interconnection points. Secondly, interconnection will be demanded by a far more differentiated number of entities (public network operators but also service providers and end-users). Thirdly, interconnection may have to take account of different protocols and the layers to which they are associated.

It seems worth to be noted that the ITU will continue to work on the preceding issues in its NGN 2004 Project, see ITU (2003). Providing further guidelines on how to define a functional architecture for NGNs is defined as one of its main study areas. The objective is "to decompose a NGN into an appropriate set of functions. Relationships and connection between functions will be shown in terms of reference points" (ITU (2003, p.3)) which, in turn, are candidates at which interfaces could be defined.

8.2 Market definition and vertical integration

In view of the multi-operator, multi-service provider and multi-layer environment of the NGN in which there is a much higher potential to create new services and applications by decentralized entities it is highly likely that new markets will arise. Thus, inevitably the necessity will arise to scrutinize today's market definitions with respect to telecommunications markets. Candidates for new markets are

- The layers of the NGN environment, i.e. the access and transport layer, the media layer, the control layer and the network service layer (see Figure 3-2).

- It might very well be the case that there will be a hierarchical structure within each of the mentioned four layer(s) of the NGN environment, thus, giving room for additional (sub-)markets. Two examples may make this assertion clearer. Firstly, it is plausible for the access and transport layer where one might speak of access[101] and backbone markets. As long as PSTNs are still present it might in addition be reasonable to differentiate between local, long distance and international markets. Secondly, the examples of potential future service provision in NGNs presented in section 5 underline that also on the network services layer sub-markets might be reasonably defined.

- Moreover, section 3.3 on the long-term evolution of the local exchange network shows that in all likelihood there will be several different architectures (comprising different transmission and switching/routing equipment) enabling access of residential and business customers to the network. Future policy has to scrutinize whether operation of these network facilities mainly located on OSI layers 1 and 2 might constitute a distinct market. In addition, focusing on the network layer and an end-to-end packet switched (e.g. all-IP) world it seems to be worth to investigate whether a separate access market (e.g. the connection between the terminal equipment and the edge router of the customer's ISP)[102] and a market for IP backbone services[103] can be defined.

Within these potential new markets presumably many requirements for access to and interconnection of resources (networks, network services, protocols etc.) will arise. Thus, vertical integration of market players becomes a crucial issue.

Broadly speaking, vertical integration takes place if two or more separable stages of the production process belong to the same economic entity. If markets are competitive, vertical integration virtually poses no competition or efficiency problems because integrated and non-integrated entities are competing to each other on a level playing field. Problems with vertical integration always arise if a single company has a dominant position on one production stage. The reason is that in this case the dominant firm has an incentive to discriminate against competitors regarding access to the (near) monopoly resources. The dominant firm can e.g. try to restrict access to the resource,

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[101] Focusing on market definitions in the new European regulatory framework for electronic communications based on current technologies de Streel (2003, p. 34) argues that it is appropriate to define both a retail market for narrowband access and for fixed broadband access where the latter is to comprise all substitutable available technologies such as telecom and cable infrastructure. Especially with respect to the latter market the author stresses that it is not identified in the recommendations.

[102] It is worth to be stated once again that in a fully fledged NGN environment the access market is not (only) related to the traditional (physical) access network, rather access generally will be a broader term and encompasses physical access and service oriented access.

[103] A comprehensive discussion of IP/Internet markets has taken place in the course of the recent MCI/Worldcom and Worldcom/Sprint merger cases, see e.g. EU Commission (1999) and US Department of Justice (2000). With regard to an economic and technical appraisal of IP backbone markets see Elixmann and Scanlan (2002).

to offer unfavourable terms to competitors (e.g. by cross-subsidizing services) or by degradation of Quality of Service. Abuse of market power of a vertically integrated firm can only be avoided if and only if all companies have non-discriminatory access to the resource.

In a NGN world vertical integration might come into play from two perspectives:

- Companies are active on two or more layers of the NGN environment (see above).

- There is a hierarchical structure within one or more of the mentioned four layer(s) and a company is active on two or more stages of the hierarchy[104].

It is far too early to assess today the economic viability of business models in a NGN environment and, thus, it is beyond the scope of the present paper to make an assessment of the actual extent of vertical integration in the future.

In this context the paper by Kavassalis et al. (1997) is relevant. The authors have dealt with the issue of vertical integration although not explicitly focusing on a NGN world. Rather, essentially they focus on a four layer world consisting of

- a "bearer service" (practically IP, i.e. an abstract bit-level service on top of networking technology like ATM, Frame Relay etc.),

- a "transport service" (e.g. TCP),

- a "middleware service" with functions like file support system, privacy assurance, billing and collection, network directory services etc.) and on top of that

- "applications".

Their main focus is if there is a sustainable market for bearer services in the absence of vertical integration. Their conclusion is "yes" and in particular, they argue that the bearer service will not become a commodity product. In addition they conclude that the ability to vertically integrate to absorb the bearer service is possible.

Thus, it is likely that competition policy and regulation, respectively, tomorrow will have unprecedented vertical integration issues in a NGN environment on the agenda. In particular, it has to be scrutinized if particular network elements and services, respectively, are controlled by a dominant provider and if service providers are discriminated with respect to their input demand.

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104 One might call the second case also horizontal integration, see Arnbak (2000, p.482).

8.3   Essential facilities

Regarding unbundling the issue of essential facilities is crucial[105]. Simply speaking, if NGN network elements or functions controlled by a (quasi-) monopoly provider are necessary to offer innovative services and applications, yet, it is not technically or economically feasible to duplicate them, a regulatory policy obliging the operator controlling the network to provide these elements and functions unbundled might be necessary. Access to essential facilities of a dominant firm is an important prerequisite for the establishment and support of competition[106].

In the following we focus on the issue whether different components of a NGN might constitute essential facilities. It is too early to derive actual implementation patterns of NGNs and we therefore do not intend to give definite answers, rather, we are aiming at setting up an agenda for more thorough examinations in the future.

Access to a transport platform

It is highly likely that there will be no limitation regarding access to a bearer service platform (e.g. IP platform) in the future. However, this general statement holds true only with regard to "pure" access. If one takes into account that future IP networks will be much more characterized by different QoS service classes there might be limitations to availability. Yet, we believe that provision of high-quality access services mainly will be a matter of price (and the respective Service Level Agreements)[107]. This assertion does not preclude competition policy concerns and the necessity for respective actions if the strong position national telecommunications incumbents today have in the market carries over to the future. Moreover, ensuring QoS in a NGN environment might rest on access to OSI layers below IP, see below.

Transport of packets

With regard to (up-stream) transport of IP packets Kolesar and Levin (2002, p. 11) argue that it is not clear that any essential facilities exist on a packet network and they view in particular the development of the Internet as consistent with the absence of

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[105] Several studies have dealt with the foundations of this concept and its applicability in the telecommunications market; see e.g. Haas (2000), Höckels (2001) and Rottenbiller (2002).

