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New ICTs and their Implications for Regulation

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New Technologies and their Impacts on Regulation

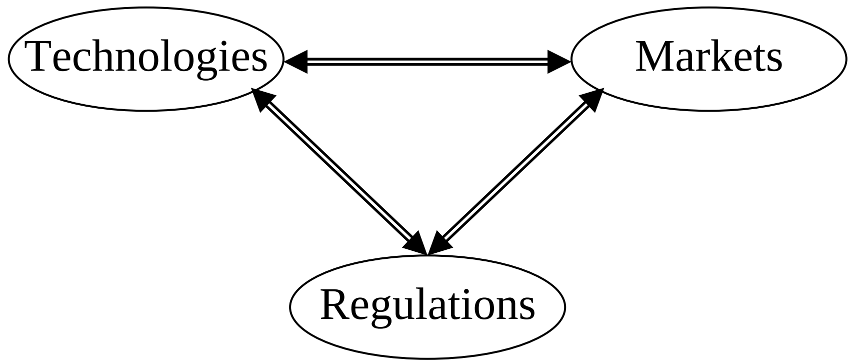
I. Introduction

This paper is intended to inform and assist telecommunication (telecom) regulators, policymakers and others involved in the telecom reform process about new information and communication technology (ICT) trends and their implications for telecom regulation, with particular reference to developing countries. During the initial phase of telecom reform, incumbent national telecom operators were commercialized and in most countries partially or fully privatized. Additional operators were licensed, especially in mobile, and limited competition was permitted or encouraged. National policies and supporting legislation were developed, and national regulatory authorities were established to implement government policies and monitor sector developments. These reforms are being implemented with varying degrees of success in most countries. Generally, they have had a significant positive impact on network and services development.

While these important telecom reforms were being implemented over the past two decades, there have been continuing dramatic improvements in ICTs that are fundamentally changing the telecom sector, creating significant new opportunities for further development. In this dynamic environment, policies and regulations that were appropriate to the first phase of telecom reform may become major barriers to achieving further network and services development. Today, regulators and policy makers examining the diffusion of new technologies and services are encountering major new challenges in the design and implementation of an appropriate set of regulatory standards, models and tools to guide the next phase of telecom reform and regulation.

II. Technologies, Markets, Policies & Regulations

The interrelationships and interdependencies among technologies, markets and regulation are important considerations determining technology trends. These are illustrated in the following diagram.



Forces Shaping Telecom/ICT Sector Development

Technological change opens new technical opportunities. But these will only be taken up if the economics are favorable and they are associated with market opportunities. And both the technical and the economic opportunities are heavily influenced by the policy and regulatory environment which can foster new opportunities or restrict, delay or even sometimes prevent them from being realized. Policy and regulation often follow technological developments, modifying policies and regulations to accommodate new technologies only under pressure after they have been implemented elsewhere. However, pro-active regulation can foster the development and application of new technologies in ways that will better serve network development and other policy objectives. In fact, both the telecom reform and Internet development processes began with policy and regulatory changes that made reform possible.

Some new technologies are more significant than others for net work development and for regulation. By focusing first on the key underlying technologies and technology trends, this report enables regulators to understand better the direction and significance of technological changes. This will place them in a better position to make informed decisions on technology related issues.

III. Three Waves of ICT Technological Development

There are three major waves of ICT technological development that are leading to fundamental changes in network and industry development.

Digitalization Technologies.
The first wave is the technologies associated with the conversion of telecom networks from analogue to digital communication. It includes three interrelated technologies of Network Digitalization, Computerization and Packet-based

Switching. This wave has provided the technological foundation associated with the first wave of regulatory reform, and provided the building blocks for a second wave of technological change. These technologies are now well established and widely implemented globally. There will be continuing improvements in these technologies that will enable further reductions in the costs of equipment and services. Regulatory issues are seldom raised anymore with respect to these technologies as this technology trajectory is by now mature. It is well understood that their continued development is beneficial, and any remaining regulatory barriers to their full implementation should be removed.

Mobility and Internet Technologies.
The second wave of technological changes, which build upon the digital networks established during the first wave, includes the Internet (including Internet Protocol), Mobile Communication, Next Generation Access Networks (NGAN), Convergence and Ambient ICT (e.g., e-commerce). These are technologies that allow new network services to be developed, network capacity to be expanded and the convergence of services to take place. These technologies are now at different stages of development and implementation and are raising a number of important issues for regulators. Voice over Internet protocol is an example. National regulatory authorities already are playing a significant role in influencing the conditions under which these new technologies are being implemented, or restricted, in different countries. In most countries, some changes in regulations are necessary to enable the full benefits of these technologies to be realized.

Application Technologies to Restructure Organizations and Activities.
The third wave of technological changes builds on the second wave. It involves applications of the second wave ICT network services and equipment as a valuable resource, or generic technology to change the way all organizations function. It makes it possible to redesign and rationalize production, administration and transaction processes of all kinds, and to create new products and processes commonly associated with visions of future information societies. The third wave of technology changes is at an early stage of development and implementation, and therefore subject to significant influence by policy and regulation. But most of the potential regulatory issues associated with third wave changes will not become significant until the regulatory issues associated with the second wave have been resolved. The opportunities and effectiveness of third wave policy and regulation will depend heavily on the foundational developments with the second wave technologies.

Telecom reform so far has been primarily associated with, or in response to the technological changes of the first wave of technological development. The key features of the second and third waves of technology changes challenge the established regulatory paradigm in a number of ways. Telecom networks are becoming more multi-faceted and complex. The end-to-end design of Internet Protocol (IP) networks gives rise to a range of new issues, e.g., VoIP competition, network security, etc. The moving of network intelligence from the central core of networks to the edges allows many new kinds of ICT service and application providers to become significant market players. It also poses new security risks that need to be managed. End-to-end design also means that a whole new range of players can be active in markets in which they remain outside traditional regulatory oversight and control.

The implementation of second and third wave technologies gives rise to the further advanced development of infrastructure networks, including ubiquitous networks, the portable internet and the automated Internet of communicating objects. Further, many new technologies are expected to be smaller scale and cheaper to deploy, so this will change investment cycles and patterns, speed up the introduction of new products and services, and enhance possibilities for competition. Smaller players will be able to enter markets and fuel network expansion with relatively small scale investments if the policies and regulations permit them.

The policies and regulations established in this more multi-facetted and complex environment will influence the technological trends, affecting the speed, direction and extent of development in different countries. Compared to the more simple success criteria of fostering network development through competition and universal service rules that has characterized the first wave of telecom reform, regulators will need to establish multi-dimensional success criteria. The second and third waves of technological development introduce major new challenges that now must be examined by policymakers and regulators. The sooner they are able to address these challenges, the greater influence they will have over the development of the telecom and ICT sectors, and of the information society that develops in their respective countries.

III.1 Selection and Classification of Specific Technologies

In addition to examining the underlying waves of technological development, this paper identifies and examines specific key technologies. The following criteria were applied in selecting them:

- they must be important parts of the second wave of ICT technological change;
- they must significantly affect market conditions and, consequently, the conditions for regulation;
- they require changes from the current regulatory paradigm, either now or in the foreseeable future;
- they are affecting, or will affect, the fundamental cost structures and investment patterns in the ICT/ telecom sector;
- they must include infrastructure as well as applications, services and content oriented technology developments;.
- they must have direct implications for developing countries.

As a further step in the technology selection process, the specific technologies that are considered essential in shaping and driving the future market structure, and the emergence of a new regulatory regime, were identified using the following criteria,

- Capacity – to what extent will the new technology increase the speed of transport and delivery and thereby enhance the potential for new services?
- Costs - how will the technology influence the level and structure of costs for infrastructure and services provision?
- Scalability – to what extent are the solutions offered by the technology scalable, i.e. are possible for general application as opposed to only local solutions?
- Flexibility – how can the solutions offered by the technology adapt to change?
- Mobility – to what extent is mobility offered?
- Platform for innovation – to what extent does the technology enhance convergence and development of new services?

Based on these criteria, specific technologies are selected for detailed discussion as a background for the analysis of their regulatory and market impact and their implications for an emerging new regulatory paradigm. These technologies are examined in Part II of the report under the following generic classification scheme:

- First Wave Technologies – digitalization; computerization; packet switching;
- Internet – Internet protocol (IP), QoS, security, mobility and nomadicity, IP version 6, and Peer-2-Peer;
- Mobile – standards, services, future technologies;
- Next Generation Networks – core networks, access networks;
- Convergence – mobile/broadcast, fixed/mobile, triple/multi play services;
- Information Society Technologies – transforming applications in other sectors.

This review demonstrates that the pace, significance and impact of new technologies for the future will be even faster and greater than they have been in the past. The impacts on markets and regulation will be both major and diverse. This dynamic technology environment can create vibrant and flexible markets, but it will require dynamic and flexible regulation if the opportunities are to be realized.

III.2 First wave Technologies

Digitalization, Computerization and Packet based switching are the fundamental technological changes that have massively revolutionized the communication landscape during last two/three decades. As seen in the following, these technologies have massively improved resource utilization and increased the bandwidth capacity in the communication networks. Furthermore, these technologies have enabled possibilities for the creation of new services and created conditions for gaining synergy in the technological development.

These changes have directly influenced the communication markets and the regulation framework, as they are the basis for the IP revolution, the convergence process and emergence of Next Generation Network (NGN) technologies, which in turn have reshaped and restructured different communication sectors.

