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ODTR BRIEFING NOTE SERIES

Next Generation Networks

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Foreword

As part of the ODTR's Forward Looking Programme we have introduced a series of briefing notes, dealing with technology developments in the information and communications sector. These briefing notes are primarily aimed at non-technical readers with some background knowledge of telecommunications technology. The main purpose of the briefing notes series is to raise awareness of new or developing technologies that could have important implications or present significant opportunities in the telecommunications sector in Ireland. An initial collection of briefing notes; "Technology Developments in Telecommunications" was issued in August[1].

This latest briefing note is an introduction to 'Next Generation Networks'. It is a very broad subject touching on many aspects of future broadband telecommunications networks. The note gives an overview of some of the key issues that are likely to arise from these networks, highlighting some of the opportunities and challenges that will emerge.

Next generation networks will be based on high speed packet technologies that will enable multiple services such as voice, video and data to be integrated and efficiently carried over the same infrastructures. These networks will be more than just high capacity upgrades of current circuit switched networks in that they will require major changes in network architectures affecting the ways in which operators deliver services. These changes in network architectures should enable operators to save on operational costs while allowing them the flexibility to more easily provision new capacity and services.

Some of the broadband applications and services that may drive demand for next generation networks are briefly described here. There is little doubt that next generation applications in areas such as e-business, tele-presence, tele-medicine and tele-education will play an important part in the rapidly evolving 'Information Age', and it is important that Ireland is well prepared.

[1] ODTR Doc. 01/59

To review briefly where we are now - telecommunications infrastructure build was liberalised on 1 July 1997, and while some operators started work quickly, most progress has been made since the telecoms market in general was opened on 1 December 1998. Three years is a long time in telecoms but it is a very short period in the creation of infrastructure, especially in a country with as complex planning rules as apply in Ireland. For the most part, this paper considers next generation networks as they are likely to appear in 5 to 10 years, once they have matured and when most real time traffic is carried over packet based networks.

As Ireland reviews progress to date on the provision of competing infrastructure, and seeks ways to develop the current networks' capacity to meet unmet demand for broadband at reasonable prices, it is important also to look ahead at the next generation of network technologies and applications to see what the opportunities are. In particular we need to consider whether there are any possibilities for leapfrogging forward in terms of whole networks or key elements.

However we should not expect that there are any easy solutions. The major transformation of communications infrastructure that will be called for is by no means straightforward. In this context it may be useful to note that in the UK, which opened its telecommunications market well ahead of Ireland, little over 50% of households now have access to network competition, concentrated mainly in urban areas. For Ireland, we need to establish practical targets and work out effective plans for achieving them.

This paper looks at some of the issues for the longer term 'end-game'. Further work is being carried out within the ODTR and elsewhere on infrastructure development for telecoms. Together, there should be a strong debate on the issues to find workable and realistic solutions.

Etain Doyle.
Director of Telecommunications Regulation.

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Comments on this briefing note

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to arrive on or before 5.30pm on Friday December 14th , 2001.

In submitting comments, respondents are requested to reference the relevant section from this document. Responses to this document will be available for inspection by the public on request. Where elements of any response are deemed confidential, these should be clearly identified and placed in a separate annex to the main document.

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1 Introduction

The introduction of new bandwidth intensive applications such as tele-education, tele-medicine and tele-presence, will require high capacity networks that are flexible and universally accessible. Such telecommunications networks are commonly referred to as Next Generation Networks (NGNs) and will be the converged successor to today's mostly separate voice and data networks.

In addition to current services (e.g. voice), next generation networks will be able to carry more demanding services such as video conferencing and other multi-media applications requiring capacities of tens of megabits per second per user. Abundant capacity throughout the entire network (i.e. from international links, to the desktop, or to the user on the move) will be a key feature of NGNs in order to provide broadband services on a mass scale (i.e. broadband for everyone). Also, next generation networks will integrate broadband mobile technologies enabling users to communicate using broadband services regardless of whether they are using a terminal in a fixed location or if they are moving. Furthermore, according to Probe research, current traffic growth rates are set to continue[2] and accelerate as new high capacity applications are developed and adopted on a mass scale.

It is essential that these next generation networks are more stable and reliable than today's networks as society in general will be become more dependent on them, in an environment where the transfer of information is even more closely integrated into our daily lives.

For the most part, next generation networks will physically consist of high capacity fibre optics links, carrying packet based data[3], that can simultaneously support various types of services. The NGN elements (e.g. switches and routers) will be capable of operating in various network configurations running different protocols (see Annex 3).

NGNs will initially have to be integrated with existing circuit switched networks and will evolve over time taking on various forms using a variety of protocols and standards. Many network operators are already integrating some of the new technologies into their networks. Some next generation networks will be developed by new operators without any existing infrastructure and others will evolve from operators' existing networks. For

[2] Overall traffic growth rates are set to continue at 20 – 25% annually over the next five years (Probe Research, 2001).
[3] See Annex 1 for an explanation of packet based networks.

the most part, this paper examines the next generation networks as they are likely to appear in 5 to 10 years, once they have matured and when most real time traffic is carried over packet based networks.

This paper is intended to give a broad overview of the major NGN technologies and issues. It is intended to develop the regulatory implications of these issues along with other topics arising from this paper in future briefing notes.

2 Creating the demand: Applications

2.1 Introduction.

In order to scope out the requirements of NGNs it is necessary to examine the possible types of applications that will be operated over them and to consider the network characteristics that these applications are likely to require. These new applications and services will to a large extent determine how NGNs develop.

Telecommunications operators and service providers will probably implement NGNs in order to help them to increase revenue and reduce operating costs (see section 5), and this too is likely to be a significant driver. Furthermore, equipment manufacturers will continue to develop advanced technology and press for its deployment in telecommunications networks.

With increased provision of broadband telecommunications access, high capacity applications are likely to appear that will probably rapidly absorb any temporary excess of capacity on core networks. In order to help understand the design considerations of next generation networks, the major trends in application development and usage are considered in the following sections.

2.2 Telepresence

Telepresence is the ability to interact in real-time with another person who is at a different location using telecommunications. Telephony is a telepresence application in its most simple form.

Advanced telepresence systems operating on next generation networks will enhance users' experiences of realism while communicating. Applications such as high quality video-conferencing systems would require capacities of between 2 and 8Mbit/s[4] per user. Video conferencing technology is currently most common in the business world, and applications are also being developed in the fields of education and medicine. When NGNs make ample capacity available it is conceivable that video conferencing could be adopted on a mass basis as a replacement or augmentation of basic telephony.

2.2.1 *3D Imaging*

Adding three dimensional aspects to the imaging systems of telepresence will further enhance the experience of telepresence. Initially, this sort of enhancement could have applications for business users, enabling delegates to sit down to a virtual meeting and hold real time discussions while viewing other delegates on three dimensional monitors. For example, a prototype of a three dimensional teleconferencing system connecting three users, each requiring a capacity of 77Mbit/s, has been developed in the US[5]. Other applications are in the medical and educational fields (see below). At a more advanced stage telepresence will become interchangeable with virtual reality, and applications in entertainment are envisioned.

2.2.2 *Virtual Reality*

When we think of virtual reality we often think of applications involving complete tele-immersion. However it is likely that applications will develop that blend reality and virtual reality forming hybrid realities to enhance our experiences. An example of this could be a type of visual display that could project images onto a user's normal field of view using devices mounted on eyeglasses[6], allowing them to receive augmented information relating to their environment such as directions to the nearest hospital or police station.

To further enhance users' sense of realism the sense of touch could be incorporated into virtual reality systems through haptic interfaces. Such systems allow users to touch and manipulate virtual objects. This aspect is essential for telesurgery applications, (see Telemedicine section). It is conceivable that in the future the senses of taste and smell could also be incorporated in virtual reality systems.

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[4] Current video conferencing systems can operate at capacities of between 128 and 384 kbit/s but provide a low quality service.
[5] National Tele-Immersion Initiative. www.advanced.org/teleimmersion.html
[6] A product called 'Nomad' from Microvision projects images from modified glasses directly onto the user's retina. This product is being tested by Eurocontrol for use by air traffic controllers. Medical applications of this product are also being tested by the Mayo Clinic in the US. www.mvis.com/default.htm

Apart from the obvious entertainment applications virtual reality is important in areas such as tele-medicine (see below) and tele-training (e.g. flight simulators have been used since the Second World War to train pilots) or in assisting designers in industry[7].