[106] With respect to traditional interconnection and unbundling policies in PSTN/ISDN networks there is a widespread debate if only essential facilities are to be mandated or if a broader policy mandating also unbundling of non-essential facilities is to be applied. Current regulatory practice in North America and Europe is based on the broader policy approach. In the USA a detailed list of network elements to be offered unbundled has been introduced since the Telecommunications Act of 1996. The specific form of unbundled access to distinct network elements in the USA can be viewed as a close substitute for resale, see Vogelsang (2002). In Europe the EU Commission has made different forms of unbundling mandatory as well as access to network parts, see Höckels (2001, section 8).

[107] We have, however, heard complaints from ISPs in Germany and Switzerland acting as access providers pointing out that the incumbent who provides the IP transport platform degrades QoS from time to time in an unforeseeable way.

essential facilities[108]. We basically agree to this argument as long as it is essentially concentrating on OSI layer 3 and 4 conditions in the market. However, in our view Kolesar and Levin's assertion does not necessarily preclude challenges for competition policy regarding access to necessary input resources in a NGN environment on lower layers, see below. Vanberg (2003, pp. 23) pursues a more disaggregated view regarding components making up "Internet connectivity"[109]. She differentiates between the (1) operation of Internet Exchange Points, (2) the operation of routers, (3) maintaining routing tables, (4) the operation of DNS servers, (5) the allocations of IP addresses to networks and (6) software for establishing and managing logical connections, the fragmentation and reassembly of data messages, monitoring network performance, and for transmission error control as well as flow control. Her main conclusion is that her analysis "did not disclose any regulatory requirements for … core elements of Internet service provision. These network elements … do not show characteristics of monopolistic bottlenecks", see Vanberg (2003, p. 35).

Termination of IP traffic to an end user

Termination in a NGN environment, i.e. the IP link between the last router and the end user might constitute an essential facility, see the discussion in section 8.5 and 8.6.

Call servers and gateways

A call server can be placed anywhere in the network provided there is access to IP. Based on our interviews we believe that access to call servers will be no critical issue. Two arguments underline this assertion:

- Firstly, obviously there are sound incentives for non-facilities based providers to buy and deploy them themselves. One argument is that only in this case service providers have enough control to specify their services and applications. Yet, due to vendor specificities of the facilities it might very well be that service providers to some extent are dependent from specifications of network operators.

- Secondly, investment costs of call servers are relatively low compared to other investments. The expectation is that these costs will be further diminished in the future due to technological progress and the fierce competition on the manufacturing market, see also Arnbak (2000) and Kolesar and Levin (2002).

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[108] A similar conclusion is drawn by Vanberg (2003) who argues that "the claim of market power in the Internet backbone industry is not substantiated by monopolistic bottlenecks in backbone network capacity".

[109] Vanberg actually investigates three sub-markets of Internet service provision: the sub-market for local network access and long-distance network capacity (the network level), the sub-market for Internet connectivity, and the sub-market for Internet applications and customer relations.

Likewise, following the manufacturing industry mainstream opinion there is obviously an incentive to own the gateways at the interface between networks of different nature and the preceding arguments also apply in this case.

All in all, call servers and gateways can be viewed as a minimum requirement of infrastructure to offer innovative services and therefore are not likely to become essential facilities.

Access to facilities on layers below IP

The basic reference model for NGNs presented in chapter 3.1 basically consists of different network devices connected by a packet switched network. Moreover, NGN's in all likelihood will be characterized by a four layered model (chapter 3.2), the lowest of which is the access and transport layer. It seems obvious, that the latter, in turn, will encompass both the packet switched network as such (i.e. in today's terms the OSI layers 3 (IP) and 4 (e.g. TCP)) and facilities located on lower OSI layers.

Indeed, the scenario of the evolution of the local exchange network presented in chapter 3.3 might clarify what is meant by this assertion. Chapter 3.3 shows that in the long-run one can expect that the (higher-level) IP networks will mainly be served by a (lower-level) optical transport network encompassing Wave Division Multiplexing (WDM) switches and WDM multiplexers. Moreover, residential and small business customers will be served by so called "deep fiber systems", i.e. Very High-Speed Digital Subscriber Line (VDSL), Fiber- to-the-Premises (FTTP), or Advanced Hybrid Fiber Coax (AHFC) systems. Moreover, it is expected that direct communication via DWDM technology and MPLS will become the prevailing mode of communication.

We see therefore several items on the agenda of future competition policy and regulation, respectively. It will have to be scrutinized

- if and where optical transport and switching network facilities[110] might constitute an essential facility,

- if the establishment of deep fiber systems requires access to essential facilities, and

- if the establishment of particular QoS levels in a NGN environment can be restricted to the IP level or if this requires access to facilities below IP which are essential.

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110   This might relate both to specific optical devices and optical channels. Essential facilities might come into play e.g. if two ISPs are involved in a private peering relationship, see chapter 8.5.1 on peering. Today it is usual that local leased lines are used to link the POPs of two ISPs. Often neither ISP has deployed the respective physical transmission infrastructure at this local level, rather, they have to lease the link from a third party. The market for leased lines, however, is not necessarily competitive in sub-urban or rural areas. Thus, the issue arises how important private traffic exchange between ISPs will be in the future and how it is carried out in a (all- or mainly-) optical world.

Of course, the analysis of these issues will depend on actual technical developments, on actual deployment of network facilities of different market participants and on actual business plans of players in the market.

Network and service related interfaces

We have seen in section 8.1 that it is likely that market participants in a NGN environment not only need access to/interconnection with physical (technical) facilities, rather, they will need access to/interconnection with distinct network functionalities, e.g. regarding the signalling (control) plane, the network management[111] plane and the application layer, including software interfaces.

In our interviews with manufacturers we have in particular discussed if (functionalities of) routers or switches could become essential facilities. However, we could get no definite answer. To make a judgement on this matter becomes even more difficult as it is foreseeable that more and more functionalities are shifted into terminal equipment and operating systems, respectively.

Thus, in our view it is too early even to try to give an assessment if these interfaces may constitute an essential facility. NRAs have to deal with this aspect if respective NGN network structures have been further deployed[112].

Access to locations of facilities

Notwithstanding that it is not yet clear where logical interfaces in the network and physical facilities like e.g. gateways are actually located, locational aspects may become crucial in the future NGN environment. At least an obligation for a market dominant firm to provide collocation or other forms of common utilisation of facilities like buildings might be reasonable[113].

Numbers, names and addresses[114]

IPv4 addresses are a scarce resource. Failure to treat them as such in the past has lead to pending address exhaustion and the need for the Internet Community to adopt a new addressing scheme before the end of this decade. However, Elixmann and Scanlan (2002) come to the conclusion that despite the fact that the efficiency costs

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111 Network management functions are e.g. diversion of traffic in peak periods, maintenance of the routing table, billing and selection of traffic which is accepted.

112 Denton points out that in the current interconnection and unbundling regimes it is not possible to buy or lease network elements unbundled according to the layers built in the protocols of the Internet. He suggests that in order to make available the functionalities of the Internet to all one needs a form of unbundling appropriate to the Internet, i.e. one needs unbundling the network and data link layers of the PSTN. Only in this case competition is enabled in an Internet area. See Denton (1999, p.16).

113 Article 12 f) of the EU Access Directive takes account of this, see EU (2002). Regarding the location of nodes in future local access networks and the equipment hosted in these locations see chapter 3.3.