III.2.1 Digitalization

Digitalization is the technological foundation for the modern convergence process. In the beginning the concept digitalization was used synonymously with the simple conversion of an analogue signal to digital. However, even though the Analogue Digital conversion is the precondition for digitalization, the concept digitalization, as it is used today, goes beyond this and encompasses the whole digital platforms & standards. Three main technologies have been important to make ICT digitalization become a reality: 1) Compression, 2) Modulation and 3) Forward Error Correction. These are described in separate sub-sections in the following.

In the beginning of the1960's, a radical transformation was introduced, as analogue telephone signals were digitized and multiplexed digitally using Pulse Code Modulation (PCM). A telephone signal has a frequency bandwidth of 3.1 KHz. The signal is sampled, using sampling frequency of 8 KHz and quantified by 8 bit per sample resulting in a digital bandwidth of 64 Kbit/s for a telephone signal. Two major digital transmission systems and multiplexing schemes, PDH and SDH, were developed to transmit these PCM codes within the backbone network.

III.2.1.1 Compression

There is normally a considerable amount of redundant information in the analogue audio and video signals. Compression techniques reduce the bandwidth necessary for transmission of a given signal. These can be removed and, consequently, the amount of bits per second that must be transmitted will be reduced substantially. Compression technologies determine the digital bandwidth by making a trade off between how much capacity is available and the quality of service that is needed.

Compression standards have been a vital factor for enabling distribution of audio/video services on the IP networks. Furthermore, compression techniques are the main pillars in the digital broadcasting standards. A number of different standards are defined for audio/video compression. ITU, ETSI, and a number of other standardization organizations have been involved in development of compression standards. Moving Pictures Expert Group (MPEG) has developed three audio/video compression standards, widely deployed in development of audio video services:

- MPEG-1 Primarily intended for applications like computer images and graphics.
- MPEG-2 is used in digital broadcasting. MPEG-2 is intended to be generic in the sense that it serves a wide range of applications, bit rates, resolutions and services. MPEG-2 covers different picture resolution from

Low Level (352X288) pixels to a very high resolution of 1920X1152 pixels, also called High Definition TV (HDTV) resolution.

- MPEG-4 Unlike the MPEG-1 and MPEG-2, which are frame based, MPEG-4 is object based. MPEG-4 supports two-dimensional arbitrarily shaped, natural video object as well as synthetic data. Synthetic data includes text, generic 2D/3D graphics, and animated faces, enabling content-based interaction and manipulation. MPEG-4 is an important standard for distribution of Digital TV to Handheld devices and also for broadband IPTV and Video on demand (VoD).

III.2.1.2 Modulation technologies

Modulation technology is used to encode information, including audio and video signals prior to transmission. The information transmitted is modulated on the carrier wave when and then demodulated at the reception point. In principle, the technology is used for both analogue and digital transmission, though the techniques used in digital modulation – where a stream of binary numbers is sent is different from analogue modulation.

The modulation technologies are developed, based on the characteristics of the transmission medium, so that the data is transmitted in the most efficient way. The modulation efficiency in digital transmission can be measured in bit per symbol or bit per second per Hertz (bit/s/Hz). The modulation efficiency depends on the deployed modulation technology which again depends on the type of the deployed delivery network. There is always a trade off between the error performance required and minimum data payload needed, which makes some modulations more attractive to a particular broadcast media.

Modulation technologies have expanded the transmission capacity of all communication infrastructures. This is especially true in radio spectrum modulation as it has improved spectral efficiency and allowed new spectrum to be deployed for communication. In this relation, a number of other technologies like Software defined radio, Cognitive radio, smart antenna and technologies which use new spectrum (such as in the frequency range at 60 GHz and above) are important.

III.2.1.3 Forward Error Correction (FEC)

Especially in the wireless environment, due to among other things, noise and multi-path interference in the transmission medium, the signals that are received at the end users' site are often erroneous. These errors are experienced at the end-user as signal degradations, and consequently degradation of the quality of service. In two-way communication networks, the problem of errors is often solved by retransmission of the signal. Another technology that can be used, when there is no return path to send commands up-stream and request the transmission source to retransmit the signal, or alter the timing requirements if the signal does not permit retransmission, is Forward Error Correction (FEC).

FEC is implemented so that some administrative information is calculated and added to the signal prior to transmission. The FEC administrative information is then used in the decoder to detect and, if possible, correct the errors in the signal. An important issue regarding FEC is the fact that a part of the transmission capacity is 'sacrificed' to reduce errors and increase quality. The more capacity that is used for the FEC administration the more secure is the transmission. In practice, the level of FEC is determined by the characteristic of the transmission medium.

III.2.2 Computerization

The development of computers has had vital influence on effective organization and operation of network infrastructures. As terminal devices, computers act as intelligent terminals. Using computers in the network nodes has reduced the cost of technology, network management, operation and maintenance.

The processing power of computers and the new applications have had a radical impact on the ICT sectors. On the one hand, the expensive and complex functions in the network like switching, Intelligent Network services, etc. are done to a large extent by computers. On the other hand, computers have diffused in practically every function necessary for operation of an ICT network, like billing, Human Resource Management etc.

III.2.3 Packet switching

The development from circuit switched to packet switched paradigm is another important technological development. In a circuit switched network a dedicated connection (circuit or channel) is set up between two parties for the duration of the communication. The connection and by that the network resources are occupied during the whole session. POTS network is an example of circuit switched network. The problem with circuit switched network is that the network resources are occupied even when they are not in use.

Packet switched technologies, on the other hand, are designed to use the network resources only when meaningful data is subject to transport. Hence, packet switched networks utilize network resources more efficiently through bandwidth sharing. Another aspect of packet switched networks is their capabilities in carrying different types of services. Many modern packet based technologies like ATM and IP are designed to be able to carry different types of services; however, specific technologies/protocols must be implemented for different services.

Different packet switched networks are designed to support variable or fixed packet size and to operate in connection oriented or connection less modes. To be able to handle the packet loss, retransmission is implemented in some packet based technologies.

The most important packet technology with the widest spread and use in the ICT platforms is the Internet Protocol (IP).

III.3 Second wave Technologies

III.3.1 The Internet

The emergence of the Internet, which interconnects billions of IP based devices like computers to each other, may be seen as one of the most important changes in the ICT sector in recent times. The internet was in the beginning primarily used for data services. After it became widely available, E-mail and World Wide Web (WWW) were the most important services on the Internet. However, the number of services over the Internet has expanded, and today these include a variety of audio/video services like Internet radio and TV, Blogs, computer games, etc. The next development we are witnessing is the emergence of an 'Internet of things' (i.e., terminal and equipment signaling without human intervention), which is mainly connected to the development of radio frequency identification (RFID) technology and 'sensor networks'. While a number of issues related to the organization of the general Internet are in place[1], there are a number of unsolved problems and challenges related to the 'Internet of things' which will be on the political agenda in the coming years.

Even though the Internet itself has not been regulated directly in many countries, it has had massive implications on the regulatory framework, as the Internet in different levels of development has been able to facilitate provision of regulated services like voice telephony and TV/radio. Also issues such as IP Interconnection are becoming more important as Internet development expands in the developing countries.

In the following, some fundamental technological issues related to the Internet are described.

III.3.1.1 Internet Protocol (IP)

Internet protocol (IP) was first developed in the US in the mid-1970s, when the Defense Advanced Research Projects Agency (DARPA) became interested in establishing a packet-switched network that would facilitate communication between dissimilar computer systems at research institutions. With the goal of heterogeneous connectivity in mind, DARPA funded research by Stanford University and Bolt, Beranek, and Newman (BBN) [2]. The result of this development effort was the Internet protocol suite, completed in the late 1970s. TCP/IP was later included with Berkeley Software Distribution (BSD), UNIX, and has since become the foundation on which the Internet and the World Wide Web (WWW) are based.

The IP packets contain all the addressing information, which is necessary to be routed in IP networks. The IP routers transmit the IP packets within the network based on the destination address available in the IP packet in a connection-less manner. This reduces network complexity considerably. However, to provide

[1] The current organization is subject for discussion; one of the main problems is the dominance of the US in the organization of the Internet and the skew allocation of number resources. For more discussions on this see the part on IPv6 later in this chapter.

[2] See amongst others: Cisco: Internetworking Technology Overview, June 1999

services in the IP network, connection oriented protocols like TCP and UDP must be implemented to establish a session and make sure that it functions properly.

IP technology is designed in a way that enables a radically different environment for service development, innovation and competition, when it comes to infrastructure platforms and service development platforms. Some of the important characteristics of the IP platforms are outlined as follows:

- Separation between network technology and services
- End-to-End architecture, and extension of intelligence from the core to the edge of a network
- Scalability
- Distributed design and decentralized control

The separation between the underlying network technology and the services removes entry barriers for the service providers. The only precondition for service provision is access to the network. This has created a huge change in the service development within the Internet, but it also creates a problem of revenue sharing between the owners of the network infrastructures and the service/content provider. This is more obvious in the broadband IP infrastructures that are mainly provided by the telecom operators. Especially because the flat rate billing for connectivity has become the dominant business model, it is obvious that the development in value proposition is mainly concentrated in service provision.