2.2.3 Data Augmentation

Further value can be added to telepresence applications by augmenting services with additional information. In many ways this could allow telepresence to surpass real face to face communication. For example, future face to face communications may often have files attached to them such as work that had been jointly undertaken during a telepresence meeting.

2.3 Tele-Learning/Tele-Education

Tele-learning or tele-education is the application of telecommunications technology in education and training. Next generation tele-education applications will use advanced graphical visualisation tools to help users understand difficult or abstract topics and also provide users with an opportunity to learn in a safe and non-critical environment (e.g. flight simulation training, surgical procedure training). Some of these applications will require the use of three dimensional and virtual reality simulators.

Interactivity is also an important feature of tele-education, allowing users in remote locations to focus on areas where they are experiencing particular difficulties for example, and will enable a higher level of one to one interactivity with tutors (real or virtual). Applications of this type could involve a mixture of real-time and stored data. Interactive tele-education is also applicable in class-room environments and is being tested in European universities (e.g. University College Dublin) by the BiC (Blueprint for interactive Classrooms) initiative[8]. Already on-line learning is a growing internet application.

Tele-education provides users with the convenience of being able to learn at more convenient times and places (e.g. from home in the evenings instead of at a college during the day, or in work at the desktop). Also, tele-education gives users the opportunity to select more specific course material that is directly applicable or tailored to their individual interests.

The capacity requirements of these systems will vary according to the level of quality

[7] A project from the Heinrich Hertz Institute in Germany enables a single user to view and interact (using hands) with three dimensional images via a modified PC. http://imwww.hhi.de/blick/3-D_Display/3-d_display.html

sought from the video images, and it can therefore be expected that capacities of 2Mbit/s or more would be required for video-conferencing applications.

2.4 Tele-Medicine

Tele-medicine, or medical informatics is the use of telecommunications technology in medical applications. These applications would be greatly facilitated by highly reliable next generation networks. Tele-medicine will allow the transfer of records or actual medical conditions between patients and medical personal in geographically diverse locations. Furthermore, telepresence applications will enable medical staff to conduct face to face meetings with other staff and patients without the need to travel.

An important future tele-medicine application is tele-surgery, in which a surgeon views the patient through a three dimensional display and conducts a surgical operation via robotic instruments from a remote location[9] using a high capacity telecommunications link. The first transatlantic tele-surgical procedure was recently successfully carried out using a 10Mbit/s link between surgeons in New York and a patient in Strasbourg, France[10].

Other medical imaging techniques are well suited to tele-medicine allowing for the diagnosis process to occur at a different location from the patient and collection of information (e.g. digital imaging, tissue sample analysis). This form of tele-medicine is now common on hospitals' local area networks with the transmission of x-ray images. Next generation networks will enable widespread use of such applications.

Tele-education also has applications in the medical area. Similar imaging techniques to those used by the remote surgeons mentioned above can be used in the training of medical staff.

2.4.1 Home Care

Home care involves monitoring and caring for patients at home using telecommunications technology. Time and costs can be saved by allowing nurses to conduct daily virtual visits to patients in geographically dispersed areas. Furthermore,

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[8] The Blueprint for interactive Classrooms (BiC) www.avd.kuleuven.ac.be/bic/products/classrooms/ucdclassroom.htm

[9] Aside from more sterile un-manned operating theatres, this technology could potentially enable surgeons to perform operation from anywhere in the world regardless of the location of the patient. These techniques are undergoing various trials (e.g. da Vinci robot at East Carolina University: www.hoise.com/vmw/00/articles/vmw/LV-VM-12-00-24.html

[10] The project was a partnership between the Institute for Research into Cancer of the Digestive System (IRCAD), France Telecom and Computer Motion Inc. The procedure involved removing a gallbladder was removed from a 68 year old woman.

the concept of person to machine communications could be utilised here as home care patients could be constantly monitored, reducing the recovery times needed in hospitals.

Home care using telecommunications links can allow the elderly to extend the time that they can live independent lives in their own homes. This application will become increasingly important in Ireland and the rest of Europe due to ageing populations. Although many of these applications do not require high data rates their mass adoption could produce significant traffic loads on next generation networks.

2.4.2 Data Integrity and Privacy

Important data integrity and privacy issues arise from the application of tele-medicine. Tele-medicine applications that involve real time data concerning the well-being of patients are critical in terms of data integrity. Any erroneous transmissions could result in mistreatment with potentially serious consequences. Also, as medical information is of a highly private nature security is a priority and will become a key consideration in the design of next generation networks[11].

2.5 Social Interactivity and Entertainment

High capacity applications will emerge in the areas of gaming, movies and social interactivity. Interactive gaming with multiple participants is already an established internet application. However, with increasingly intense gaming applications (e.g. high resolution video graphics) more and more capacity is needed from telecommunications networks to support multi-player real-time use.

Streaming video and audio entertainment will be important applications of next generation networks as traditional broadcasting services and delivery methods converge with telecommunications (e.g. interactive TV). Applications such as video on demand (VOD) providing users with personalised viewing services and applications with added interactivity will require high capacity networks to serve them.

Peer to peer networking of video, audio and even 3D virtual reality archives could also bear heavily on next generation networks as users swap massive amounts of data[12].

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[11] EUROMED-ETS is a European Commission project that examines the operation, regulatory and legal issues of tele-medicine. http://www.cordis.lu/infosec/src/study12.htm

[12] Freely available peer to peer networking programmes such as BearShare and Swaptor which allow users to browse and share other users' stored data could dramatically increase traffic loads on telecommunications networks as Napster did.

2.6 Machine[13] to Machine Communication.

In the paragraphs above mostly human to human and human to machine communications have been considered. As the number of devices or machines that are able to communicate continues to increase, telecommunications traffic between these machines will continue to increase exponentially[14]. A number of commentators have suggested that machine to machine communication will exceed person to person communication on next generation networks in around five years. Although, for the most part, the early applications envisioned here will be narrow band applications (e.g. environmental sensors to detect temperature, moisture levels, light intensity, movement etc.), the vast numbers of routine communications will make their aggregate capacity significant.

Machine to machine communication could also allow for the development of smart environments which are environments or work spaces that are aware of the context in which they are being used. For example, if a child approached a TV terminal, childrens' programmes could be shown instead of stock market information. In a business environment a user could automatically receive relevant information based on a particular caller, or the attendees at a meeting.

Other applications of machine to machine communication could include improved safety on our roads by allowing road traffic to be automated. This would enable guidance systems in vehicles to communicate with one another to ensure that collisions did not occur.

2.7 Business Applications

Increasing levels of e-commerce and m-commerce will place increasing demands on next generation networks. Highly secure and reliable next generation networks will in turn encourage the growth of business applications as users become accustomed to and develop trust in e-commerce and m-commerce applications.

Increased telecommunications traffic from applications such as online banking and shopping will create large amounts of e-commerce traffic. Furthermore, video conferencing and virtual reality show-rooms may change the way in which we choose products and services.

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[13] In the context of telecommunications a "machine" means any device that is capable of communication, such as a computer or a thermostat for example.
[14] Metcalfe's law states "the usefulness, or utility, of a network equals the square of the number of users".

3 Characteristics of Next Generation Networks

Next generation networks will for the most part be high speed packet based networks capable of delivering a multitude of broadband services. Among other things these networks need to be both flexible and reliable. Although next generation networks will develop in many different ways they will all have a common set of broad characteristics. These characteristics are outlined below.

3.1 Protocol Independence

In order to facilitate multiple forms of communications, next generation networks will need to be capable of operating a multitude of different communications protocols[15].

Traditionally networks have been designed and implemented to transmit certain specific types of data such as voice, video or data. This required separate networks, using different sets of equipment (although usually using the same cables or transmission media) to support multi-media communications.