114 See Elixmann and Scanlan (2002, chapter 6.3).

entailed in this could be considerable the adoption of IPv6 appears unlikely to cause significant disruption, and thus to require official involvement to facilitate transition.

Providers are controlling access to their customers via numbers and addresses. Data about customers like numbers and IP addresses are indispensable information for each provider in the market. Access to this information is crucial. Viewed as a resource numbers and addresses constitute essential facilities. Thus, there need to be publicly available directories and providers controlling these resources should be obliged to provide interconnection to enable any-to-any connectivity[115]. Data protection regarding numbers and addresses will become an important and difficult issue on the regulatory agenda, in particular because (geographical and network) cross-border aspects are involved. Topics to be discussed are e.g. the right of a user to be not listed in the directories, the transfer of addresses across network borders etc.

8.4 Frame of an unbundling policy

It is highly likely that a dominant firm in a NGN environment has an incentive to bundle network functionalities and to manipulate network elements and interfaces, respectively, to limit the flexibility of competitors to develop new services and applications. Thus, unbundling might remedy this situation. Moreover, one can argue that a far reaching unbundling policy with regard to network elements, services, functions etc. limits the room for establishing a dominant position.

In the following we will not discuss if and to what extent unbundling is actually necessary in a NGN environment. A prerequisite to this issue would be to determine actual essential facilities ("bottlenecks"). Moreover, as in traditional circuit switched networks, a policy decision has to be made regarding the scope of the unbundling policy, i.e. if the unbundling policy should cover unbundling of non-essential facilities[116]. We therefore restrict ourselves to discuss a frame in which an unbundling policy should be developed. The decision if a firm, which perhaps is dominant and vertically integrated, should be obliged to give other network and service providers access to its network (elements and services) and how this should be implemented has to take account of several arguments.

Integrity of the network

The more open a network system is to which different network operators and service providers have access the more the issue of data security and integrity of the network

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[115] The EU Access Directive points out: "Network operators who control access to their own customers do so on the basis of unique numbers or addresses from a published numbering or addressing range. Other network operators need to be able to deliver traffic to those customers, and so need to be able to interconnect directly or indirectly to each other." See EU (2002, No. 8).

[116] See section 7.3.1.

arises. If a third party has access to a connection between A and B in a NGN he is in principle able to manipulate traffic e.g. by changing data (packets) or by diverting IP addresses. Thus, each entity which is obliged to give access to its own facilities and services has an inherent incentive to protect itself against manipulations and damages. A-priori one might expect that the security and network integrity issues can be sorted out on the basis of private contracts between the partners.

However, there should be a legal frame in which this takes place[117]. In particular we see a need for specifying conditions to exclude "non-qualified" entities. The less successful a market solution is generated the more relevant it is that public policy enforces and monitors data security and integrity of networks.

Technical neutrality

A key objective of regulatory policy is to be technically neutral. We have seen above that at least for the time being one can expect that NGN solutions are only standardised "to some extent", i.e. there is plenty of room for vendor specific service features and perhaps also architectural features of the network[118]. Thus, it seems that the scope for regulatory intervention regarding unbundling is limited unless regulatory policy accepts willingly to become involved in investment policies of the entities to be regulated.

Somehow related to this argument is technological progress. Technological progress in the field of IP-based network technology has been very dynamic until today[119]. Product life cycles are much shorter than in the past regarding PSTN networks. Otherwise stated, each entity deploying hardware and software into the NGN has a much higher risk of technological obsolescence of the facilities and, thus, in a competitive environment the need for new investments in a relatively short period is increasing. This development might therefore be in conflict with a mid- to long-term stable and non-discretionary regulatory policy.

Regulated entity

It can be expected that unbundling in a NGN environment will become much more complex in particular if distinct network services can be demanded unbundled. This will affect the number of entities potentially involved in regulation. At least theoretically an established network operator can e.g. outsource network management functions to a distinct entity which has the functional sovereignty over the latter. A service provider might have a partial functional sovereignty over parts of the network related to the end user. Thus, the number of entities involved will crucially depend on the actual interface

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[117] See also section 7 and ITU's objective to specify operational security guidelines.
[118] In our view this holds true even if the ITU (or other institutions like ETSI) has finished its current work, see the issues outlined in chapter 7.
[119] Capacity of routers, i.e. the capability to deal with routing tables has increased enormously. Moreover, many innovations have focused on Quality of Service management, see e.g. McDysan (2000) and Minoli and Schmidt (1999).

to which unbundled access has to be established and thus, is likely to be greater than two.

Incentives to invest

The main argument against a broad unbundling policy rests on both the incumbent's and the entrants' (diminished) incentives to invest in infrastructure. Although not focusing explicitly on NGNs one can refer to Arnbak (2000, p. 483) in this context. He argues that imposing restrictions on dominant players of their lines of business inside an otherwise Open Space[120] may be deemed necessary to prevent dominant players from stifling competition. However, he underlines his assessment that such business restrictions have, in the past, tended to affect market dynamics in a counterproductive way. Arnbak points in particular to the development of mobile markets in the Nordic countries which according to him was led by incumbents subjected to the discipline of vigorous competition from new entrants[121]. One should, however, note that e.g. the case of the German fixed-link market shows that a relatively far reaching unbundling policy, implemented soon after the liberalisation of the market in 1998, by no means leads to a diminished investment activity of the incumbent. Indeed, Deutsche Telekom has massively invested in DSL access technology and Germany has by far more DSL access lines than any other EU Member State, see EU Commission (2002).

Likewise, regulatory policy should incorporate investment incentives of alternative providers in the market. The existence of access obligations should not limit the incentives to invest for these entities. The crucial issue is to what extent "open access requirements encourage firms to refrain from significant investment because they anticipate the ability to utilize the investment of their competitors"[122]. In this context the EU Access Directive points out: "The imposition by national regulatory authorities of mandated access that increases competition in the short-term should not reduce incentives for competitors to invest in alternative facilities that will secure more competition in the long-term."[123]

We emphasize that we don't see necessarily a trade-off between infrastructure and service competition, rather, they can be viewed as complementary. A competitor who has already established a customer base can make investments with less risk. In this context resale, i.e. the possibility to (re)sell services of a market dominant provider, can be viewed as a prerequisite for service competition. Due to roll-out limitations with respect to time and coverage resale competition can be a viable market entry strategy preceding the market entry based on infrastructure competition[124].

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120 "Open Space" in this context can be understood as NGN.
121 A similar critical stance regarding a broad mandated unbundling policy can be found in Kolesar and Levin (2002, p.4) who report in particular on the discussion in the USA after the 1996 Telecommunications Act.
122 See Kolesar and Levin (2002, p. 6).
123 See EU (2002, No. 19)
124 See Neumann (2002).

8.5   Interconnection in IP-based networks

8.5.1   General interconnection policies

Interconnection in IP-based networks follows very different practices compared to circuit switched PSTN practices. Two main approaches are known:

- Peering and

- Transit[125].