End-to-End architecture and extension of intelligence from the core to the edge of a network is another factor that moves the development and innovation activities to the edge of the network. The concept was first introduced in a paper named: 'End-to-End argument in system design'[3]. The main argument here is that an efficient network design can be based on 'dumb core network', where processing is moved to the edge of the network.

Scalability is another main feature of the IP design. One of the barriers for further scalability is the shortage of address capacity or room in the current IP version 4 (IPv4) systems. As discussed in the section on IP version 6 (IPv6) the shortage of address room is a considerable problem for developing countries, mainly due to uneven allocation of the IPv4 address room.

Distributed design and decentralized control is another characteristic that has improved conditions for the development of services, innovations and creations of new businesses. This is due to the fact that different networks can easily connect to other IP networks, including the Internet and obtain value-add from network effects, etc.

These characteristics of the technology create more favourable conditions for development and competition where several actors can be involved in service creation and provision. The general Internet is the major IP network in the world but it is far from the only IP network. In recent years, several private IP networks

[3] Jerome H. Saltzer, David P. Reed, and David D. Clark, 'End-to-end argument in system design', 1981

have been established and utilized for both corporate and residential services, and the future of communication platforms, like the Next Generation Network architecture is based mainly on IP technology. However, when it comes to NGN, the level of competition or monopolistic characteristics depends heavily on the chosen architecture for the deployment of NGN.

III.3.1.2 Quality of Service (QoS)

QoS denotes the capability of the network infrastructure, client applications and the end user terminals to deliver a service living up to certain quality levels. QoS requirements vary from service to service and depend directly on the specific services. In POTS, for example, there are detailed recommendations on QoS from ITU on maximum delay, blocking rate, MOS (Mean Opinion Score), etc.

QoS on the Internet is affected by a number of factors, such as:

- Delay
- Bit Error & Packet loss
- Speech compression
- Echo
- Firewalls

The main deployment of QoS is connected to the introduction and development of IP version 6 (the advanced or next generation IP), which enables possibility for end-to-end QoS provision.

In the managed IP infrastructures it is possible to provide measurable QoS. But this is more difficult in the best effort infrastructures like the Internet; however, in both cases regulatory measures may be necessary. An important issue is the facility based operators willingness to offer access to QoS provision to non-facility based operators. For example, a major debate in Europe and other regions is the lack of QoS provision in the wholesale Bit stream access products offered by the PSTN incumbents. The role of the regulator in relation to QoS is discussed in Part IV of this report

III.3.1.3 Security

In regular telephony services the security and consumer protection standards have been defined and are generally found adequate. With regard to the IP services there is no one-to-one relation between the service and the physical infrastructure. In the IP networks anyone with access to the network can intercept the signal and actively damage the integrity of the message and the signal. For example to assure privacy in VoIP application, the VoIP provider can implement end-to-end encryption, which is not 100% secure but can establish security levels comparable to those of regular telephony. The end-to-end encryption will on the other hand prevent the authorities from lawfully intercepting the VoIP signal.

III.3.1.4 Mobility and Nomadicity

Generally we can distinguish between two types of mobility in relation to ICT:

- Terminal mobility: A mobile terminal can move around the network without disrupting the service;
- Personal mobility (nomadicity): A user can move to different terminals and networks and remain connected

Terminal mobility requires a wireless connection, while personal mobility can be implemented without necessarily having wireless access. What is available now on the Internet could be called personal mobility or portability (i.e. one can move to different places, connect to the Internet and check e-mails, etc.) Through their advanced services, mobile operators are attempting to provide terminal mobility.

Mobility can be implemented at different levels:

- At link layer
- At application layer
- At IP layer

When it comes to e-mail application, the mobility (nomadic use) is implemented at the application level. This type of mobility is highly relevant for the VoIP. The VoIP service can be offered like e-mail (i.e., so that the only precondition for service accessibility is availability of an IP connection). Here it is extremely complex to determine the location of the caller, which creates regulatory problems for emergency calls, discussed in the section about VoIP.

III.3.1.5 IP version 6 (IPv6)

The current Internet Protocol, which is primarily based on IPv4 (IP version 4) has experienced exponential growth both when it comes to the number of IP enabled devices and when it comes to applications and services. IPv4 suffers from major weaknesses when it comes to dealing with the rapid growth in the number of devices connected to the Internet and the new applications and services. This has resulted in standardization of a new version of Internet Protocol, IPv6 (IP version 6), to cope with the shortcomings of IPv4.

One of the main weaknesses of IPv4 is the amount of IP addresses available globally. The IPv4 address consists of 32 bits meaning that there are about 4 billion addresses available. On the one hand, it is obvious that 4 billion addresses are not enough in a world, where more and more devices and terminals become IP enabled. On the other hand, even the current addresses available are allocated so unevenly that many of the developing countries lack IP addresses to develop their ICT infrastructures. According to a consultation paper on 'Issues relating to transition from IPv4 to IPv6 in India'[4]: 'India has merely 2.8 million IPv4 addresses compared to 40 million acquired by China'. Here it is important to note that any common US university has more IP addresses than the total of India, and that a US ISP, Level-3, alone has more IP addresses than China. The distribution is much worse when it comes to the least developed countries, where, e.g., Bangladesh has about 150.000 IP addresses.

[4] TRAI: Consultation paper no. – 8/2005, TRAI, 'issues relating to transition from IPv4 to IPv6 in India, August 26, 2005

IPv6 extends the address room to128 bits such that the number of IP addresses will not present a problem for the foreseeable future. This gives the possibility for allocating more addresses to different countries and regions. Allocation of IPv6 addresses can be done more evenly as it does not suffer from the legacy effects created by allocation of IPv4 address room. In the future development, where we are surrounded by the 'Internet of Things'[5], there will be an even greater need for IP addresses.

The other issues that are dealt with in IPv6 are the QoS and security issues. QoS is important in relation to real time services, and security at IP level will generally be required by a number of services in the future.

III.3.1.6 Peer2Peer

The Internet is traditionally based on a client-server approach. There are a number of servers in the networks performing specific tasks, such as e-mail server, web server, etc. The end-users install clients on their IP terminal; computers, mobile phones, PDAs, and connect to the servers for specific services. There is however another approach that is used more and more, where the end-users IP terminals act both as a client and a server. In this approach the IP terminals connect directly to each other and share information, files, etc. This approach is called Peer2Peer to indicate that the peers communicate directly with each other.

The Peer 2 Peer concept is as old as the Internet. The first Internet was Peer2Peer, and it was in the later development that client server approach was invented and developed to offer services like E-mail, WWW, etc. However the large deployment of Peer2Peer is mainly connected to the applications designed for sharing music and later movies. The Peer2Peer technology is by no means limited to the sharing of music and movies and can be used in any network applications, which need information sharing. These are, e.g., multiplayer games, signaling in telecommunication, corporate applications, etc.

One of the main challenges to make Peer2Peer networks work efficiently is locating of information. This can be compared with the role of signaling in the telephony networks to locate the parties, who want to communicate with each other. Through the last 5-6 years a number of Peer 2 Peer applications have been developed; some known examples are: 1) Napster, 2) Gnutella, 3) FreeNet and 4) BitTorrent. The aim of these applications has been to facilitate document sharing and mainly sharing of music and movies. Many of the current applications, which are based on Peer 2 Peer, are based on one of these technologies, or a combination of them. The VoIP application Skype has based its signaling protocols on the Peer 2 Peer approach.

[5] See amongst others the ITU Internet report 2005: the Internet of Things

III.3.2 Mobile Communication

The development of mobile technologies and services in the last two decades has had massive implications on the ICT landscape. Mobile technologies enable mobility and flexibility in use of ICT services. Mobile technologies have primarily been driven by the voice telephony but in their development and especially when it comes to wireless standards and the new generation mobile technologies, they embrace the whole portfolio of converged services.

The emergence of mobile communication has influenced the telecom regulation at all levels. Licensing and frequency management have been main regulatory issues for introduction of mobile services. Furthermore, the regulatory design related to interconnection and tariff regulation, pricing, numbering, etc. have been important in making a competitive and innovative mobile market to develop. Due to its 'time to market' and flexibility, mobile communication has been important in offering telephony to the developing countries.

III.3.2.1 First Generation: 1G

The first generation mobile standards were based on analogue technology. The mobile market in this era was fragmented, where a variety of standards were developed and used in different countries. The Nordic Mobile Telephone (NMT) is one of the earliest 1G-standards. A number of other 1G-standards were used in different countries/regions. Some important examples are: Total Access Communication Systems (TACS) in the UK and Ireland, NMT-F and RC 2000 in France, NTT in Japan, Advanced Mobile Phone System (AMPS) in the US, C-450 in South Africa and C-Nets in Germany and Austria,

III.3.2.2 Second generation: 2G

The second generation mobile standards are based on digital technology. Digital technology utilizes the transmission resources in an efficient way, both due to advances of audio compression standards and also due to advances in digital modulation technologies. Another important characteristic of the 2G mobile is the less fragmented mobile market. This is especially due to Europe's decision on using common standard and creation of a single mobile market, but also because the European standard, GSM, has had enormous success beyond Europe and is used in a number of other countries.

Group Special Mobile within the CEPT started to develop GSM in 1982. Later it was standardized by the ETSI and branded as a Global System for Mobile (GSM). One of the most important conclusions from the early tests of the new GSM technology was that the new standard should employ Time Division Multiple Access (TDMA) technology. This ensured the support of major corporate players like Nokia, Ericsson and Siemens, and the flexibility of having access to a broad range of suppliers and the potential to get products more quickly into the marketplace[6]. After a series of tests, the GSM digital standard was proven to work in 1988.