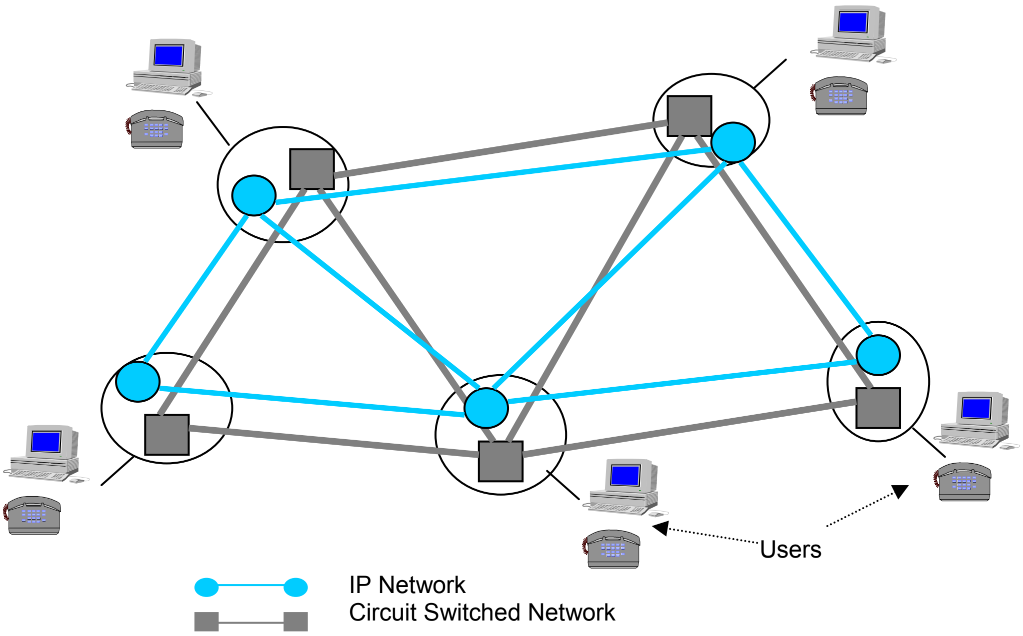

Figure 3.1: A simplified diagram of overlaid IP and Circuit Switched Networks showing the duplication of network resources.

[15] Communications protocols are sets of rules that enable devices to communicate.

Essentially, protocol independence is the ability of a network to operate any protocol that may be required. The term 'protocol agnostic' is often used in association with next generation network equipment (e.g. such a device could handle IP, DSL and ISDN traffic simultaneously). This property will be implemented mostly at the 'intelligent edge' of the network (see NGN architecture section).

The ability of equipment to be multi-functional is increasingly required by telecommunications operators. It enables them to save on operational costs as equipment is managed from a single platform. Also, the physical space and hence costs that are saved with multi-functional equipment is a critical factor. Another significant factor is a reduction in the amount of power consumed by using less equipment[16].

3.2 Reliability and Resilience

Increased dependency on advanced new applications in the future will place even greater reliability requirements on next generation networks. Individuals' expectations of availability and quality of service, grounded in a perception of high quality in traditional telephony and television services, will impose high standards of performance[17].

E-commerce applications will lead to highly resilient telecommunications networks as businesses become increasingly reliant on telecommunications to function[18]. For other highly sensitive applications, such as tele-medicine, network reliability and resilience is imperative, since a patient's health could depend on the quality of the information transmitted

In order to achieve the necessary levels of resilience and reliability next generation networks will need more diverse topologies and redundant elements than is normal in today's networks.

3.2.1 Threats to Network Resilience

Some of the common threats to network resilience are listed below:

- Equipment Failure

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[16] Power consumed by telecommunications equipment has typically increased by a factor of twenty over the last ten years.
[17] With video conferencing it has been found that whilst users are generally quite tolerant of poor or interrupted/intermittent vision signals, they are very sensitive to poor quality audio signals.

Fully redundant fault tolerant systems with "hot stand-by[19]" can prevent network outages due to equipment failure, but capital expenditure is approximately doubled.

- Software Faults

Similarly fully redundant fault tolerant systems with "hot stand-by" can prevent network outages caused by isolated software faults.

- Overloading of Networks

Networks need to be easily scalable in order to allow for extra provisioning of capacity to prevent overloading. Networks should also be provisioned to cope with capacity loads under exceptional circumstances.

- Physical faults (natural/accidental/malicious)

Physical damage to network equipment or cables can result in serious consequences to network operation[20].

- Software Attacks (Viruses etc.)

Ongoing network security precautions have to be taken to protect against attacks on software.

3.3 Controllability

It is essential for network managers to be able to design, adapt and optimise their networks to accommodate simultaneously different types of media with varying network requirements. The main issue here is of quality of service, (i.e. the ability of a network to provide a particular level of service or to guarantee a certain amount of bandwidth and response time over a specified period). For example a voice or video conferencing application could not normally afford to have information packets (i.e. pieces of the conversation) lost or even delayed. Therefore these types of services need a guaranteed high level of quality of service to function adequately. On the other hand, non critical applications such as internet browsing can afford to lose occasional packets of information as these can be re-sent without degrading the service.

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[18] The average cost of network downtime in the US has been estimated at approximately $1400 per minute, and up to $6.5 million per hour for brokerage operations. Randolph A. Fisher "*Business Recovery over wide area networks: Are you ready?*", AT&T

[19] Hot stand-by is where an element in a network works alongside a redundant element that is ready to instantly take over the full functionality of the primary element in the event of failure.

[20] See ODTR Doc 01/77 "Network Resilience – Consultation Paper".

Control of these aspects of a network is an important characteristic since it allows network managers and network management software to optimise utilisation of network resources by dynamically setting the balance between the amount of capacity that is dedicated to real time applications and mission critical applications. Network managers also need to control the amount of flexibility that is applied to non-real time services such as file transfers (e.g. downloading of design files from a design centre to the manufacturing plant). This is known as traffic engineering. Traffic engineering features of next generation networks will help overcome both the problems of guaranteed quality of service in current packet switched networks (e.g. IP) and the problem of wasted capacity in dedicated circuit switched networks. See annex 1.

A common shortcoming of current packet switched networks is that it can be difficult for telecommunications network operators to specify or guarantee an end to end quality of service, particularly where part of the communications link is carried over a third party's network. For example a call originating on a network with a sufficiently high quality of service may terminate on a network, perhaps in a different country, where the quality of service is noticeably lower, thus resulting in a poor quality call. Using traffic engineering, operators can define specific levels of service and then enter into service level agreements with other operators who have similar traffic engineering capabilities. This process facilitates further interconnection between operators and networks.

3.4 Programmability

The more programmable and re-configurable next generation networks are the more flexible they will be, and the more they will be able to cope with new services and user requirements. Programmability will allow for traffic engineering and the dynamic allocation of network resources enabling next generation networks to adapt quickly to new services or requirements.

Programmability yields more simple scalability since the less manual configuration that has to be performed during a network upgrade the more quickly services can be expanded. The time it takes to provision new capacity in networks can be reduced from several weeks (in manually configurable networks) to a few hours or less through programmability. Fully programmable networks could be upgraded remotely from a single location eliminating the need for expensive site visits.

To aid interoperable and programmable networks open standards need to be supported by all equipment vendors. This will mean the provisioning of open Application

Programming Interfaces (APIs) enabling developers to create software for equipment from various vendors to operate in interconnected networks.

3.4.1 Service Creation

An important feature of modern, intelligent next generation networks will be that through the use of open APIs operators will be free to customise and create new services with the networking equipment that they already have. In many existing telecommunications networks, services are in effect controlled by equipment manufacturers, thereby sometimes imposing lengthy lead times on the introduction of new services.

3.5 Scalability

Scalability is an important attribute that can help protect next generation networks from becoming obsolete. In order to cope with growing traffic loads network operators will have to over-provision transmission capacity (i.e. lay more fibre optics than currently needed). Next generation network equipment will need to be scalable to allow for the addition of capacity as required without the need to replace equipment once it reaches its design capacity.

The more general purpose that telecommunications equipment is the greater the chance that it can be programmed, adapted and scaled to cope with future needs.

Furthermore, next generation networks will need to be scalable in terms of address space (i.e. the number of devices that can be connected and individually identified on a network). Currently, the public internet does not satisfy this requirement and hence IPv6[21] has been developed to help overcome this problem, (see Annex 3).