Peering

Peering denotes a bilateral business and technical arrangement between two ISPs who agree to exchange traffic and related routing information between their networks. An ISP will only terminate traffic under a peering arrangement which is destined for one of its own customers. Packets handed over at interconnection points that are not destined for termination on the receiving ISPs network, will only be accepted under a transit arrangement, see below[126]. Interconnection between peers does not involve monetary payment and therefore this type of interconnection is known variously as: "bill-and-keep"; "settlement-free" or "sender-keeps-all".

If packets are accepted under a peering arrangement (i.e. for termination on the peering partner's network), there is no charge levied by the accepting network. This reciprocity does not specifically require that peering partners be of equal size or have the same number of customers. Rather, it requires that both network operators incur roughly comparable net benefits from the agreement; with arguably the main elements being the routing and carrying of each other's traffic, and the benefits provided by access to the other ISP's address space. Thus, the implicit price for peered interconnection is the cost of providing the reciprocal service.

Transit

Transit is the most important means through which most ISPs obtain global connectivity. Transit must be purchased when one ISP wants to hand packets over to a 2nd ISP which are not for delivery on the second ISP's network, rather, they are for handing over to a 3rd ISP. In a transit arrangement, one ISP pays another for interconnection. Unlike in a peering relationship, the ISP selling transit services will

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[125] In the following we rely heavily on Elixmann and Scanlan (2002). Peering and transit are the two basic alternatives for interconnection in an IP world. However, in practice there exist mixtures between the two, see Elixmann and Scanlan (2002, section 5).

[126] If two ISPs peer they accept traffic from one another and from one another's customers (and thus from their customers' customers). Peering does, however, not include the obligation to carry traffic to third parties. See Marcus (2001).

accept traffic that is not for termination on its network, and will route this transit traffic to its peering partners, or will itself purchase transit where the termination address for packets is not on the network of any of its peering partner. As such, a transit agreement offers connection to all end-users on the Internet, which is much more than is provided under a peering arrangement. Even though many ISPs are multi-homed it is unlikely that any significant ISP acquires access to all Internet addresses through self-provision and a single peering or transit arrangement. Rather, ISPs will often enter into multiple transit and peering arrangements, more than is required to secure access to the entire Internet.

Development patterns regarding peering and transit

Peering has been the usual interconnection scheme during the Internet's initial development years. Thus, little attention was given to (metering) traffic flows and cost causation[127]. Internet traffic usually was exchanged at public exchange points. Since the mid-1990's, however, transit became more and more important. Refusals to peer have sometimes been looked on with suspicion by competition authorities in the recent past. Probably in part because of this history peering is often associated with the most powerful ISPs, i.e. those that are active on a supra-national level (mainly in North-America, Europe and the Pacific Rim). Today, it is virtually the only form of interconnection negotiated by core ISPs. There was a restructuring of interconnection 'agreements' in the mid 1990s whereby many firms have increasingly focused their peering relationships with organisations of similar size, requiring other ISPs to interconnect with them on the basis of (paid) transit contracts[128]. However, simultaneously in the last few years peering has proliferated at a regional level among smaller ISPs, i.e. ISPs that have transit contracts for a significant proportion of their traffic. Today ISPs who can offer each other similar peering values often choose to peer at a regional level.

However, it is fair to state that most interconnection arrangements (but not most interconnected datagrams) involving the Internet are now resting on a transit arrangement, i.e. there is a situation where the ISPs have to pay for interconnection.

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[127] In this context Frieden (2001) points out the significance of positive network externalities expressed by the so-called "Metcalfe's Law": the value and the utility of a network increases as the number of access points grows.

[128] The main argument of the large ISPs was that they need settlement fees from smaller ISPs in order to cover the costs of infrastructure investment to sustain growth, see Kolesar and Levin (2002, p.9). Frieden (2002) identifies several reasons why the original peering model of the early days of the Internet has changed. First, the number of ISPs has grown substantially. Second, ISPs have become more and more diverse, i.e. homogeneity was no longer existent. Third, only a small number of larger ISPs continued to expand their infrastructure both with respect to coverage and bandwidth. Fourth, congestion at public Internet exchange points have become more and more crucial. Fifth, especially in the USA the biggest tier-1 ISPs no longer could rely on reimbursements by the government.

8.5.2 Mandated interconnection arrangements

Regarding mandated interconnection obligations in an IP/Internet world there is a broad range of views and arguments in the literature. One can find proponents of a far reaching policy of imposing such obligations and proponents who virtually deny the necessity for such obligations.

Speta (2002) recently has published an analysis of Internet interconnection issues in which he came to the far-reaching conclusion that generally Internet carriers should be subject to mandatory interconnection obligations. Speta actually is focusing on the regulatory and competition law concepts of the USA and he is not focusing on NGN issues as such. Yet, his arguments basically carry over to a NGN world.

Speta's arguments rest on legal, economic and technical grounds. From a purely legal perspective he concludes that Internet carriers seem presumptively to be common carriers[129] and, thus, should be subject to some form of common carrier regulation. From an economic perspective he argues that two features underline that common carrier duties are to be imposed:

- De jure or de facto monopoly power.

- Network effects.

Speta argues that both the backbone and access markets are at least highly concentrated and that network effects, first and foremost obvious by the need of Internet Service Providers to sell access to the entire Internet to their customers, are very significant regarding the Internet. From a technical perspective Speta underlines that in each predecessor common carrier markets (like railroads and telecommunications networks) interconnection duties created the possibility of new services that used the carrier as an important input. As we have seen in the preceding chapters the IP protocol is an important bearer service and it is vital for NGNs and its ability to create the opportunity for the development of new applications.

Following Speta, there is, thus, a sound basis for common carrier regulation regarding Internet interconnection. Simply speaking, the main argument is that Internet carriers are simply the most recent form of carrier and all of their predecessors have been subject to some form of common carrier regulation.

Speta emphasizes that common carrier duties should be limited to interconnection and that a requirement on a carrier to unbundle its own network should not be imposed.

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129 Speta argues that the principal legal test for whether a company is a common carrier is whether they make their services generally available to the public at large in a non-discriminatory manner and he concludes that both Internet service providers and Internet backbone providers do so.

Internet carriers should be obliged to interconnect with other carriers or with end users under the mandatory interconnection obligation. Speta (2002, p. 277) continues that

"in order to limit the costs imposed on the party from whom interconnection is being demanded, the carrier demanding interconnection should be required to build its own facilities to a point of interconnection with the carrier. Because Internet carriers already substantially interconnect with other carriers, however, Internet carriers should be required to permit new interconnection at any facility where they currently interconnect. Additionally, to take care of a situation of localized monopoly power, carriers should have the right to demand interconnection with other Internet carriers if they can demonstrate that there is no reasonably available facility for direct and indirect interconnection."

Speta underlines the further need for the regulatory agencies to comprehensively evaluate the structure and competitive nature of Internet markets. He emphasizes that a potential outcome of such a proceeding might be that at least some segments of the industry do not need interconnection regulation.

Kolesar and Levin (2002) come to the opposite conclusion which says that mandated interconnection virtually is not necessary in IP networks. The authors assume a market situation without market dominance. We will take account of their arguments in the following analysis.