[6] GSM case study, ITU

GSM operates mainly on 900 and 1800 frequency bands. However, in North America it operates on 1900 MHz. There is also a version which uses the 450 MHz band (GSM400) which can be used in the less populated areas, and can be relevant for the less populated rural areas in the developing countries.

However, there are a number of competing standards to GSM; mainly:

- *TDMA IS-136* is the digital enhancement of the analog AMPS technology. It was called D-AMPS when it was fist introduced in late 1991 and its main objective was to protect the substantial investment that service providers had made in AMPS technology. Mainly used in North America.
- *CDMA IS-95* increases capacity by using the entire radio band with each using a unique code (CDMA or Code Division Multiple Access). It is a family of digital communication techniques and South Korea is the largest single CDMA IS-95 market in the world.
- *Personal Digital Cellular* (PDC) is the second largest digital mobile standard although it is exclusively used in Japan where it was introduced in 1994. Like GSM, it is based on the TDMA access technology.
- *Personal Handyphone System (PHS)* is a digital system used in Japan, first launched in 1995 as a cheaper alternative to cellular systems. It is somewhere between a cellular and a cordless technology. It has inferior coverage area and limited usage in moving vehicles.[7]

In the transition from 2G to 3G a number of standards have been developed, which are categorized as 2.5G. These are add-ons to the 2G standards and mainly focus on deployment of efficient IP connectivity within the mobile networks.

III.3.2.3 Evolution of 2G towards 2.5G

In the 2G and 2.5G mobile, several technological developments have been introduced to increase the capacity bandwidth of the networks and to enable provision of new services in these platforms. Standard bandwidth for data services in GSM networks is 9.6 Kbps per time slot[8]. However, many providers offer 14.4 Kbps per time slot using more efficient modulation technologies. To increase the available capacity at the end user's site in GSM networks, two approaches are used:

- Deployment of several time slots. This is called HSCSD (High Speed Circuit Switched Data).
- Deployment of packet oriented IP based technologies like GPRS and EDGE.

[7] http://www.itu.int/osg/spu/imt-2000/technology.html
[8] One time slot corresponds to the capacity of one standards GSM connection

When using HSCSD technology, a maximum capacity of 38.4 Kbps will be achieved if 9.6 Kbps per time slot is used (and 57.6 Kbps in the case of 14.4 Kbps per time slot). In both cases, the assumption is that all 8 time slots are used: 4 time slots for uplink and 4 for downlink.

GPRS, on the other hand, is packet based and is optimized for IP traffic. In GPRS, the capacity per time slot depends on the deployed technology: CS1: 9.05 Kbps per time slot; CS2: 13.4 Kbps per time slot; CS3: 15.6 Kbps per time slot; CS4: 21.4 Kbps per time slot. In theory, using 8 time slots and CS4 technology, a maximum capacity of 171.3 Kbps can be achieved.

EDGE can be seen as a technology with the same characteristics as GPRS but with more efficient modulation techniques and, consequently, higher capacities per time slot. Theoretically, it is possible to achieve 59 Kbps per time slot, providing a maximum capacity of 472 Kbps. The capacity will depend on the deployed technology (MsC1 to MsC9), and a maximum capacity per time slot of 48 Kbps is considered as realistic in mature EDGE networks giving a maximum overall capacity of 384 Kbps.

One important issue here is that even though GPRS and EDGE are capable of offering high bandwidth connectivity to the end users, the amount of frequency resources in the GSM network are far below the resources necessary to cope with the ever increasing demand of the end users for data services.

The technological evolution path towards 3G networks and the standards that will be deployed in different markets depend primarily on the current 2G markets. The natural consequence of this has been definition of a variety of variants of IMT-2000 standard that can be chosen by different operators based on parameters like reusability, interoperability, etc.

III.3.2.4 Third generation: 3G

The main development in the mobile networks has been the development from 2G to 3G and beyond. This has been primarily driven by the lack of frequency resources in 2G to cope with the rapid development and penetration of mobile services and the need for new mobile services with varying demand on bandwidth. The 3G platforms on the one hand include new frequency bands for provision of mobile services, and on the other hand deploy more efficient technologies than 2G resulting in increased spectral efficiency. Furthermore, the 3G technologies have been developed due to their potential in meeting universal access goal. This has been one of the arguments at ITU for backing the development of 3G standards.

3G standards are a set of standards called IMT 2000, issued by ITU in March 1999[9].

[9] The standards or the variation of standards are can be found at http://www.itu.int/osg/spu/imt-2000/technology.html

In order to generate a more efficient usage of available frequency, IMT-2000 had the task to standardize the new air interface that would enable this. The WCDMA air interface was selected for paired frequency bands (FDD operation) and TDCDMA (TDD operation) for unpaired spectrum. CDMA2000 standard was created to support IS-95 evolution[10].

W-CDMA (Wideband Code Division Multiple Access). W-CDMA is the task scheme defined by the ITU to be the main technical platform for UMTS or 3rd Generation Mobile services. W-CDMA services are to operate within the following frequency bands: 1920 MHz -1980 MHz and 2110 MHz - 2170 MHz.

NTT DoCoMo's FOMA network uses a version of the W-CDMA standard in its network deployment. The ITU had selected W-CDMA as one of the global telecom systems for the new IMT-2000 3G mobile communications standard. In W-CDMA interface different users can simultaneously transmit at different data rates and data rates can even vary in time[11]. W-CDMA is capable of delivering up to 384 kbps in outdoor environments and up to 2 Mbps in fixed in-door environments.

CDMA2000 (Code Division Multiple Access 2000). CDMA2000 (with the ITU designation IMT-2000 CDMA Multi-Carrier) represents a family of technologies. CDMA2000 supports data communication speeds ranging from 144kbps to 2Mbps, with 144kbps being the maximum possible speeds outdoors and 2Mbps being the maximum speed in an indoor environment.

Because CDMA2000 is evolved directly from the previous generation of proven CDMA systems, it provides the most effective path to 3G services. While all 3G technologies (CDMA2000, WCDMA and TD-SCDMA) may be viable, CDMA2000 is much further ahead in terms of product development, commercial deployment and market acceptance[12].

The world's first 3G (CDMA2000 1X) commercial system was launched by SK Telecom (Korea) in October 2000. Since then, CDMA2000 1X has been deployed in Asia, North and South America and Europe, and the subscriber base is growing at 700,000 subscribers per day. CDMA2000 1xEV-DO was launched in 2002 by SK Telecom and KT Freetel. The commercial success of CDMA2000 has made the IMT-2000 vision a reality.

TD-CDMA (Time Division- Code Division Multiple Access). UTRA TDD is planned to operate in the unpaired spectrum. TDD uses a combined time division and code division multiple access scheme. It is based on radio access technique proposed by ETSI Delta group and the specifications were finalized 1999[13].

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10 http://www.umtsworld.com/technology/technology.htm
11 http://www.umtsworld.com/technology/tdcdma.htm
12 http://www.qualcomm.com/cdma/3g.html
13 http://www.umtsworld.com/technology/tdcdma.htm

III.3.3 Mobile services

Mobile services in the 1G and 2G are dominated by regular voice services, offered primarily in circuit switched network architecture. In 2G however also the SMS service has been an important service. Furthermore, IP connectivity and Internet access have been the drivers of the development towards 2.5G and 3G. Especially in 3G it is generally accepted that the data and Internet type of services will dominate the 3G markets. Furthermore, the voice services will be further differentiated and will not remain as a unique and coherent set of services as we know them today. In figure 1 below a categorization of the mobile services is illustrated.

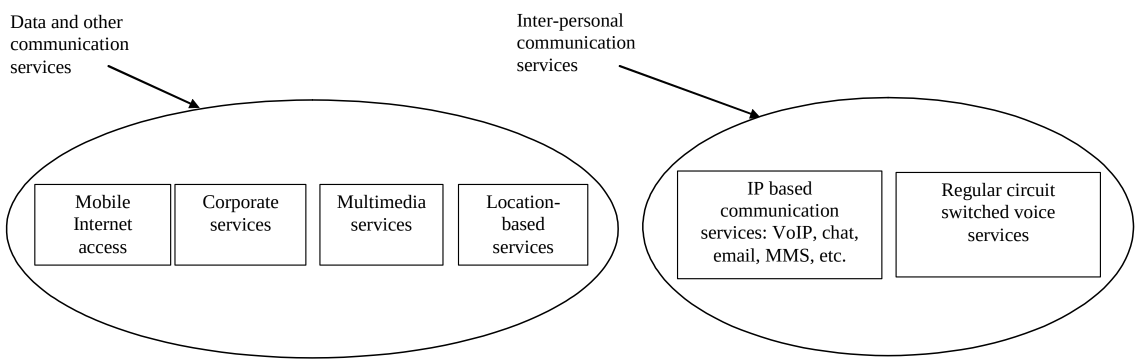

Figure 1 *Categorization of Mobile services*

The services can be divided in two categories:

- Inter-personal communication services: These are the main services in the current mobile networks with voice services as the absolute dominant one.
- Data and other communication services: These are primarily communication services between a service provider (or a workplace, a machine, an application) and the end-user. These services are developed rapidly on the Internet and the majority of them are based on IP protocols provided on the Internet and / or other IP based networks.