4 Implementation of Next Generation Networks

4.1 Architecture and Capacity

In terms of network architecture next generation networks will be fundamentally different from traditional circuit switched telecommunications networks (see Annex1). In traditional circuit switched networks the 'intelligence' of the network[22] has tended to lie at the core in central switches. In the next generation model more of the intelligence

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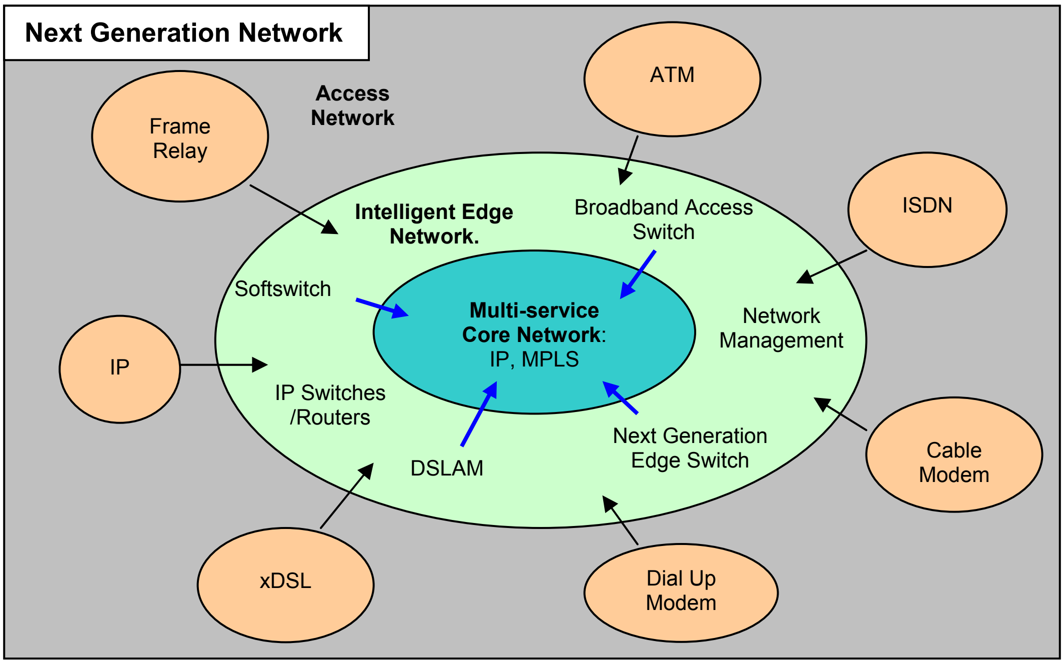
[21] IPv6: Internet Protocol version 6. The public internet currently uses IPv4.
[22] Network 'intelligence' means switching, value added services, network and traffic management, in this context.

and the switching or routing functionality will be decentralised and found at the edge of the network.

A major advantage of having intelligence in centralised locations is that network management is centrally controlled and therefore operating costs tend to be lower. On the other hand a network with distributed intelligence is more resilient to network failures.

The basic architecture of next generation networks can be divided into three main segments:

1. The Multiservice Core
2. The Intelligent Edge
3. The Access Segment



ATM: Asynchronous Transfer Mode
IP: Internet Protocol
DSLAM: DSL Access Module
ISDN: Integrated Services Digital Network
MPLS: Multi Protocol Label Switching
DSL: Digital Subscriber Line.

Figure 4.1 – Next generation network architecture.

4.1.1 *The Multi-service Core*

The multiservice core is the centre of the network that carries multiple services over high speed optical links (typically at speeds of Terabits or Petabits per second). This part of the network acts as a long haul transport system connecting together intelligent edge segments. The types of equipment or devices that are typically employed in this segment of the network are core ATM switches, SDH switches and switching routers. These are currently the most developed segments of next generation networks.

4.1.2 *The Intelligent Edge*

The intelligent edge will contain much of the intelligence of next generation networks. This is a distinct shift from traditional circuit switched networks where the intelligence of the network resided almost exclusively in the core. The intelligent edge network is capable of handling different types of communication traffic and services and connecting with the network core. This allows for the implementation of different types of access network to be seamlessly connected to the same intelligent edge (e.g. DSL, leased lines, FWA).

Common elements of the intelligent edge are multiservice softswitches which are able to operate regardless of the different protocols they have to mediate between (see Annex 2).

The ability to create new services is an important feature of the intelligent edge. This feature allows users to customise their networks and allows service providers to generate and provision new services without intervention from equipment manufacturers.

4.1.3 *The Access Segment*

The access segment of next generation networks will consist of various different broadband access technologies. As more and more capacity is required, access networks will almost certainly use optical technologies as their main means of transmission. Broadband wireless solutions are however likely to be prevalent for mobile or portable applications (e.g. WLAN, broadband mobile).

Figure 4.2 below illustrates how different types of access technologies can be interconnected to the same next generation multi-service edge.

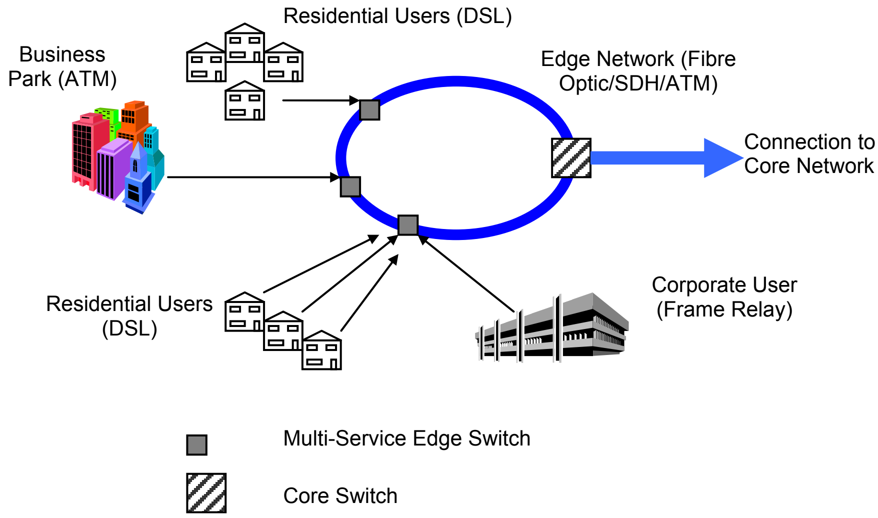


Figure 4.2: Multiple services connected to a multi-service edge.

4.2 Transmission and Protocols

Having outlined the architecture or shape of next generation networks we can describe how they actually work in terms of what they consist of physically and the protocols they use. Again it is important to be aware that next generation networks will not be implemented with one specific transmission method or set of protocols. A combination of different interworking networks will all form part of these next generation networks.

Operators will try to implement next generation networks with as few protocol layers as possible to try to reduce equipment, operations and maintenance costs, while increasing the range of services that they can provide.

Some technologies that will be key to next generation networks are described in Annex 3.

4.3 Evolution to next generation network architectures

The evolution from current telecommunications networks to next generation networks will mainly be gradual and will initially develop in network cores eventually moving out toward the network edges and the access segments. However, while some next generation networks will evolve from existing architectures others will be developed as entirely new networks. Nevertheless, public networks will have to integrate with one another regardless of the level of advancement or protocol types used.

There are significant opportunities for new next generation network developments in

Ireland, particularly in regional areas which currently require new infrastructure roll-outs. Such areas could conceivably be developed under 'test-bed' or 'demonstration' projects with the aid of government incentives.

The following section briefly considers the development of next generation networks at the international, national and local levels.

4.3.1 National and International Trunk Networks

Next generation network technology (e.g. MPLS) will initially be implemented in core national and international networks and has already begun in some cases (e.g. Level 3, Global Crossing). New entrants into the long distance carrier market have the most incentive to build networks employing the latest next generation technology while traditional carriers are likely to be slower to do so.

4.3.2 Wide Area Networks (WANs)

Wide area public networks will generally evolve to next generation networks from the inside out, with core long haul sections being the first to be up-graded. However, new WAN technologies such as next generation public mobile networks will utilise next generation architectures in the edge segment from the start.

4.3.3 Enterprise Networks

The users of large scale virtual private networks (VPN) or enterprise networks are expected to be early adopters of next generation network technology. This is due to their need for high performance in terms of capacity and quality of service for applications such as video conferencing and peer to peer networking. Operators have also identified this as an area where revenue can be generated fairly readily from value added services.