Subsequently we assume that we are already in a fully-fledged all-IP based NGN environment. In our view, the basic principle should be giving freedom to market participants to negotiate efficient and mutually beneficial interconnection arrangements. Of course, regulatory policy suggests that mandated interconnection arrangements are necessary if there is a bottleneck providing market power to extract above-normal profits. Thus, the crucial issue is if market conditions are actually bringing about the necessity of regulatory intervention. We first focus on interconnection in international core networks and then on interconnection on a national, regional or local level.

It is worth to be noted that, albeit being technically and economically different issues, mandated interconnection and unbundling can become very much intertwined in reality. Kolesar and Levin (2002) point out that mandatory interconnection *at any technically feasible point* is virtually the same as a policy for compulsory unbundling of all network elements[130]. And this assertion holds true irrespective of whether the network elements are essential facilities or not. Subsequently, we focus, however, on interconnection.

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[130] Thus, it is not surprising that proponents of a narrow definition of mandated interconnection like Kolesar and Levin favour the objective to minimise functionality to be unbundled and maximise functionality that is competitively determined. See also Cawley (2001).

Interconnection arrangements regarding the international IP backbone

With regard to incentives for unfair practices regarding the international IP backbone Elixmann and Scanlan (2002) come to the following conclusion:

Where market power is distributed among a sufficient number of interconnected networks, and services that function as partial substitutes for transit interconnection are widely purchased (i.e. regional interconnection between smaller ISPs (secondary peering) and multi-homing (transit contracts with several core ISPs)), direct *ex ante* regulation of the core of the Internet is unnecessary in order to prevent monopolisation from occurring. Merger regulation should be relied upon instead. There are several reasons for this:

- Firstly, the loosening of the hierarchy has reduced the bargaining power of core ISPs when negotiating service contracts with 'downstream' ISPs and major content providers.

- Secondly, analysis of the strategic interests of the largest player(s) suggests that in many cases they will not gain by degrading interconnection unless they already have a share of the global market well in excess of anything observed presently.

- Thirdly, research evidence regarding price discrimination suggests that in a wide variety of circumstances backbones have an incentive to set interconnection prices according to "the off-net pricing principle": that is, customers pay the same price for receiving traffic independently of whether the traffic was originated on the ISPs own network (on-net) or on another ISPs network (off-net).

If, however, ISPs have the power to price discriminate between on-net and off-net traffic, this situation may become unstable and the market tip in favour of the largest network.

To sum up, the different incentives of big and small ISPs to seek for (backbone) interconnection usually lead to a competitive outcome based on a free contractual negotiation of the interconnection terms. This is true as long as there is no dominant market position of a single ISP. Thus, a crucial task for policy is to assess the degree of competition in the market[131].

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[131] See also Cave (1999) who argues that the issue of whether the co-existence of peering and transit arrangements is anti-competitive depends essentially upon the degree of competition among Internet backbone providers for transit business. If they set prices collusively, discrimination with respect to the payment regime could create barriers to entry and lead to excess profits. However, he concludes that there is no evidence at present of such effects.

National/regional/local IP interconnection

We now are focusing on the issue if mandated interconnection between IP networks could be appropriate on a national, regional or local level.

It is highly likely that in a NGN environment both large ISPs and small ISPs are active in a national geographic market. An example of small ISPs are the German city carriers which are active only in a very limited geographical region usually in more densely populated areas.

We would anticipate that large national ISPs will have an incentive to interconnect with their peers. Likewise, smaller ISPs in our view will have an incentive to interconnect with their (smaller) peers. It might very well be the case that traditional (settlement free) peering among these peers is no longer the prevailing policy, rather, traffic will be measured and billed according to different service classes. However, this doesn't change the argument that in all likelihood these links between peers can be established without the need of the regulator, i.e. no bottleneck exists.

Thus, the only critical issue might be if there is room for unfair practices regarding the relationship between large national ISPs and small regional or local ISPs. Kolesar and Levin (2002, p.11) and Cawley (2001) generally argue that in a packet based architecture the only candidate for a bottleneck is the final link to the customer's terminal device, i.e. the link between the last router and the end-user[132]. These authors emphasize that any regulatory intervention should be limited to ensuring that the terminating ISP maintains an obligation to accept and deliver packets and that the price for delivering packets is no more than is required to recover costs[133].

In this context both Kolesar and Levin (2002) and Cawley (2001) point out a fundamental difference between circuit switched and packet switched networks. In circuit switched networks a user expects his operator or service provider to make arrangements to terminate a call anywhere in the world *and* arrange for return of communication from the terminating user. Consequently, the operator or service provider of the originating user bears the costs of the entire call, i.e. both for originating voice content and voice content being conveyed back. In packet switched networks, however, a user only expects his provider to deliver his packets to any address in the world or to make (the necessary peering or transit) arrangements with other network operators to deliver his packets to the outside world. In the latter case the respective ISP of the address receiving the packets is responsible for final delivery, i.e. for termination of the data traffic. Thus, on packet networks usually the service provider of

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[132] The reader will recognize the similarity to the call termination bottleneck in a PSTN. However, in the new all-IP world the local network architecture will be different from the current PSTN architecture (there is e.g. no longer a main distribution frame).

[133] See Kolesar and Levin (2000) and Cawley (2001) who are emphasizing that any negotiated rate should have a strong relationship to the average marginal cost of transit traffic in both ISP networks in order to make the settlement attractive to both parties.

a customer receiving packets does not know the origin of those packets. The crucial point regarding communication on packet networks is that the originating user expects to *receive* packets from the outside world by virtue of the other users making similar arrangements with their providers. Since the obligations of the operators in packet switched networks differ from those in circuit switched networks it is obvious that there is also a fundamental difference regarding the respective costs of the operators. Costs of termination in a NGN, thus, in all likelihood are lower than today's costs in circuit switched networks and it seems likely that they will be lowered further by technical progress.

Applying the general arguments of the analysis of Kolesar and Levin (2002) to the issue of national/regional/local IP interconnection it would be in practice unlikely that a need for regulatory intervention is going to arise. Generally speaking, their assertion is that a difference in (e.g. network) size between different ISPs does not lead to an anti-competitive outcome. We would like to discuss this assertion a bit further. In our view the issue has two facets:

- incentives for an upstream[134] ISP to act in an anti-competitive way towards a downstream provider. The authors claim that there are no incentives for larger (backbone) ISPs to discriminate or deny interconnection to smaller ISPs who are willing to abide by commercially negotiated terms and conditions.

- incentives for a downstream ISP to act in an anti-competitive way towards an upstream provider. The authors argue that consumer demands will drive backbones to interconnect with each other and local access providers to allow access to their customers for packet termination. With regard to the latter they emphasize customer sovereignty, i.e. consumers have a high preference for universal connectivity as well as choice with regard to local ISPs[135]. In addition, they claim that with current technology ISPs are virtually not able to discriminate among packets. Future technology might alter this, however, even then they argue that little economic incentive exists to incur the costs of tracking the origin of incoming packets simply because the potential exists to bill service providers delivering packets for termination[136].

As long as consumers really have choice with regard to local ISPs the argument in the second bullet point seems convincing. We can, however, in general not agree to the argument brought about in the first bullet point. The reason is as follows.