III.3.4 Future technologies

III.3.4.1 Software Defined Radio & Cognitive Radio

Software defined radio (SDR)and Cognitive Radio are new technologies that provide a more flexible design for the wireless and mobile industry and at the same time these technologies enable alternate utilization of frequency resources. However, correct deployment of the technologies requires radical changes in the regulatory framework of frequency management.

Software defined radio (SDR) is a flexible radio architecture programmed through software, which is reconfigured depending on the usage scenario. SDR consists of a programmable hardware base that is controlled through software, where different parameters, like power level, frequency band, modulation, etc. are changed/configured depending upon the environments in which users move.

In the current Hardware Defined Radio (HDR) era all the parameters in the radio access interface are fixed parameters that cannot be changed. A GSM interface is designed for the GSM band, so a GSM phone cannot be reconfigured to work in a CDMA environment[14]. So using the analogy of the pre-PC era to the current HDR era, there are a number of specialized wireless devices for specialized tasks. The SDR platform will like the PCs create the possibility of changing the character of the device depending on the application and by downloading different software modules.

SDR creates a number of regulatory challenges especially when it comes to frequency allocation and management. For regulators, SDR has the potential to bring radical changes to how spectrum is used, and therefore to the regulations that apply to radio communication systems.

In the HDR era it was relatively easy to maintain frequency management, because 'the manufacturer sets power limits and other restrictions based on the regulations that govern the type of device being built, and the device must be certified before it can be sold. But in Advanced Wireless Technologies and Spectrum Management, the ITU suggests that if a device can change its function simply by loading a new application onto it, the current, hardware-based approvals process will not be sufficient. "This raises some difficult questions for regulators since rather than focusing on the hardware elements of electronic devices... the key approval must lie with the software that controls the radio,"'[15].

Furthermore, there are important issues related to the way the SDR market will emerge. In the SDR era (like PCs) one can acquire hardware from one firm, software from another and the operative system from a third firm. Which one of these must be regulated? And what if somebody modifies the software, for example, to change the power level? These questions and uncertainties show that even though there are lots of possibilities and flexibilities connected to the SDR development, there are also a number of challenges from the regulatory side to make this revolution take place.

Cognitive Radio is a technology that could make efficient use of unused spectrum, potentially allowing large amounts of spectrum to become available for future high bandwidth applications. Most of today's radio systems are unaware of their spectrum environment - they are designed to operate in a specific frequency band. A Cognitive Radio system senses and understands its local radio environment to identify temporarily vacant spectrum to operate in. Cognitive

[14] Another approach is to implement different hardware standards in the same terminal, like dual band, etc.
[15] INTERNATIONAL TELECOMMUNICATION UNION, WORKSHOP ON RADIO SPECTRUM MANAGEMENT
FOR A CONVERGING WORLD, Document: RSM/08, February 2004,GENEVA — ITU NEW INITIATIVES PROGRAMME — 16-18 FEBRUARY 2004

Radio would detect unused bands of the radio spectrum and transmit to another frequency if the licensed user of a primary user[16] of a band requires that spectrum[17].

The work undertaken into SDR suggests that flexible, multi-protocol, multi-band Cognitive Radio systems are some way off. Handsets employing this technology are unlikely before 2010. In the interim there is the possibility of specific band sharing technologies emerging which would provide a stepping stone towards the full Cognitive Radio vision[18].

III.3.5 Next Generation Networks (NGN)

The NGN concept is mainly used in two ways: 1) A broad concept encompassing the whole development of new network technologies, new access infrastructures and even new services, and 2) A focused concept of specific network architecture and related equipment, with one common IP core network deployed for the entire legacy, current and future access networks. ITU defines NGN as: "a packet-based network able to provide telecommunication services and able to make use of multiple broadband, QoS-enabled transport technologies and in which service-related functions are independent from underlying transport related technologies. It enables unfettered access for users to networks and to competing service providers and/or services of their choice. It supports generalized mobility which will allow consistent and ubiquitous provision of services to users"[19].

The first concept definition is so broad that in a sense it covers the whole current chapter on technological trends. The second definition relates to the transition path towards a converged IP based core and access network. In the ITU definition there is a major emphasis on one of the main characteristics of IP platforms namely the separation of network and service layers. In this report the concept NGN denotes the second definition. Here we distinguish between the Next Generation Core Network (NGCN) and Next Generation Access Network (NGAN). The NGCN is about the new switching, gateways and transmission equipments in the core network, enabling several access networks to use the same core network. The NGAN is about new *access* networks, like deployment of optical fibers, and the challenges derived from that.

NGN is about transition of current dedicated voice (and radio/TV) networks to the IP based networks. From a technology efficiency point of view this is a natural development of all network technologies, however, there are a number of problems related to the overall organization of the NGN platforms, which are among the range of contentious issue before regulators at present. One of the main issues is the interconnection model, which will be used in the NGN. Will

[16] For example a license holder to that part of spectrum
[17] Ofcom Technology Research Program
[18] Ofcom Technology Research Program
[19] ITU-T Recommendation Y.2001

this, for example, be dominated by the IP interconnection models like peering and transit or will the PSTN interconnection and tariff regime be modified and used in the future NGN platforms? The telecom incumbents tend to see the NGN as a means of significantly reducing their network operating costs and complexity, while the market players from the IT world see the NGN as an opportunity for changing and revolutionizing the organization model of the entire future network.

The NGN covers different network technologies with different technical parameters. With respect to NGCN, the important parameters are the high level of flexibility and scalability. Also the bandwidth levels and the innovation possibilities are quite high in these platforms. With regards to NGAN, the characteristics are very different. The cost of establishing fiber networks is very high, and the scalability is low, due to the high cost of extension of the network. However, the scalability depends on the geographical conditions. On the other hand, in the wireless networks the level of mobility can be high, the cost of establishing networks is quite low, and the level of scalability is quite high. The level of bandwidth in the wireless networks depends on the chosen technology; however, the bandwidth levels of all the modern wireless networks are comparatively high.

III.3.5.1 Next Generation Core Networks (NGCN)

Figure 2 illustrates the difference between today's telecom networks and tomorrow's NGN platforms. Today, the PSTN, mobile networks, Cable TV networks, Wireless networks, etc. use several dedicated metro and core networks.

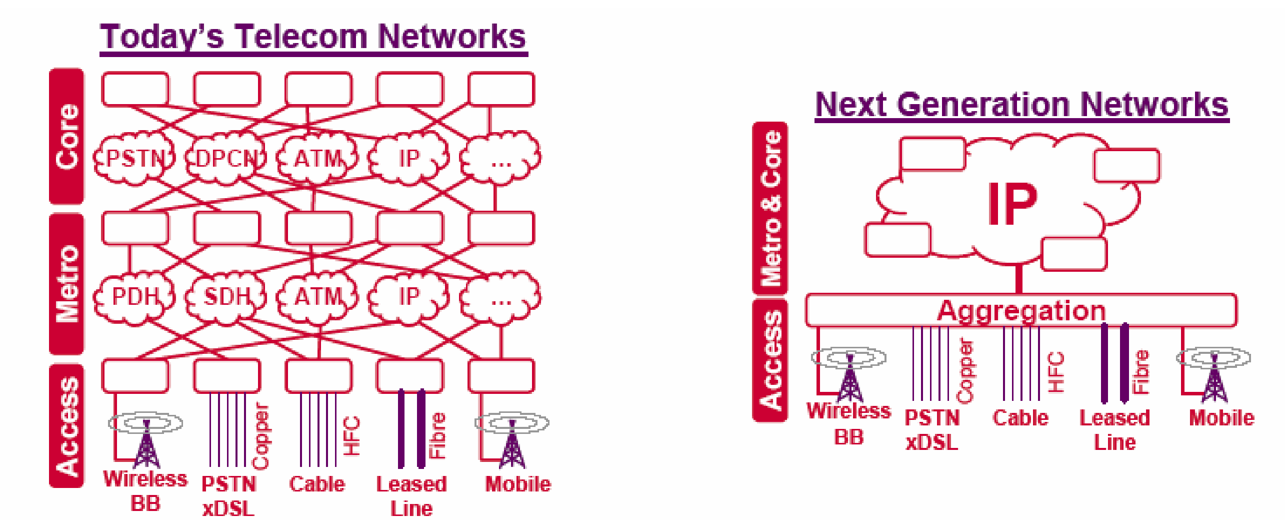

Figure 2 *NGN*[20]

[20] Ofcom: Next Generation Networks: Further Consultation, Issued: 30 June 2005, Closing date for responses: 12 August 2005

In the NGN platform all of these different access technologies share the same IP core network. The main arguments for transition to the NGN architecture include:

- The fact that is not efficient to maintain several core networks for different access networks. Substantial cost savings can be achieved due to the economy of scope inherent in a single converged network. BT predicts[21] to reduce costs by £1 billion per annum by 2008/2009 as a consequence of migrating to NGN.
- According to BT, NGN enables improved time to market for new services and improve customer experience.
- NGN enables continuation of offering services in the legacy access networks. For example the analogue PSTN access line/service does not need to be changed in transition to NGN. The main changes here are the efficiencies gained in the core network, especially when one operator owns and operates several parallel core networks. The latter is the case for a majority of incumbent operators. So the operator on the one hand utilizes the backbone efficiency gains and on the other hand continues to make profit from the investments in the access networks.
- NGN enables provision of value added innovative services using the possibility that one core network is connected to and manages different access networks. For example a SMS can be sent to a mobile subscriber to inform the users if there are problems with the operation of DSL.