4.3.4 Metropolitan Area Networks (MANs) and Edge Networks

There is generally a lack of capacity for next generation networks in the metropolitan area network and this is therefore currently the most expensive part of a telecommunications network. Development in the metropolitan area is key to the implementation of next generation networks as these are the networks that will carry most of the traffic. Metropolitan Area Networks (MAN) often consist of rings that circumnavigate an urban area connecting various key locations such as access service providers, large corporate buildings and business parks. These MANs are then connected to other MANs for the same area and onto interconnecting core trunk networks.

The use of Ethernet in the MAN is increasing as new Ethernet standards such as Gigabit

Ethernet and Ten Gigabit Ethernet develop. Ethernet technologies are less expensive to operate and can be increased in capacity more quickly than other competing MAN technologies (e.g. ATM, SDH).

4.3.5 Local Area Networks (LANs)

With the increasing use of LANs both in the work place and at home (many Home Area Networks are simply LANs installed at home) and with Ethernet technologies being pushed out further into the metropolitan area networks LANs will form an important entry point for next generation networks. Furthermore, increased traffic seems likely to come from Wireless LAN (WLAN) applications as they are installed in public places such as shopping malls, airport lounges and coffee shops.

4.3.6 Personal Area Networks (PANs)

These are networks that will consist of devices operating together in an immediate personal area (i.e. held by a user, integrated as part of a user's clothing, on a user's desk). Much of the information carried in these miniature networks will be local in that it will not need to be inter-networked, however as user interfaces between the human and machine worlds these devices are ultimately connected to other computer networks and will thus form part of next generation networks.

5 Factors influencing the deployment of Next Generation Networks

5.1 Driving Factors

From the operators' perspective there is a need to contain operating costs as their telecommunications networks grow in capacity and in the variety of services that they are expected to provide. Many current telecommunications operators can provide a wide range of services (e.g. voice, data, IP) over a single access segment (e.g. DSL, Leased Lines, Cable Modems), but these services are typically implemented on separate platforms within the operators' core networks, with each platform incurring its own operational costs. Furthermore, adding more broadband access to current networks (e.g. through DSL) will in many cases quickly produce scalability problems in the core network architecture. One way of reducing operational costs is through convergence of separate services (e.g. voice and data networks) on to a single integrated next generation network infrastructure. Such a multi-service approach in general also helps to reduce capital expenditure when expanding networks, since less equipment needs to be installed. Furthermore, flexible next generation technologies offer operators the means to create new services, attract new customers and increase levels of revenue per user.

User demand for broadband telecommunications access will also be a significant driver of next generation networks. Furthermore, once next generation networks become more accessible it is likely that new applications will emerge that have yet not been identified.

The level of actual and anticipated competition in the telecommunications market is a significant factor in the development of next generation networks as it affects the level of investment that telecommunications operators are willing to make.

5.2 Investment in the Metropolitan Area Network

Metropolitan area networks have been identified as a major bottleneck in many developed economies and it is likely that this problem will emerge in Ireland also. This is partially due to recent investment by long distance international carriers in core networks, leading to a drop in core capacity costs. This means that for many communications links, the most expensive portion is the metropolitan section (e.g. a 3km MAN connection in some European cities can cost as much as a 500-1000km link in the core network[23],[24]). It seems likely that core network operators will invest in metropolitan area networks to add value to their existing core networks and to reduce the cost of having to use other metropolitan operators. If widespread adoption of new, high bandwidth applications is to occur, next generation networks will have to provide ample capacity in the metropolitan area.

The metropolitan segment is particularly important as most telecommunications traffic is local and is growing at a faster rate than international traffic. This has been shown to hold not only for telephony services but also increasingly for internet traffic[25]. Despite the "global village" concepts we tend to communicate with those we know and typically users know other users in their own localities.

5.3 Ownership of Next Generation Networks

[23] Source: Tola Sargeant, *"Bandwidth price erosion driving investment in the core MAN"*, IP-Core network analysis, September 2001, pp4.

[24] In Ireland leased line rentals can be between 3 and 20 times more expensive per km in the access segment (i.e. first 2km) than in long distance core segments. High capacity (i.e. 155Mbit/s) links tend to be relatively more expensive in the access segment. www.eircom.ie/About/Activities/Section1/Part15.html

[25] It is estimated that between 30 and 70% of internet traffic is now local (Probe Research, 2001).

The following factors will be important in determining which companies will operate in the various sections of next generation network markets:

- Increased flexibility, enabling instant provisioning of capacity and the possibility of bandwidth trading, will allow for telecommunications carriers and carriers' carriers to create new arbitrage business opportunities.

- Consolidation and restructuring of international telecommunications companies seems likely to continue in the near term and as next generation networks develop. In recent times we have seen examples of non-telecommunications companies moving into the telecommunications sector. Utility companies such as Energis (a telecommunications operator formed by the UK national electricity supplier) is an example of how non-telecommunications companies can leverage their assets (i.e. rights of way and marketing channels) to enter the telecommunications sector and deploy new cost effective networks[26].

- Branding is also an important issue in the telecommunications industry and will continue to influence the market in the future (e.g. successful brands such as Virgin and Benetton now operate in the telecommunications sector).

5.4 Next Generation Network Implementations

Some countries are more advanced than others in their migration to next generation networks. Countries such as Sweden, Norway, South Korea, Canada and Japan are relatively advanced in the access segment with strong commitment to high levels of deployment of optical technologies. In Sweden a major initiative to provide fibre to every home, relying heavily on utilities networks (i.e. fibre cables attached to the electricity grid[27]) to create an "an information society for all" is in place. Advancements typically stem from a combination of market demands, upgrading existing telecommunications infrastructure and government incentives.

5.5 Development in Ireland

The liberalised Irish telecommunications market is open to domestic and inward investors alike, and important progress has been made in developing infrastructure in core national networks (e.g. "national fibre optic network"[28]*)*. Various new projects are currently underway in Ireland, some under the National Development Plan, which has

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[26] New cable laying technologies are developing that enable existing gas, water and sewage pipes to carry fibre optics cables.

[27] http://naring.regeringen.se/pressinfo/infomaterial/pdf/n2000_075en.pdf

allocated a total of ε200 million in funding for e-commerce and communications infrastructure projects for the period 20001 and 2006. Some of these projects involve the implementation of new networks or network segments that will contribute to the development of next generation networks in Ireland, including the roll out of new fibre optics cables[29]. Furthermore, the Department of Public Enterprise is supervising various projects aimed at increasing the application of telecommunication technology in Irish society[30] (e.g. tele-education and tele-government projects).

Other significant opportunities for development in Ireland are in the edge and access segments. Fibre optic rings can be built around metropolitan areas attracting industry and facilitating the roll out of broadband access networks (see section 5.3). However, there are serious local planning issues which must be overcome to encourage the development of new networks[31]. Overall, while progress has been made in improving Ireland's telecommunications infrastructure, much remains to be done in order to bring about the deployment of next generation networks.

6 Conclusion

6.1 Applications Driving Demand

The implementation of next generation networks will facilitate many next generation applications and services that will continue to change the way in which we communicate. Such applications will enable users to experience even closer interactivity with others through telecommunications yielding benefits in many areas of life such as business, health and entertainment.

6.2 Characteristics

Even the most advanced next generation networks will consist of multiple elements operating multiple different protocols and standards optimised for a multitude of different purposes. Although no single technology standard is likely to completely dominate next generation network markets there are several key characteristics that these networks will need:

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[28] Project undertaken by the ESB to provide a national fibre optic core network under the National Development Plan.
[29] A recent call for expressions of interest in the creation of a telecommunications networks on the west coast of Ireland ended on the 31st of October. http://www.irlgov.ie/tec/communications/corridor.htm
[30] http://www.irlgov.ie/tec/cait
[31] ODTR Doc. 01/82, "Information and Communication Technology – Challenges and Opportunities"

1. Protocol Independence
2. Reliability and Resilience
3. Controllability and Quality of Service
4. Programmability
5. Scalability

Furthermore, next generation networks will mostly consist of the following key technologies:

1. Optical Technology

Optical technology is a key technology because its ability to provide raw transmission capacity is incomparable. Furthermore, developments in optical switching and multiplexing will help reduce the number of different protocols needed in transmission networks.

2. Packet Technology

Packet technologies with the necessary quality of service capabilities will almost certainly be the dominant method for routing information from one point to another. This approach moves much of a network's intelligence to the edges of the network.