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[134] Kolesar and Levin (2002) only use the terms "large" and "small" ISPs. In the context of national/regional/local interconnection we prefer to use the terms "upstream" and "downstream" ISPs.

[135] The argument is that unlike in circuit switched networks for an end user A in a packet switched network it is much more important for selecting an ISP how expensive it is for other customers to terminate packets to him. The customer responsive ISP, thus, virtually has no significant room for charging "higher" termination fees.

[136] See Kolesar and Levin (2002, p.11).

One can take for granted that the current national incumbent telephone companies e.g. in European States will also be important if not dominant ISPs on a national level in a NGN environment. Thus, it is very likely that a significant portion of the up-stream traffic of small ISPs is directed towards addresses administered by the incumbent ISP. Likewise, one can expect that the incumbent ISP also accounts for the bulk of downstream traffic received by the small ISP[137]. In such a situation it might become an issue of regulatory policy if the large ISP denies peering to the small ISP, rather, offers only transit[138]. This becomes in particular crucial if the transit arrangement means that the small ISP has to pay (usually volume sensitive) fees for *both* traffic directions, i.e. for downstream and upstream traffic. Moreover, degradation of quality of service by the incumbent ISP regarding traffic of the small ISP might play a role.

8.6   Interconnection and interoperability

Due to the disaggregated structure of the NGN interoperability will become a crucial issue. In order to be able to offer services and applications ubiquitously in a NGN networks have to be interoperable and the required network functions have to be supported by all networks. Needless to say that availability of a service and product portfolio as big as possible, i.e. not disturbed due to technical restraints, is also in the interest of the end users.

Generally, it seems likely that in a competitive world each provider A the facilities of which are to be used for the provision of an application of another provider B has an incentive to care for interoperability. The reason is that provider A is also dependent on interoperability if he wants to offer network overlapping services and applications. Thus, in a competitive world without any market power of a market participant it is hardly possible to establish proprietary solutions because it is in the best interest of each provider's customer base to give them global reach.

In case a provider has a market dominant position, however, the incentive to care for interoperability is different. Due to the large customer base interoperability presumably is much less important for a large provider than for a small one. Indeed, the strategy of a large provider in all likelihood centres on offering to its customers innovative and differentiated products and QoS, respectively. "Vendor specificity" of networks of different market participants, thus, bears the potential that market dominant firms determine technological features which have to be applied by smaller providers. Otherwise stated, it is highly likely that the potential to enforce particular norms and standards (e.g. of interfaces) is much higher for a provider with market power.

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[137]   The relatively few customers of the small ISP are likely to communicate intensively with the much higher number of customers/content servers of the incumbent (upstream). Otherwise stated, the big ISP is much more important for the small ISP than the other way round.

[138]   Transit could even be denied. In this case a third ISP manages the traffic exchange between the small ISP and the incumbent ISP.

However, does this observation already warrant regulatory intervention? In our opinion, regulation should be cautious and first and foremost leave it to the market to establish norms and standards for interoperability. Ex-ante imposition of broad interoperability requirements by regulation in a technically highly dynamic market is much more likely to impede market development than to support it to the detriment of customers. Nonetheless, regulation will have an important task to organise and monitor the process of standard setting[139]. The new EU framework specifies in this context that European norms should be made mandatory in the frame of institutional arrangements based on comprehensive public hearings in order to ensure open access and interoperability[140]. In particular, there might arise the need for regulatory practice in this field to develop appropriate conflict resolution mechanisms.

Let's now assume that the market participants have already agreed on standard industry protocols in an NGN environment. Then the crucial issue arises which provider, the originating or the terminating provider, should be responsible for the necessary adaptations, e.g. protocol conversions, and, thus, incurs the costs to ensure the exchange of traffic across the networks. In this respect the analysis of Kolesar and Levin (2002) suggests the following principle in a NGN world: Basic to any interconnection arrangement should be the rule that the only obligation of the terminating service provider is to accept traffic and deliver it. Thus, the solution to the issue raised before is very simple: It should be incumbent on the originating provider to deliver traffic to the terminating provider in a format in which it can be delivered (or to bear the cost of any necessary conversion).

Kolesar and Levin point out that this general solution does only hold subject to the fact that the market participants have agreed on standards. The general solution therefore only applies in case both the originating and the terminating provider are using a standard industry protocol. In case the terminating provider uses proprietary protocols that are not available to the originating provider their suggestion is that the terminating service provider has to accept traffic in any standard industry protocol and accomplish the necessary adaptations at his own expense[141].

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[139] A vital public role in standard-setting and enforcement is underlined by Botterman et al. (2001, p. 77). They claim this role should "include making sure that standards do not create distorted competition, making sure that social objectives are well-served and that incentives to develop and invest in infrastructure, services and applications are not diminished (i.e. serve the public interest)".

[140] Moreover the Directive points out that "encouraging interoperability is one of the objectives for national regulatory authorities ....which also provides for the Commission to publish a list of standards and/or specifications covering the provision of services, technical interfaces and/or network functions, as the basis for encouraging harmonisation in electronic communications. Member States should encourage the use of published standards and/or specifications to the extent strictly necessary to ensure interoperability of services and to improve freedom of choice for users." See EU (2002, No. 9).

[141] There might very well be an incentive for the terminating ISP to care for the necessary conversion of data and to incur the costs simply because his customers using his proprietary technology (for whatever reasons) expect the terminating ISP to enable exchange of traffic with other customers.

Cawley (2001) applies the principle just stated in particular to traffic between circuit-switched and packet switched networks. He underlines that interworking between PSTN and an IP network requires the interconnection rule to impose an obligation on the terminating operator to accept traffic and deliver it. The related obligation in this case should be that the originating operator should deliver traffic to the terminating operator in a format in which it can be delivered or bear the cost of conversion[142].

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[142] Cawley (2001) claims that today new entrants with packet networks usually are adopting circuit switched PSTN interconnection arrangements and are bearing the costs of any protocol conversions whether or not they are the originator or terminator of traffic.

9 Conclusions

Our analysis has shown that there are fundamental differences between Next Generation Networks (NGNs) and the traditional PSTN/ISDN. The main building blocks of NGNs are devices with specific functionalities connected by a packet switched network. NGNs are capable of handling voice, data and video traffic simultaneously. In this network transport and control functions are separated. In contrast to the centralized architecture of the circuit switched PSTN/ISDN networks where the switch with all its hardware, call control and services software is located in the geographical market it serves, in the NGN architecture the functional elements can be fully distributed within the network. Moreover, the intelligence is more and more located in terminal devices.

NGNs presumably will rest on a layered structure consisting of a basic access and transport layer, a media layer where network gear is located which provides for interconnectivity of PSTN/ISDN networks and the packet switched network, a control layer hosting the main intelligence regarding control and signalling functions and the network service layer (application layer). The abstract discussion on NGNs does not go into the details how the local exchange network might evolve. Our look into the literature shows that in all likelihood the local exchange network of tomorrow will have transformed from a narrowband circuit switched network based on copper cable to a broadband network of packet switches and fiber optics.

The disaggregated nature of NGNs enables increasing specialisation of competitors on distinct functional parts of the provision of services and applications. In particular, a competitor is able to specify own services and applications independent of the transportation network. Moreover, services can be created by the end user.