These facts show that the implementation of NGN is a radical change in the network architecture of incumbent telecom operators. This raises the question of the role of regulation in this process: Should regulators intervene in the practical implementation of the NGN, and if so in what way? The role of regulation regarding NGN is on the one hand to make sure that effective competition can take place in the NGN era, and on the other hand make sure that the consumers and the level of services they receive are not affected in a negative way in this transition.

III.3.5.2 Next Generation Access Networks (NGAN)

One of the main challenges of network infrastructures development is efficient deployment of broadband technologies. Broadband is growing fast and its role in creation of values in the new economies is more and more recognized. In Europe the development has been dominated by DSL technology so far, but other broadband technologies – cable, fiber optic lines, wireless, satellite - count for a substantial part of broadband households and growth rates. In other countries and regions, the other technologies dominate growth. In the developing countries, it is likely that traditional broadband like DSL will play a minor role and the development of broadband will mainly be influenced by the development of new wireless technologies.

[21] Ofcom: Next Generation Networks: Further Consultation, Issued: 30 June 2005, Closing date for responses: 12 August 2005

One of the main challenges in the development of broadband has been the ability of regulation to open up the legacy telecom networks for provision of DSL services through, e.g., unbundling and Bit stream access.[22] The open access discussion has further been raised with reference to the provision of broadband through cable TV networks. The cable TV open access discussion is mainly important in the US, where the number of cable broadband is many times that of DSL broadband. In the European countries cable broadband is becoming an attractive competitor, especially in the era of triple/multi play[23]. Here the open access can spur variety in ISPs and may reduce nominal prices for services[24].

Another technology which deploys a legacy network infrastructure is PLC, Power Line Communication. The emergence of PLC and argumentations on its viability has been based on the ubiquity of the Power line infrastructures but in reality the PLC technology has at best become a niche broadband product.

Mobile and wireless technologies use the radio spectrum resources to offer new narrowband and broadband access technologies. As mentioned earlier the scarcity of frequency resources put high requirements on efficient utilization of radio spectrum resources, which is partly implemented by development of new technologies and partly by combination of different technologies.

Mobile Communication is identified as a major technological trend and is described in a separate chapter in this part. In this section the potential of wireless systems as access infrastructures in the framework of NGAN is analyzed.

xDSL

Due to the pervasive installed base of the PSTN physical infrastructure, PSTN has been the basis for fast and efficient development and penetration of the Internet. In the pre broadband phase, this was implemented by modulation of data signal in the same frequency spectrum as regular voice in the copper access lines. The data capacity in this frequency bandwidth is small and it can reach the maximum of 56 kbps. The next phase was introduction of ISDN, which improved the capacity and could offer 128 Kbps to residential households. ISDN was soon replaced by technologies with real broadband potentials, primarily based on different variants of xDSL technologies. The advantage of the xDSL is the availability of the physical infrastructure and by that the low deployment cost. As seen in the following, the technology has certain limitations when it comes to coverage and capacity. New xDSL technologies and standards try to solve some of the problems; however, as seen in the following some of the problems are connected to the physical characteristics of the PSTN copper infrastructure,

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[22] Page: 24
This applies where competitive operators are trying to enter the broadband provisioning market through unbundling or bit stream access. But it's not an issue if there is no legacy infrastructure to upgrade. In the developing countries the new broadband deployments such as 3G and WiMAX, are more important.
[23] Provision of three main services, Internet, VoIP and IPTV in broadband networks is denoted as triple play. The term multi play refers to broadband networks which offer additional services to the triple play.
[24] See amongst others Bittlingmayer G. et al 2002

which necessities solutions that include changes in the architecture of the infrastructure. This goes, however, against the mentioned advantages of xDSL related to deployment and cost.

Cable TV

Cable TV infrastructure is another infrastructure with a huge installed base and with great potentials for delivery of broadband connections. The penetration of cable TV networks varies from country to country. In Denmark, e.g., the cable TV penetration is about 70%.

A cable TV system is a distributive system, where the resources are organized as a number of 8 MHz channels for broadcast TV distribution. Cable TV systems have a huge capacity, however, the total capacity depends on how modern the system is and, consequently, on how much frequency bandwidth of the coax is utilized.

Cable TV infrastructure is optimally positioned in the future broadband market due to its capabilities in offering triple/multi-play services. This is because the network is optimized for TV distribution and capable of delivering broadband. Many other broadband infrastructures face a huge challenge in delivering of broadcast TV.

One of the weaknesses of Cable TV network in relation to broadband is that it is a shared medium, i.e., a number of users share the capacity in a network segment. Another problem which is connected to the current structure is that it is not a simple task to open the cable networks to a third party operator and establish competition. This is both due to the ‘shared medium’ aspect and because the cable TV networks are not standardized.

An important element in utilization of Cable TV structure for broadband is introduction of VoIP with QoS support. Especially in DOCSIS 1.1 there are specific procedures for establishing prioritization to minimize delay and jitter which are highly necessary for VoIP. The problem is, however, that because of the mentioned problem of opening the network to third part operators, the general ‘best effort’ VoIP operators cannot take advantage of these QoS improving measures.

PLC

For promotion of competition, establishment of new communication access infrastructures has been very important (”Several pipes to the home”), and in connection to this, broadband over power lines has been discussed, especially in Europe, for many years.

PLC utilizes the high frequency part of spectrum in the existing power line infrastructures. Electricity supply is provided in the low 50-60 Hz band and the frequencies over 1 MHz can be used for broadband. With regards to the capacity, PLC has been able to match DSL technologies in the recent years. One of the important arguments for utilizing PLC as IP infrastructures has been the ubiquity of the physical infrastructure. Power line infrastructures have very high penetration and the idea has been that one can use this infrastructure to offer broadband in an easy way and without establishing a totally new physical infrastructure. Another aspect is that all rooms in a household are connected to the power line infrastructure, and this gives possibility for new and innovative services within the ‘intelligent home’ technologies paradigm.

PLC has suffered from several problems with noise and interference, which are solved today to a certain degree in the low voltage part of the power line infrastructureThe EU recommends the member countries to remove any barrier to development of services over PLC.

Even though the major technical obstacles like noise and interference are being solved, there are not that many market players (within and outside the power line business) that see any future for this technology as a means to deliver IP/broadband services[25]. For more discussions about techno-economics of PLC, please refer to part III.

In Denmark, e.g., only one power Line Company has commercial trials with PLC but they are planning to out-phase it and replace it with FTTH (Fiber To The Home) connections. Other power companies that have a very solid broadband business have decided not to put any efforts for PLC technology from the very first day and solely deploy FTTx technology in their networks. This is however the main tendency in power companies’ involvement in the IP business and what is evident is, that the power companies get more and more involved in the IP/broadband business but mainly by focusing on fiber technology.

PLC is deployed in a niche market with low scale in connection to some FTTx solutions. For example when a big apartment complex is supplied by fiber to the cellar, connecting the apartments to this fiber requires, that either the suppliers extend the fiber to all apartments, they establish a new electrical cabling to the apartments or use PLC to deliver broadband to the apartments. Here it has been shown that PLC is a good solution when the number of interested apartments is low. The strategy of the provider in this case is typically that the PLC is used only for Internet connectivity, and real triple/multi play may wait until new broadband infrastructures are established.

Optical Fiber Technology and FTTx

Optical fibers are broadband infrastructures with huge potential. Here, the physical capacity is not indicated by Mbps but by Gbps and with respect to coverage (e.g. distances of around 10 Km from the central points.) Even though it is possible to offer capacities of Gbps, these capacities are not implemented at the end users site. Different reasons for this are amongst others cost of termination and the resource planning as well as pricing issues at the service provider side.

[25] Data communication over PLC can be relevant when it comes to operation and maintenance and monitoring of the power line infrastructures

Optical fiber infrastructures are implemented using different architectures which can be denoted commonly: FTTx (FTTHome, FTTArea, FTTCabinet, FTTCurb, …).

Cost of deployment of the optical infrastructures is higher than other broadband technologies but the broadband product which can be offered in the fiber infrastructures are incomparable with the traditional broadband. The development in the last couple of years shows that the implementation of fiber infrastructures becomes more and more viable and that especially the power companies have been very active in the area. This is mainly due to decreasing cost of fiber, decreasing cost of termination equipments, general liberalization and the possibilities for offering triple/multi play.

WiFi and WiMAX

The wireless network standard 802.11, which has gained a lot of attention, was published by the Institute of Electrical and Electronics Engineers (IEEE) in 1999. Several variations of the standard have been published since - the best known is IEEE 802.11b, better known to the public as WiFi (Wireless Fidelity). The 802.11b standard uses the unlicensed Industrial, Science and Medical (ISM) band. In the absence of licensing barriers, and because of the simplicity of the technology and its cost effectiveness, WiFi networks have developed rapidly in both industrialized and developing countries. Indoor coverage of 50 to 100 meter is normal and depending on the standard, bit rates of 11 to 54 Mbps (in some proprietary version even more) are possible. It is, however, important to mention that the net data capacity is far below these figures.