3. Flexible and Open Standards

Flexible and widely available non-proprietary standards will enable operators to more easily generate new sources of revenue.

6.3 Evolution/Migration to Next Generation Networks

Part of the move from traditional telecommunications networks to next generation networks seems likely to take place via evolution rather than a revolution, especially in developed countries. Carriers with large amounts of capital already invested in their telecommunications networks are often reluctant to move towards new technologies with which they have little experience (and few experienced staff). Therefore hybrid networks (often loosely referred to as next generation networks) are initially developing and seem likely to evolve to become true multi-service next generation networks.

However, it is also likely that other next generation networks will be developed by operators without any existing infrastructure. Next generation technology offers attractive alternatives to operators rolling out new networks affording them more flexibility, scalability and savings in operational costs. New entrants in the core and edge segments may employ next generation technology over new fibre, purchased dark fibre or leased dark fibre. Next generation network technologies may also be more attractive to new competing operators in the access segment as an alternative to using un-bundled existing technologies. These sorts of implementation could lead to more rapid deployment of next generation networks.

6.4 Next Steps

In operating existing packet networks, some of the more advanced carriers are already using some of the technologies that will feature in next generation networks. Also, there are a lot of initiatives and trial projects underway involving network operators, equipment manufacturers and research institutions. For example, one such initiative is the Internet 2[32], which is a high speed network connecting participating US universities and research institutions (i.e. the minimum access speed is 155Mbit/s). This trial network is being used to test and develop high capacity next generation applications.

There is also a European Commission initiative as part of the IST (Information Society Technologies) programme called the Next Generation Network Initiative. This project consists of several high speed networks that span Europe. The mobile sector is also addressing the needs of the mobile portion of next generation networks in the 3GPP (third generation partnership project). It is important that the ICT sector in Ireland tracks these and other initiatives that will influence the development of next generation networks.

Next generation networks are going to be required in order to run the efficient and advanced communication applications of the future, and such networks will be the foundation on which the 'Information Age' will be built. Hence, the building and deploying of next generation networks will be crucial in terms of enabling Ireland to fulfil its information society and e-business aspirations.

[32] www.internet2.edu

Annex 1 – Background

The need for next generation networks has in part arisen from the need to cope with certain shortcomings of current telecommunications networks. Therefore, it is useful to compare some of the different key technologies of current and next generation networks.

Note: In the paragraphs below the two main traffic types discussed are voice and data. In more modern networks it may be useful to think of these as real time and non-real time applications respectively since all of the telecommunications traffic that we are concerned with here is digital and therefore data, irrespective of its analogue origins. In reality there are many different levels of service requirement between real-time and non real-time, and many ‘data’ applications could require real-time delivery.

A1.1 The Origins of Next Generation Networks

A1.1.1 Circuit Switched Networks – Current/past generation

In a circuit switched network dedicated traffic channels are set up between users after a number is dialled and this circuit remains dedicated to that call until it is terminated by one of the users. This is a connection orientated service providing users with a guaranteed amount of capacity for uninterrupted telephony.

Such networks are designed in hierarchical structures with end users connected to local switches or exchanges at the bottom and international switches at the top. 64kbit/s telephony channels are trunked together using time division multiplexing techniques such as SDH (Synchronous Digital Hierarchy) and transmitted over copper cables (in the access or local segment) and mostly fibre optic cables in the rest of the network.

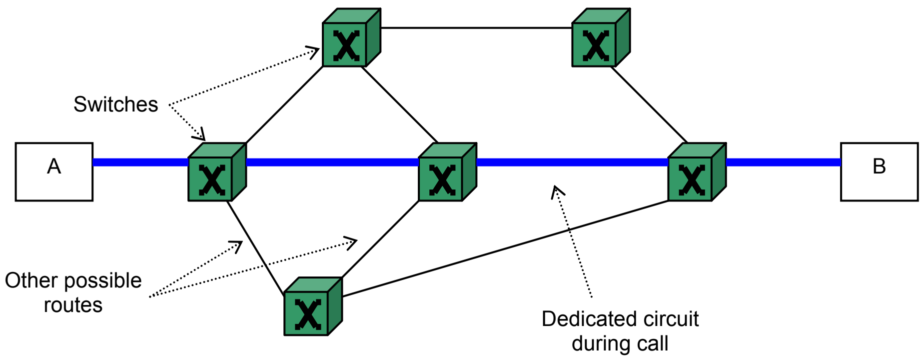


Figure A1.1: A connection orientated circuit between two users (A and B) in a circuit switched network.

A1.1.2 *Data Traffic*

The emergence of data traffic on switched networks presented problems for telecommunications operators. Since most data traffic is transmitted in relatively short bursts (compared to telephony) the overhead associated with setting up dedicated circuits and holding them open for the duration of a transaction proved to be inefficient and costly for operators. This is particularly so since users are mostly only willing to pay for the amount of data transmitted and not the length of time that a circuit is held open, as in traditional telephony models.

A1.1.3 *Packet Switched Networks*

Networks designed specifically to carry data were designed on a different principle than the circuit switched model described above. The approach here was to maximise efficiency on the transport networks by dividing data up into more suitable portions. Each of these packets[33] of data is given a preamble (header) that contains, among other things, its destination address. The packets are then sent out into the network to find their own way to their destinations through routers on a connectionless basis.

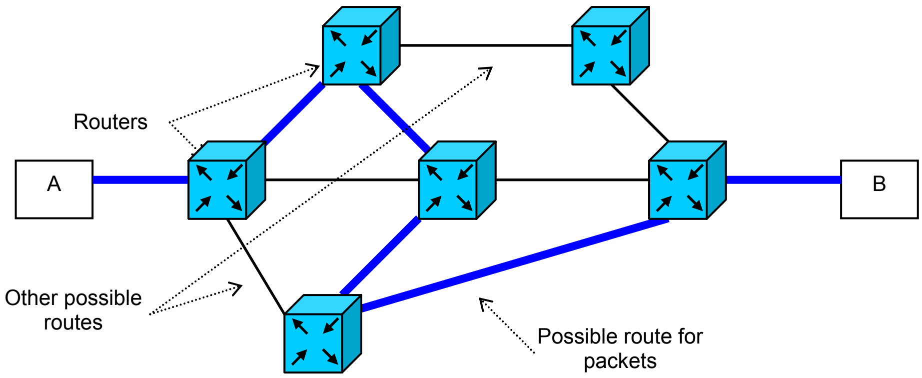


Figure A1.2: A connectionless transfer of packets between two users (A and B) in a packet switched network.

A1.1.4 *The Internet*

As internet usage grew it became increasingly difficult for telecommunication operators to cope with data traffic on their circuit switched networks, so they began to roll out separate packet switched networks.

[33] A packet of data is a unit that is transmitted between logical network elements at the network layer (e.g. IP).

A1.1.5 Voice over Data

As data traffic began to equal and surpass voice traffic (1998 was the cross-over point for many US carriers) on telecommunications networks it became economic for operators to consider transporting their voice traffic over packet switched networks. This convergence would help reduce the costs associated with operating and maintaining separate networks. However there are many problems associated with obtaining circuit switched levels of service for real-time traffic (e.g. voice) on packet switched networks which may not always have the sufficient capacity (packets are discarded under congested conditions in packet switched networks resulting in delayed or lost data which is unacceptable during telephone conversations).

A1.1.6 Traffic Engineering and Quality of Service in Packet Switched Networks

To help cope with this inherent problem of packet switched networks various techniques are being introduced allowing multiple different services to operate over a single network whilst accommodating their various service level requirements. Techniques such as DiffServ, IntServ and MPLS enable connections to be made or capacity to be reserved over packet switched networks giving them traffic engineering capabilities.