To carry voice over data networks there are two main protocol approaches: H.323 backed by the ITU and Session Initiation Protocol (SIP) backed by the IETF. Deployment of NGNs today mainly focuses on softswitch based solutions. Softswitches today primarily are deployed as replacement of Class 4 trunk switches; replacement of Class 5 local switches is only beginning.

NGNs will lead to a blurring of traditional PSTN/ISDN concepts of ownership and operation of a network. Functional control of a network will no longer be directly linked to physical terminal points of the network. Rather, NGNs will have reference points which not necessarily are physically determined. A-priori there will be a broad spectrum of feasible points of interconnection. In a fully-fledged NGN environment service providers may at least conceptually need access to control plane functions, user plane functions and management functions.

NGNs will bring about a multi-operator, multi-service provider and multi-layer environment. Communications, software and media will become much more decentralized. In all likelihood there will be a need to define new telecommunications

markets. New possibilities and incentives for vertical integration might arise. Thus, competition and regulatory policy might be forced to define, assess and find remedies against abuse of market power in a much more differentiated way than today in telecommunications policy where networks (transport, control, management) are integrated.

It is likely that (1) access to IP transport platforms, (2) transport of IP packets, (3) call servers and gateways, and (4) IP addresses are not an essential facility. Termination in a NGN environment, i.e. (5) the IP link between the last router and the end user a-priori might constitute an essential facility. If (6) access to facilities on layers below IP and (7) network and service related interfaces may constitute an essential facility has to be left for future examination as well as (8) locations of facilities. Access to (9) data about customers like numbers and IP addresses are important information for each provider in the market and therefore there need to be publicly available directories.

Unbundling in an NGN environment will bring about several challenges. Due to the disaggregated nature of NGNs the issue of ensuring integrity of the network will become more complex. Moreover, (at least migration towards) NGNs foreseeably will be characterised by vendor specific service features and architectural features of the network. Together with the dynamic technological progress generating much shorter product life cycles than in the PSTN world the scope for regulatory intervention regarding unbundling of NGNs is limited provided regulation aims at being technologically neutral. In addition, the number of entities potentially involved in regulatory unbundling cases will increase.

Regarding mandated interconnection in (end-to-end) IP-based networks basically we see no need for regulatory intervention as long as the international or national backbones of ISPs are affected. The differences of network size across Internet Service Providers (ISPs) as such are not leading to distorted competition. Rather, there are (market based) incentives of both large and small ISPs to come to an interconnection (peering or transit) agreement. This holds true as long as there is no real market dominant position. Up until today no such position has ever been established in the Internet backbone.

Market dominance is much more likely to come into play regarding IP interconnection between large national ISPs and small regional or local ISPs. A local ISP is likely to exchange a much higher percentage of his total (upstream and downstream) traffic with a large national ISP than the other way round. Competition policy or regulatory concerns might arise for two reasons. Firstly, the large ISP might deny peering to the small ISP, rather, offering only transit and the latter means that the small ISP has to pay (usually volume sensitive) fees for *both* traffic directions, i.e. for downstream and upstream traffic. Secondly, the large ISP might have the potential to degrade quality of service regarding traffic of the small ISP.

In case the future NGN market is characterised by competition market players have an incentive to care for interoperability. However, as soon as a firm has a market dominant position an asymmetric incentive structure arises, i.e. the market dominant firm a-priori has a lower incentive to ensure interoperability. Yet, development of norms and standards for interoperability first and foremost should be left to the market. Ex-ante imposition of broad interoperability requirements by regulation in a technically highly dynamic market is much more likely to impede market development than to support it. Regulation, however, will have an important task to monitor and organise the process of standard setting and to develop appropriate conflict resolution mechanisms.

References

Anquetil et. al (1999): *Media Gateway Control Protocol and Voice over IP Gateways*, in: Alcatel Telecommunications Review, 2nd Quarter, 1999, pp. 151-157

Arlandis, J. (2001): *Next Generation Internet: Policy Issues*, Paper presented at the ENCIP Summer Workshop, June 2001, Montpellier

Arnbak J. (2000): *Regulation for next generation technologies and markets*, Telecommunications Policy 24, pp. 477-487

Badach, A. (2000): *High Speed und MultiService Networking – Technologien und Strategien*, paper presented at Online 2000, Düsseldorf, January 31-February 3

Botterman, M., Anderson, R.H., van Binst, P., Cave, J., Libicki, M., Ligtvoet, A., teVelde, R. and G.J. de Vries (2001): *Enabling the information society by stimulating the creation of a broadband environment in Europe*, report prepared by RAND Europe on behalf of DG Inf Soc of the EU Commission, Leiden, November

Cawley, R. (2001), *Traffic Exchange: Global Networks*, paper presented to the OECD Workshop on Internet Traffic Exchange, June 7-8, Berlin

Cave, M. (1999): *Interconnection and the Internet: Competition and regulation issues at local access and backbone levels*, OECD, Working Party on Telecommunication and Information Services,
http://www.csd.uch.gr/~hy490-05/projects/bandwidth/papers/interconnection&internet.pdf

Denton, T.M. (1999): *Netheads vs. Bellheads - Research into Emerging Policy Issues in the Development and Deployment of Internet Protocols*, Report prepared for the Canadian Federal Department of Industry, http://www.tmdenton.com/netheads.htm

Elixmann, D. and M. Scanlan (2002), *The Economics of IP networks – Market, technical and public policy issues relating to Internet traffic exchange*, Report prepared on behalf of the EU Commission (DG Info Soc), Brussels et al.

Elixmann, D. and U. Schimmel (with contributions of A. Metzler) (2003): Next Generation Networks" and Challenges for Future Competition Policy and Regulation, in: Communications & Strategies, no. 50, 2nd quarter 2003, pp. 239-268

Engebretson, J. (2001): *Softswitch Expo & Conference – The Holy Grail of Class 5 Replacement*, in: America´s Network, December 7, 2001

Engebretson, J. (2002a): *Softswitches´silent gains*, in: America´s Network, January 15, 2002

Engebretson, J (2002b): *Next Generation Internet*, in: America´s Network, February 1, 2002

European Commission (1999): *Commission Decision of 8 July 1998 declaring a concentration to be compatible with the common market and the functioning of the EEA Agreement* (Case IV/M.1069 – WorldCOM/MCI) (notified under document C(1998) 1887), in: Official Journal L 116, May 4, p. 1-35.

European Commssion (2002): *Eighth report from the Commission on the implementation of the telecommunications regulatory package*, COM(2002) 695 final, Brussels, December 3.