Furthermore, the capacity in a WLAN is shared and the available capacity per user depends on the number of users connected to an access point. WiFi coverage can be extended using outdoor antennas and also point to point connections can be established using WiFi.

WiMAX is the popular name of IEEE802.16 standard, which may become the international FWA standard. Other FWA standards have shown not to be competitive in the access networks. In some cases FWA is used for business users and in the backbone network. FWAs lack of success in the access networks is due to different reasons; among others the lack of open standards and the requirement for Line of Site in the installations.

WiMAX is also developing to become mobile. It may be fixed wireless access now, but is expected to go mobile in 2008. The term FWA is also changed to BWA (Broadband Wireless Access), which encompasses both FWA and mobile wireless access.

WiMAX is like WiFi becoming a standard, which is supported by several market actors. WiMAX is forecasted to be a simple and cheap technology[26] with long coverage and high capacity. Coverage of 50 Km and capacity of around 70 Mbps

[26] The real cost of the technology depends on a variety of factors

is a reality in this technology. It is however important to note that the capacity offered over long distances is only a fraction of the maximum capacity. And WiMAX as access technology is offered in distances of 5 to 10 Km. WiMAX will then be a good complementary /competitive infrastructure to traditional broadband. Another important aspect is that 70 Mbps will only be achieved if frequency bandwidth of 20 MHz is allocated and assigned by the local authorities. Probably many regulators will assign smaller frequency bands to the potential WiMAX operators.

WiFi and WiMAX technologies are highly relevant for rural areas.

Digital broadcast infrastructures

Digital broadcasting denotes a broadcasting system, where the broadcasting signal is digitalized. The digital signal at the end users' site can be fed directly into the integrated digital receivers, or in a transition period, e.g. regarding TV, through a set-top-box to a regular analogue TV receiver.

Digital broadcast denotes a set of standards that aim to distribute broadcast signals in digital form in a specific and standardized way. In this set of standards room is also created for transmission of data services. Data services in Digital broadcast standards are either stand-alone data services or program related data. Digital broadcast standards are not worldwide standards and different markets apply to different standards: European DAB &DVB[27], US ATSC or Japanese ISDB standards. The main block of the Digital TV standards, namely video compression standard MPEG-2, is deployed in a majority of standards.

Because of specific characteristics of different infrastructures, different standards apply to different infrastructures. In the European DVB standard different set of standards are developed for all current infrastructures (Cable, Satellite and terrestrial). DVB standards are widely used all over the world, both in terrestrial, cable and satellite digital TV. Also in some markets combinations of different standards are used.

For analogue broadcasting each TV program requires its own set of frequencies. A transmitter distributes the program and as a transmitter, e.g., terrestrial broadcasting has a limited coverage area countrywide, regional distribution requires deployment of several bigger and smaller transmitters. The different transmitters must use different frequencies to avoid noise or disturbance. The result is that a set of frequencies is necessary to cover a country with one TV program.

[27] In Europe the DVB-project – a co-operation between broadcasters, network operators, equipment industry etc. – specifies the standards for terrestrial, satellite and cable distribution of digital TV (denoted: DVB-T, DVB-S and DVB-C). The specifications are then standardised within the European Telecommunications Standardisation Institute (ETSI).

The shift to digital broadcasting is not straighforward, however, as it introduces a range of interrelated political, economic and technical challenges. Some of these challenges are specific to the mode of distribution – satellite, cable or terrestrial with the latter having special problems and potentials.

As the basic technologies are now ready, solutions to two sets of regulatory issues are pertinent for the development and diffusion of terrestrial DVB. One set of issues is related to the concept of Public Service Broadcasters. In almost all countries, cultural policy considerations have given rise to privileges and obligations for a few broadcasters. There is general acceptance of the need for the continued existence of Public Service Broadcasters, but to what extent are they needed in the context of new services? There are some parallels to be drawn in the discussion of Universal Service in telecommunications, but the emphasis on content in broadcast regulation adds new dimensions to the discussion. These regulatory problems are, however, not the focus for this paper.

The other set of regulatory issues is related to new facilities such as multiplexing (management of frequency sharing), Electronic Programming Guide (EPG), and Conditional Access (CA). The organization of the multiplexing function becomes crucial, as digital broadcasting allows a number of content providers to share frequencies traditionally allocated to one channel. The EPG represents users' entrance to the digital services. Especially for small language areas, the strong presence of national programs makes cultural policy and some regulation a high priority in relation to these functions. Conditional Access regulates entry to services typically via an entrance code on a PCMIA-card. From a user's perspective, it is essential that entry control is standardized and does not require different hardware for each content provider.

III.3.6 Convergence

The traditional broadcasting and telecommunication industries have co-evolved with the developing Internet, but the technological development is making this current sectoral distinction unsustainable. Content and service provision have already taken place across the traditional sectoral boundaries for some time. Different services can be carried on different infrastructures and the end users' access equipment will be designed to communicate with different services.

III.3.6.1 Mobile / Broadcast convergence

One of the main challenges that the mobile industry faces is the demand for increased broadband capacity necessary to distribute video, music, games and other digital content optimally to many mobile users at the same time. Parallel to this, the broadcast industry faces a decisive challenge in personalizing content and segmenting channels towards a still more fragmented market that, apart from digital TV and radio, includes the Internet that must be accessed through mobile terminals. In particular, young people have their own requirements for content and communication through the Internet and mobile services covered, while their consumption of the traditional TV-media is correspondingly strongly reduced. This has caused broadcasters to look for new ways to target this mobile segment by offering streaming of video and music over the net and at the same time to integrate mobile SMS services, thereby, creating interactivity in relation to existing radio and TV program platforms.

The ability, to distribute a large number of programs and other digital content to many mobile users at the same time and, to combine this with the possibilities, that lie in the 3G mobile network for new interactive services and business models are all conditions that create a corresponding/congruent interest within the broadcast- and mobile industry.

At present, there are 3 competing standards for mobile broadcast (DVB-H, DMB and MediaFLO), which create the conditions for true mobile/broadcast convergence. DVB-H is designed in the framework of the European DVB program, DMB (Digital Multimedia Broadcast) is based on DAB (digital Audio Broadcast) standard and is promoted by the Korean mobile/broadcast industry and MediaFLO is a proprietary standard from Qualcomm.

Convergence between digital broadcast and mobile services can be described as a paradigm shift, that will change radio and TV from being a broad 'push' media, in future, to delivering a large amount of segmented channels with targeted 'pull' services customized to mobile users' constant changing demands and uses. Mobile and nomadic application will result in decisive new behavior patterns that carry great potentials for research and innovation.

III.3.6.2 Fixed Mobile Convergence

Fixed Mobile Convergence or Integration, FMC or FMI is a broad concept that covers various ways of integration of mobile and fixed (wired/wireless) technologies and services. FMC is not a new development and several FMC services have been on the market for the last five to seven years, but new technological and market developments have created new incentives for further development of FMC services and creation of new types of FMC services. There are different reasons for emergence of these services:

- A high portion of mobile calls are done from home and office environment[28].
- At the same time the fixed operators are loosing voice minute and want to reallocate some of their traffic from mobile to their fixed network.
- When it comes to data capacity mobile networks are lacking far behind the fixed networks. Hence it is much more efficient to connect to the fixed network when it is possible.
- VoIP is getting momentum and many broadband operators offer VoIP services. Integration of mobile telephony and VoIP over broadband opens up new possibilities for competition in the Voice market.

[28] The Yankee Group estimate this to be 30% of calls

Due to these reasons FMC is being developed massively in the near future. However the efficient provision of FMC is connected to maturing of technologies deployed in the back-bone network and is highly connected to development of NGN

III.3.6.3 Triple/multi play services

VoIP

For a long time, POTS (Plain Old Telephony Services) was seen as a natural monopoly. In the new regulatory paradigm, it is generally accepted that the networks must be opened up for competition through unbundling and interconnection regulation. However, within the traditional telecom paradigm, competition will at best exist between a few actors in an oligopolistic market. The central reason for this has its roots in the technological architecture of infrastructure and service development platforms.

The POTS network is a dedicated network, which is optimized for voice communication. Because of the deployed technology and the way POTS services have historically been organized, a centralized structure has been implemented to offer POTS.

Using VoIP has gradually changed this situation and through the convergence process has opened up new conditions for service development. Using VoIP technology and the general Internet as backbone, new providers can offer competitive prices, particularly for long distance and for international calls. The transmission of the service over long distances within the Internet is much cheaper than keeping the service within POTS with its distance-related cost structure and interconnection pricing schemes. The entry barriers for these service providers are lower and the number of them is increasing, contributing to the overall competition in the public voice market.

IV. A New Regulatory Paradigm

Based on the technology trends identified above, and their potential market and regulatory implications, a new regulatory paradigm will be needed for the future. The main pillars on which such a new regulatory paradigm rest are the following:

- First, to open the communication sector for as many different initiatives as possible and to diversify participation in order to maximize the contributions of new ideas and organizational arrangements.
- Second, to develop a comprehensive national ICT policy and a strong, credible regulator to ensure its full implementation.
- Third, regulation takes the dynamic character of technology and market convergence into consideration in all areas of regulation.
- Fourth, recognition of the wider international context of ICT technologies, markets and regulations.

- Fifth, the organizational aspects of regulatory institutions must be adapted to the changing technology and market developments in terms of the scope of regulation and regulatory practices.