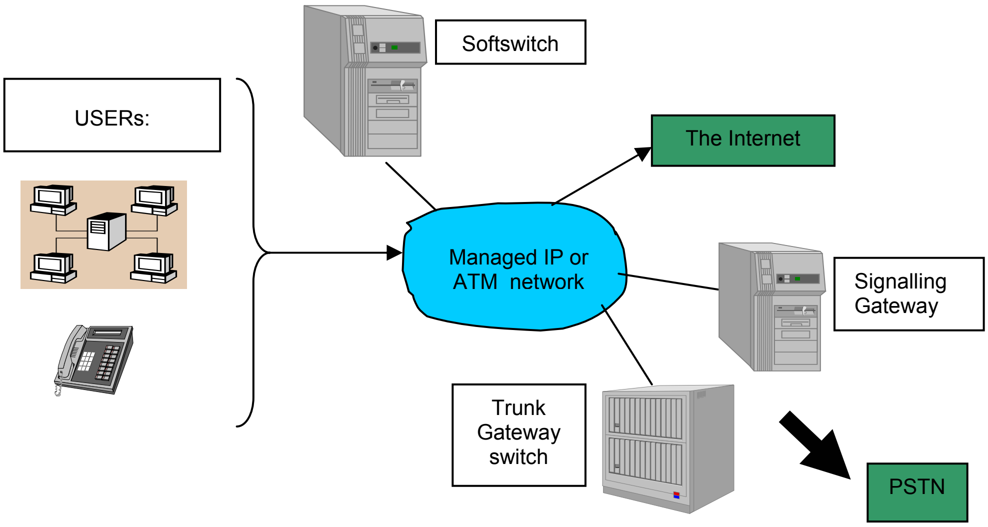
This new breed of multi-service network is known as a Next Generation Network and can take many different forms in different circumstances to achieve the required service levels.

Annex 2 – Typical Next Generation Network Elements

Some typical next generation network elements are described below:

Softswitches

These are devices that can be programmed to act as gateways allowing communication between packet based networks (e.g. IP) and traditional circuit switched networks. The softswitch can mediate between IP-centric, or VoIP services and circuit switched telephony services converting all of the necessary added services accordingly.



DSLAM

Digital Subscriber Line Access Module, used to connect multiple DSL users to the rest of a network. A multi-service DSLAM interconnects to voice networks as well as other data networks.

Next Generation Edge Switch

A multi-protocol switch that can connect users various access methods (e.g. ISDN, Dial-up modem, Analogue telephony) to next generation core networks.

Broadband Access Switch

Connects broadband access networks (e.g. Broadband leased circuits) directly to core networks. These devices connect network segments that are suitable for direct connection to core next generation networks.

Annex 3 - Protocols and Technologies

A3.1 Protocol Layers

When explaining networking protocols it is useful to make reference to a layered model (7 layer Open Standards Interconnect model). Data originates at the top end of a protocol stack and is passed down to the bottom layer (Layer 1) with each layer adding a preamble or header to encapsulate the data from the layer above. At the receiving end the data is passed back up a corresponding protocol stack until only the original data is left. The lower layers are described briefly below:

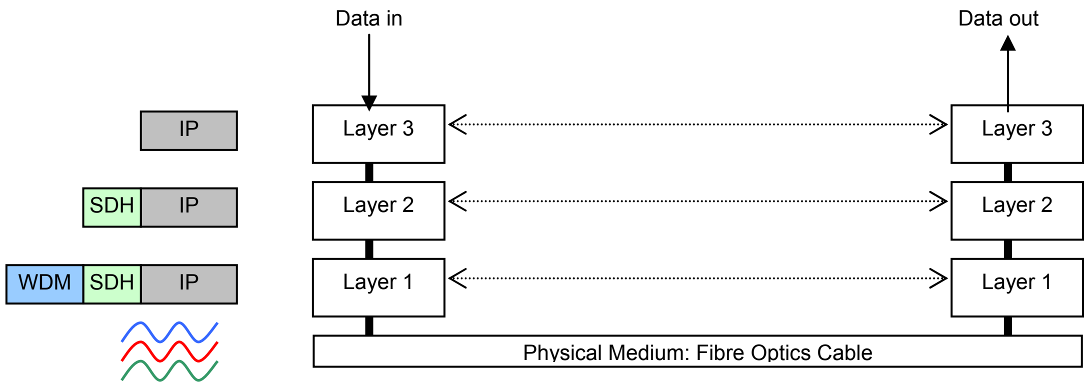


Figure A3.1: Bottom three layers of a protocol stack.

Layer 1 – Physical Layer

This layer is concerned with the physical characteristics of the transmission medium and the signals (electrical or electromagnetic) which are carried on them. Examples of physical layer protocols or protocols that address this layer could be Wave Division Multiplexing, Ethernet and SDH.

Layer 2 – Data Link Layer

This layer is responsible for the reliable transmission of data between physical points on a network. Examples of data link protocols are SDH, Ethernet, ATM, RPR, GMPLS.

Layer 3 – Network Layer

The network layer is responsible for the routing of information between logical points on a network. IP and ATM are the main examples of network layer protocols. MPLS is used to encapsulate IP packets at layer three.

Layers 4 – 7

The layers above the network layer (transport, session, presentation and application) are outside the scope of this paper.

Various protocols can be 'stacked' to form different types of networks. The diagram below shows some examples of different protocol stacks that are used to deliver IP services.

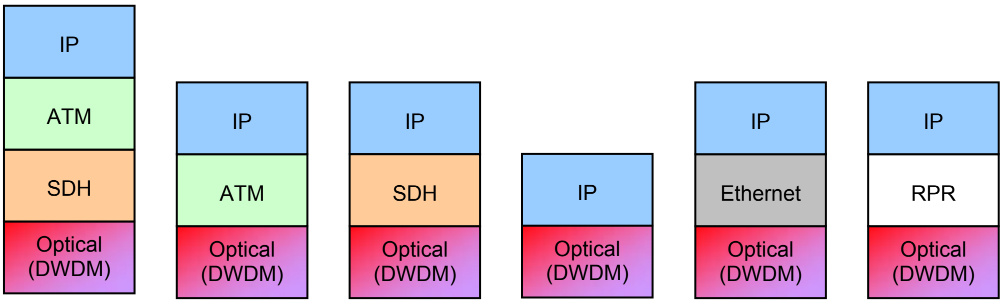


Figure A3.2: Some alternative methods of providing IP services through different protocol arrangements. See below for descriptions of these protocols.

A3.2 Protocols

Some important protocols that enhance the capabilities of packet switched networks are described below:

A3.2.1 Asynchronous Transfer Mode

Asynchronous Transfer Mode (ATM) was designed to provide both efficiency and traffic engineering capabilities, including quality of service. ATM is popular with traditional telecommunications carriers who find the approach not too dissimilar to their existing circuit switched networks with the intelligence of the network in the core switches. ATM provides capacity and transmission delay guarantees (as in circuit switched networks) and also efficient delivery of intermittent traffic (as in packet switched networks, e.g. IP).

A3.2.2 Ethernet

Ethernet[34] networks are used to transport data between physical points on a network (e.g. computers and routers). The ethernet set of standards is defined by the IEEE (IEEE 802). It was originally designed to connect computer terminals together in a local area network scenario. As ethernet speeds increased it migrated onto fibre optic networks extending its use to larger networks. Ethernet, operating at 1 Gbit/s (Gigabit Ethernet or GigE) and above, is now considered to be a viable technology to connect devices in metropolitan area networks and for data access networks. This means that IP could be run over Ethernet directly on WDM fibre links, eliminating the need for SDH or ATM. Ethernet is an inexpensive technology and has the added advantage that it is familiar to many systems engineers. Furthermore, Ethernet is very flexible in terms of scalability and can provide capacity on demand for users. Ethernet alone does not currently have sufficient quality of service and traffic engineering mechanisms for some real time applications.

A3.2.3 Synchronous Digital Hierarchy

Synchronous Digital Hierarchy (SDH) has traditionally been used for telephony circuits and can be wasteful of capacity in data applications. SDH is an ITU standard that uses time division multiplexing (TDM). This means that each individual data channel is assigned a specific dedicated time slot within a stream containing other data channels. SDH is a reliable and scalable protocol, but is not as granular as some operators require (i.e. it can only be scaled up in relatively large steps). Furthermore, provisioning of extra capacity can take weeks to achieve. SDH is currently deployed extensively in existing networks.

A3.2.4 Internet Protocol

Internet Protocol (IP) will be a key technology in next generation networks. This protocol has been made popular by the internet and seems likely to become almost ubiquitous in next generation networks.

IP is a type of packet switched communication that was initially designed for the transmission of data. IP is a connectionless protocol which means that each data unit (packet) is given a preamble (header) which contains the destination address of the data, and is sent out on the network to find its own way to its destination. Successive packets are then reassembled at the destination. This causes problems for real-time services such as voice since successive packets may take different routes through a network causing them to arrive out of sequence. A further problem is introduced as IP networks become congested, as IP routers discard IP packets once they become overloaded.