European Union (2002): Richtlinie 2002/19/EG des Europäischen Parlaments und des Rates vom 7. März 2002 über den Zugang zu elektronischen Kommunikationsnetzen und zugehörigen Einrichtungen sowie deren Zusammenschaltung (Zugangsrichtlinie)

European Institutes for Research and Strategic Studies in Telecommunications (EURESCOM) (ed.) (2001a): *Next Generation Networks: The Service Offering Standpoint, Technical Information, Requirements Analysis and Architecture Definition*, www.eurescom.de/public/projectresults/results.asp

European Institutes for Research and Strategic Studies in Telecommunications (EURESCOM) (ed.) (2001b): *Next Generation Networks: The Service Offering Standpoint, Technical Information, Service Creation Analysis in an NGN Context*

Frieden, R. (2002): *Revenge of the Bellheads: How the Netheads lost control of the Internet*, in: Telecommunications Policy, vol. 26, pp. 425-444

Haas, J. C. (2000): *"Essential Facilities Doctrine" und offene Netze, eine vergleichende institutionenökonomische Analyse von Regulierungsalternativen für den Zugang zu Netzen im Bereich der Telekommunikation*, Nomos Verlagsgesellschaft, Baden-Baden

Haaß, W., D. (1997): *Handbuch der Kommunikationsnetze, Einführung in die Grundlagen und Methoden der Kommunikationsnetze*, Berlin

Höckels, A. (2001): *Alternative Formen des entbündelten Zuganges zur Teilnehmeranschluss-leitung*, WIK-Diskussionsbeitrag Nr. 215, WIK Wissenschaftliches Institut für Kommunikationsdienste GmbH, Bad Honnef, January 2001

Horak, R. and R.A. Miller (1997): *Communications Systems & Networks. Voice, Data and Broadband Technologies*, New York

International Softswitch Consortium (ISC) (2002): *Introduction to the International Softswitch Consortium*, http://www.softswitch.org/ecducational/intro.asp

International Telecommunication Union - Telecommunication Standardization Sector (1998): Series Y: Global Information Infrastructure General (Recommendation Y110) *Global Information Infrastructure (GII): principles and framework architecture*

International Telecommunication Union – Telecommunication Standardization Sector (ITU-T) (ed.) (2000): *Global Information Infrastructure (GII): Reference points for interconnection framework*, Series Y: Global information infrastructure and Internet protocol aspects, ITU-T Recommendation Y.140, November 2000

International Telecommunication Union (2003): NGN 2004 project description document, internal ITU document, see also: http://www.itu.int/ITU-T/studygroups/com13/ugn2004/index.html

Kavassalis, P., Lee, T.Y. and J.P. Bailey (1997): *Sustaining a vertically integrated bearer service market*, paper presented at the Global Networking 97 Joint Conference (ITS-ICCC), Calgary, June 14-18

Kolesar, M. and S.L. Levin (2002); *Rationalizing Interconnection Arrangements in Competitive Communications Markets*, paper presented at the ITS Biennial Conference, August, Seoul, Republic of Korea

Kulenkampff, G. (2000): *Der Markt für Internet-Telefonie – Rahmenbedingungen, Unternehmensstrategien und Marktentwicklungen*, WIK-Diskussionsbeitrag Nr. 206, WIK Wissenschaftliches Institut für Kommunikationsdienste GmbH, Bad Honnef, Juni 2000

Lucent Technologies (2001): *Introduction to Next Generation Networks*, internal discussion paper

Marcus, J. S. (1999) *Designing wide area networks and internetworks – A practical guide,* Addison-Wesley, Reading (Mass.) et al.

Marcus, J.S. (2001), *Global traffic exchange among Internet service providers (ISPs)*, paper presented at OECD- Internet traffic exchange, Berlin, June 7.

McDysan, D. (2000), *QoS and Traffic Management in IP and ATM Networks*, McGraw-Hill.

Minoli, D. and A. Schmidt (1999), *Internet Architectures*, Wiley Computer Publishing, John Wiley & Sons, New York.

Neumann, K.-H. (2002): *Volkswirtschaftliche Bedeutung des Resale*, WIK Diskussionsbeitrag Nr. 230, Bad Honnef, WIK Wissenschaftliches Institut für Kommunikationsdienste GmbH, Bad Honnef, January 2002

Rottenbiller, S. (2002): *Essential facilities als ordnungspolitisches Problem*, Band 23 der Schriften zur Wirtschaftstheorie und Wirtschaftspolitik, Peter Lang Europäischer Verlag der Wissenschaften, Frankfurt am Main et al.

Rutkowski, A.M., (200): *Understanding next-generation Internet: an overview of developments*, Telecommunications Policy 24, pp. 469-476

Schaffers, H. and de Wit, D. (2002): *Next Generation Internet infrastructure: Creating networks for innovation*, in: Trends in telematics – innovative business models in the network economy, Telematica Instituut, Enschede (NL)

Schmidt, K.-F. (2000): *VoIP – Neue Basisplattform für Unternehmen*, Vortrag gehalten auf dem Telecom e.V. Workshop "PBX Quo Vadis II – VoIP Alternativen zur PBX", Hamburg, January 25

Siegmund, G. (1999): *Technik der Netze*, Hüthig Verlag,Heidelberg

Siegmund, G. (2002), *Next Generation Networks – IP basierte Telekommunikation*, Hüthig Verlag, Heidelberg

Sinnreich, H. und A.B. Johnston (2001): *Internet communications using SIP – Delivering VoIP and multimedia services with Session Initiation Protocol*, Networking Council Series, John Wiley & Sons, Inc., New York et al.

Smith, C. und D. Collins (2002): *3G Wireless Networks*, McGraw-Hill Telecom Professional, New York et al.

Speta, J.B. (2002): *A common carrier approach to Internet interconnection*, in: Federal Communications Law Journal, vol. 54, no. 2; pp. 225-279

SS8 Networks (2001): *SIP to H.323 Interworking*, SS8 Networks White Paper, www.ss8.com

De Streel, A. (2003): *Market definitions in the new European regulatory framework for electronic communications*, in: info, vol. 5, no. 3

Sweeney, D. (2001): *The hard sell of softswitches*, in: America´s Network, December 1, 2001, pp. 34-40

Tanner, J. O. (2002): *H.323 vs SIP Protocol*, in: America´s Network, February 15, 2002, pp. 30-32

Uebele, R. and M. Verhoeyen (2001): *Strategy for migrating Voice Networks to the Next Generation Architecture*, in: Alcatel Telecommunications Review, 2nd Quarter 2001, pp. 85-90

United States, Department of Justice (DOJ) (2000), *DOJ Antitrust Division v. WorldCom and Sprint*, http://www.usdoj.gov/atr/cases/f5000/5051.htm

Vanberg, M.A. (2003): *Internet regulation: Monopolistic bottlenecks in Internet service markets?*, paper presented at the 31st Telecommunications Policy Research Conference, September 19-21, Arlington (VA)

Vanston, L.K. (2001): *The local exchange network in 2015*, Technology Futures Inc., Austin (TX), http://www.tfi.com/pubs/2015.html

Vanston, L.K. and R.L.Hodges (2003): *Transforming the Local Exchange network: Review & Update,* Technology Futures Inc., Austin (TX)

Vogelsang, I. (2002): *Resale in der amerikanischen TK-Regulierung*, WIK Diskussionsbeitrag Nr. 231, January 2002, Bad Honnef

Weber, H. (2003), *Standards related to an integrated e-governance platform*, unpublished memo, Fraunhofer Institut Software- und Systemtechnik, May, Berlin

Wilson, C. (2003): *What is telecom's next great thing*, in America's Network, January 15

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