Implementation of the new regulatory paradigm must reflect the fact that the technologies in the second wave of technological change are facilitating the final steps of convergence of telecom services. This completes a technical unbundling process that allows for a separation of facility network capacity from the services supplied over those facilities. In the historic model of telephone service supply, services and facilities were integrated by technical design as both were supplied by telephone monopolies. Internet technologies, and particularly Internet protocol (IP), have permitted a clear separation between network facilities and services, first for data, then pictures, audio, video and private voice networks, and now with VoIP, public voice networks as well.

With Internet technologies now applied to all network services, the structure of the overall market for communication services is radically changed from the former vertically integrated structure where most services and facilities were licensed and provided together, to a horizontally structured market consisting of separate markets for network infrastructure capacity, network management, communication services and information services. This reduces the technical barriers to entry to these markets and its and provides new opportunities for increased participation by new players providing a wide variety of different service packages. It requires incumbent operators to reassess their business models and their strategies in the new market structure as they must face increasing competition at different layers in the new horizontal market structure, but at the same time they also are presented with new opportunities to develop new services in the new market environment.

Although IP was developed for, and initially applied on the Internet, the largest users of IP are the incumbent telephone operators around the world. They are in the process of converting their entire telecom systems to IP because of the enormous cost reductions to be achieved, and the potential for providing new converged services in the future information economy, including e-commerce, e-government and other e-application services. At the same time, the extended application of IP by Internet Service Providers to include public voice services has opened a major new service opportunity for them, and introduced a significant new element of participation and competition in the supply of both public voice services and new converged services.

The introduction of the second wave Internet technologies has raised a number of issues of adjustment to the new technological environment by telephone operators and service providers, by policymakers and regulators, and by users. Any major technological improvement that dramatically reduces unit costs and expands service capabilities offers the potential of enormous benefits in terms of network and market expansion, cost and price reductions, and new services development. But it brings the threat of significant losses to those benefiting from the traditional way of doing things who cannot or will not adjust to the new opportunities.

Important issues are raised for national (and in some cases regional and international) ICT policymakers and regulators. They must reassess the extent to which, in the new environment, their established structures of policy and regulation,

1) provide *artificial barriers* to the achievement of full converged services benefits for users, network development, the economy and society;
2) create *unjustified biases* favouring or retarding one segment of the industry over the others in the process of transition to the new environment;
3) adequately address new *public service* and *public interest* opportunities and requirements in the new environment; and
4) adequately *facilitate* the application of the new technological and services possibilities for extending *network and services development* to unserved and under-served regions and people,

Although the issues of structural adjustment raised by the new technologies are requiring the serious attention of policymakers and regulators in all countries, the issues for developing countries are more difficult and particularly acute. Most developing countries started the telecom reform process much later than most developed countries, and have not yet fully completed the transition to an effective structure of liberalized market participation and independent regulation. Virtually all developing countries face a daunting task of not just upgrading the national network for broadband access to Internet services, but also the more difficult task of extending the national telecom network by several orders of magnitude to unserved rural areas and the majority of the population that has limited or no access to telecom services. Policymakers and regulators in developing countries must confront the greatest challenges in adapting to the new technologies. But these technologies offer outstanding potential for overcoming inherited problems and taking advantage of the participation of many players, old and new, to extend telecom infrastructure and services networks by an order of magnitude to unserved and under-served areas.

VIII. Conclusions

Based on the potential benefits from recent and forecasted technology developments, and the experience with the present basic regulatory paradigm, it is timely to consider what the contours of a new regulatory paradigm will look like. These are,

- *Increasing diversification of participation in network and services development*

  The overall purpose of the new regulatory paradigm must be to open as many paths to network development as possible and resist attempts to control or restrain participation unless there is clear evidence of harm to the public interest, a relatively rare circumstance. Among the different areas of regulation, universal service/access remains the central issue in present regulatory developments in developing countries. The prospects for technology leapfrogging in the ICT area seem relatively good in relation to backbone infrastructures as well as access infrastructures and the services delivered. But success will require an open technology environment, open markets and credible regulation. Without the related institutional changes, there can be little progress on the possibilities of technological leapfrogging.

The most significant immediate issue for regulators is changing the licensing regime for operators and service providers. At present, in most countries, most licenses are technology specific (e.g., VSAT, G2 mobile, cable) or service specific (e.g., public voice, data, VANS, TV transmission). The convergence technologies have made these distinctions obsolete. They are now significant barriers to the next stage of market development because they prevent technologies from being used efficiently in the supply of different combinations of services, and they prevent services from being supplied over any technology, or combination of technologies. Realigning license conditions and licensing practices to reflect the opportunities in the new convergence environment must be a priority in most countries.

Infrastructure and/or service competition has become an important issue. Experience suggests that the best policy is to support all kinds of competitive strategies, as both infrastructure and service competition will stimulate network development. It is important to recognize the basic principle of *cost-based regulation,* without adopting the complex and costly methods, such as LRIC, employed in some large developed countries. Knowledge of the cost characteristics of different technologies can be used to shape regulations so that market players have incentives to take up the most efficient new technology solutions.

In developing countries, the problems of *quality of service (QoS)* remain important issues for regulation, both for PSTN and Internet services. The primary areas where regulation can have a role to play are in service level agreements (SLAs) in relation to interconnection among operators, and if necessary agreements with users. There are, however, good reasons to hesitate with respect to strict regulatory interventions in the QoS on the Internet due to the very dynamic character of Internet technologies and services and the relatively early stage of its development

- *Policy integration*

Communication regulation must be seen in the broader context of policy measures related to the development of ICT infrastructures and services. However, the principle of independent regulation must be upheld in order to secure credible, stable and accountable regulation for the implementation of policy. Regulation should contribute to opening the sector for innovations and be seen as part of a broader national strategy for innovation in the communication area. Innovation will enhance competition, which will in turn stimulate innovation. Similarly, new network developments will open opportunities for new services, content and applications, which in turn will act as drivers for network expansion.

There is an important public task in promoting the use of standards, and specifically open standards in and between public institutions, and the establishment of provisions enabling experimentation with standards in new areas, e.g., unlicensed frequencies. For most equipment, a system of mutual national recognition of type approvals should be adopted.

Public-private partnerships (PPP) have too often been limited to a privatization discourse. The fact that communication services increasingly are subject to market mechanisms makes it more relevant to examine the ways in which public sector initiatives can help build infrastructures, particularly in geographically peripheral and poor areas where private sector investment is unlikely. There should be room for other individual and collective actors, including local and regional government agencies, businesses, civil society organizations and non-governmental organizations in Multi-Stakeholder Partnerships (MSPs). The limited experience so far suggests that these new organizational structures have much to contribution to network and services development.

The important issue to be dealt with in connection with network and information security is to construct the appropriate combination of technology and legal measures taking the broader market and norms environment into consideration. Regulators are increasingly approached on security issues and they need to be involved in fashioning solutions. But there are other organizations looking into these matters as well, e.g., national Computer Emergency Response Teams (CERTs), as the issues go beyond the scope of telecom regulation alone.

- *Maintaining Competitive Opportunities in Converged Markets*

The focus in the discussions on the implications of technology and market convergence for regulation has differed between developing and developed countries. The latter have emphasized the competition enhancing aspects of technology convergence. In developing countries, emphasis correctly has been on network development and new access possibilities. They should take advantage of the new access and competition potentials created by new technologies and limit horizontal integration of market players to the extent that it would hinder competition. Similarly, vertical integration proposals should be assessed in terms of their likely reduction in competition.

If effective competition has been attained in a particular market segment, specific regulations can be relaxed and general competition rules applied in this market segment, in countries where competition rules have been established. The concept of technology neutrality should be interpreted as meaning that regulation should not establish preferences for any particular technology. All technologies should be allowed to compete on their merits. Regulation should seek a level playing field for technological development and applications.

- *International outlook*

  Most ICT equipment markets have become global, and many services and content markets are becoming more international. These developments affect more and more national regulations and the interrelationships between national and international regulations. The processes of liberalization and internationalization of communication have led to a decreasing influence of public institutions in international organizations and forums. Developing countries should consider strengthening their influence in ICT international organizations through greater south-south cooperation among telecom regulators.

- *Structuring Regulatory Organizations*

  Convergence of telecommunication, IT, broadcasting and other media has led to many initiatives around the world to establish ICT convergent regulators. There are also initiatives to establish multi-utility regulators covering a larger range of infrastructure provision, e.g., telecom, energy, transport, water. In addition, closer working relations between sector specific regulation and general competition regulation are seen as desirable. The best organizational design of regulatory institutions in any country depends on the specific national circumstances, i.e., stage of development in the different sectors, resources to be applied to regulation, available skills and national priorities.

  The regulatory organizations in developing countries are typically at an early formative stage. This means that these organizations are often relatively weak, but it also means they can more easily be shaped to the new convergence developments if there is the necessary political will. There is, in other words, a possibility for leapfrogging some of the institutional evolution that regulatory organizations have gone through in the developed countries, particularly with respect to establishing effective convergence regulation.

Telecom regulators must play an important role in facilitating, and in some cases leading the transition process to the new converged technological, market and regulatory environment. Success will require a major effort to educate the key players who will collectively influence the transition to convergence policies and a new regulatory paradigm. This will require a strategy for managing the transition that requires prioritizing the regulatory issues in light of the specific circumstances in each country.