The proliferation of the internet and data services has made it economical to pursue the possibility of transmitting real time data using IP. However, when using IP it is difficult to perform the necessary traffic engineering to obtain reliable qualities of service that users of real time services are accustomed to. There are several approaches used to help overcome this limitation such as IntServ, DiffServ, MPLS and IPv6 (see below).

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[34] Ethernet is the name given to a network operating in a LAN configuration under one of the IEEE 802 series of standards. The concept was originally invented at Xerox Corporation in 1973 by Bob Metcalfe.

A3.2.5 IPv6

IPv6 (Internet Protocol version 6) is a next generation version of current IP (IPv4) that is being developed by the IETF[35]. IPv6 will help expand the capacity and capabilities of the current Internet.

Shortage of IP addresses

IPv6 deals with the near critical problem of limited IP address space in IPv4 which is estimated by some to run out as early as 2005. With IPv4 approximately 4 billion devices can be connected to an internet with individual identities. This has led to a current global shortage of IP addresses, which is particularly apparent outside of the US and Europe[36] (e.g. certain large US corporations and Universities have more IP address space allocated to them than all of India)[37]. Although IP addresses can be shared within an organisation's domain (through a technique called dynamic address allocation), this limits the 'always on' capability of networked devices. It is worth noting that many IPv4 addresses that have previously been allocated are not actually used, and in some instances (e.g. US universities) they are being handed back for reallocation.

IPv6 has ample address space to cope with increasing demands for IP addresses in the foreseeable future, including the further deployment of IP based mobile terminals (e.g. WLAN, 3G) and machine to machine communication. Furthermore, the allocation of IPv6 addresses is more simple to manage due to some new 'auto-configuration' features.

The allocation of IPv6 addresses could have a bearing on the ODTR's work as IP addresses become translatable to, or even replace, telephone numbers in next generation networks.

Other Issues

The other major shortcomings of IPv4 that IPv6 addresses are mobility, security and traffic engineering (flow control) in IP networks.

Implementation of IPv6

[35] www.ipv6forum.com

[36] The Japanese Government is committed to having 100% deployment of IPv6 in government, education and industry by 2005.

[37] IP address are allocated by ICANN (Internet Corporation for Assigned Names and Numbers)

Implementation of IPv6 has been slow to date, however major telecommunications equipment manufacturers have recently announced the intention to support IPv6 in their products[38]. Special solutions will be needed to interwork between IPv4 and IPv6 networks.

The European Commission is committed to ensuring that IPv6 is deployed in Europe and is actively encouraging its development. The IPv6 INternet IniTiative (6INIT) is an initiative funded under the IST programme.
Their time-scale for implementation seems to be between 2003 and 2005.

A3.2.5 *Resilient Packet Ring*

Resilient packet ring (RPR) is a new protocol that is currently being defined by the IEEE (IEEE 802.17) for connecting devices together. RPR is being designed to provide resilient data networks over optical rings in MANs and WANs. This technique allows optical ring topologies to be more efficiently used to carry packet data. It also reduces restoration times following network faults to those comparable with SDH (i.e. <50 milliseconds) for real-time applications. RPR is independent of the physical layer and will therefore run over SDH (physical layer) or DWDM. RPR will enable technologies such as Ethernet to be used in high quality carrier grade networks. See the RPR alliance for further details[39].

A3.2.6 *IntServ*

Integrated Services was developed by the IETF (Internet Engineering Task Force[40]) in an attempt to introduce QoS into IP networks. It works by sending information that can reserve a certain amount of bandwidth on routers to yield the required level of service. This is done using a resource reservation protocol (RSVP). IntServ is generally not as scalable as some of the other solutions mentioned below.

A3.2.7 *DiffServ*

Differentiated Services achieves QoS using the principle of assigning individual IP packets a level of priority or class of service which affects the way in which other DiffServ enabled routers handle the packets.

[38] Cisco, Hewlett-Packard, IBM, Microsoft, Motorola and Sun have all recently indicated that their products will support IPv6.
[39] www.rpralliance.org
[40] International community of network designers, operators, vendors and researchers. www.ietf.org

A3.2.8 Multi Protocol Label Switching

Multi-protocol label switching (MPLS) and generalised multi-protocol label switching (GMPLS) are standards that are emerging from the IETF. This allows traffic engineering capabilities to be applied to IP traffic by adding labels or tags (concept originally came from Cisco's Tag Switching Protocol) to IP packets. The use of these labels enables dedicated paths (Label Switch Path – see Fig. 4.2 below) with specified classes of service to be implemented according to the levels of service (or quality of service) required by specific services. These MPLS labels are added to IP packets by Label Switch Routers and then forwarded on to other Label Switch Routers in the MPLS network.

Furthermore, multi-protocol label switch can be implemented in an all-optical network in the form of Generalised Multi-Protocol Label Switching (GMPLS[41]).

A3.2.9 Control Plane Protocols

There are also various protocols responsible for control and interoperation of voice and other services between circuit switched and packet switched networks. These protocols enable call control functions (e.g. call set-up and tear down) and value added services in packet switched networks. Protocols such as SIP (Session Initiation Protocol), MGCP (Media Gateway Control Protocol), MEGACO (MEdia GAteway COntrol , ITU-T H.248) and ITU-T H.323 will be used in next generation networks.

A3.3 Optical Technology

Next generation networks will consist of optical technology for the most part[42]. Fibre optical links will in most cases employ wavelength division multiplexing (WDM) techniques to increase overall capacity and to allow for the independent transmission of different services over the same fibre, thus simplifying the terminating network equipment.

Below is a description of some important elements of optical networks.

[41] GMPLS (Generalised MPLS) incorporates MPLambdaS which is used to route individual wavelengths of an optical signal.

[42] Other transmission media such as copper cable or wireless links will continue to be used in many cases in the access segment of Next Generation Networks, especially in the short to medium term.

A3.3.1 Wavelength Division Multiplexing[43]

Wavelength Division Multiplexing allows for the independent transmission of different services over the same optical fibre cable, thus simplifying the terminating network. WDM achieves this by dedicating an individual flow of data to an individual wavelength of light among many (e.g. 160 wavelengths, each capable of carrying 10Gbit/s). There is a trade off here between a few wavelengths with high data rates or many wavelengths with lower data rates which are known as coarse WDM and dense WDM (DWDM) respectively.

A3.3.2 Optical Add/Drop Multiplexing

A common problem with traditional optical networks is that in order to add or retrieve information the optical signal must first be converted back into an electrical signal. Such optical to electrical and electrical to optical conversions require additional pieces of hardware increasing the complexity, power consumption and floor space needed, and therefore the cost of the network. With an Optical Add/Drop Multiplexing (OADM) solution the need for expensive optical to electrical conversion equipment along with the latency that such conversions introduce is eliminated.

A3.3.3 Optical Switches/Cross connects

Optical switching (OXC) exploits the independence of separate optical wavelengths enabling them to be switched and redirected over different routes. This removes the need for optical to electrical conversion, even in the switches[44].

A3.3.4 All Optical Networks

Extending this idea further brings about the concept of an all optical network (AON), where only optical signals are transmitted, with optical to electrical conversion only occurring at the points of data creation and use.

A3.3.5 Optical Access Networks

Optical technology is beginning to be used in the access segment of the next generation network also including fibre to the building (FTTB) and fibre to the home (FTTH), (e.g. initiatives and early projects in Norway, Italy, France, Germany, Australia, Canada, Japan, Korea). Current implementations of passive optical networks (PONs) enable multiple users to be connected to the one optical system without the need to deploy

[43] Multiplexing is the process of grouping information together from two or more independent sources into a single higher speed information flow. An analogy of this is how a number of single lane roads can converge at a junction to form a multi-lane carriageway capable of transporting far more vehicles than a single one lane road.
[44] A current problem with optical switching is the inability to perform optical buffering.

expensive equipment at each network node[45]. Large scale users would require direct fibre optic connection to their service provider.

[45] For example, under the ACTs programme, Portugal Telecom (Portugal), TeleDanmark (Denmark) and Telekomunikacja Polsks (Poland) have run PON trials.