FIVE

Convergence and Emerging Technologies: Issues Faced by the Regulator

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ABSTRACT: Convergence is taking place in the telecommunications, broadcasting and information technology industries. Services that in the past were offered only on one platform are now offered on any platform by the three industries. The evolution of convergence has led to an increased demand for access to services and content. This, in turn, has led to the development of new technologies that offer high throughput to the end user. The regulator is now faced with the challenge of regulating the converging environment and dealing with spectrum management issues that arise due to the emerging technologies. This article reviews the issues faced by the regulator due to convergence and emerging technologies.

Developing South African telecommunications

In the past, many countries did not have an independent regulatory body. Regulation, policy making and network service provision were done by a state monopoly. Also, in many countries, universal service was not achieved. Frequency spectrum management was inefficient and institutions such as the military and state broadcasting corporations hoarded frequency bands. Worldwide, changes in the telecommunications, information technology (IT) and broadcasting industries have led to the liberalisation of these three industries. To reform the communications industry, many countries decided to create an independent regulatory body. Usually, this regulatory body is charged with the task of regulating all three industries.

One of the changes the world is experiencing today is convergence in the telecommunications, IT and broadcasting industries. Convergence describes the tendency of the traditional telecommunications, IT and media industries to come together in various ways (Hanrahan, 2004). For example, convergence may be achieved by the different sectors finding increasing synergy, seeking cross-product and cross-platform development, and having cross-sector shareholding. Digital encoding and decoding techniques have enabled the manipulation of different forms of information across all types of network infrastructures. Examples of converging services and applications include voice over the Internet, data services over broadcasting platforms, and web-casting of audiovisual content.

The evolution of convergence has led to the demand for ubiquitous access to content and services. This, in turn, has led to the emergence of new communication technologies that provide higher throughput to end users. These emerging technologies place demands on the already scarce frequency spectrum.

This article's contribution is that it combines knowledge on developments in technology with regulatory issues. The article examines the required regulatory changes in the light of developments in technology. The article is divided into two closely related parts: issues faced by the regulator due to convergence; and issues faced by the regulator due to emerging technologies. The two parts of the article are naturally related, because new technologies and convergence are both drivers affecting the provision of telecommunications services, and cannot be considered in isolation.

The article starts by summarising knowledge on regulatory issues related to these two drivers (convergence and emerging technologies). This work investigates the issues faced by regulators due to convergence and emerging technologies. The article continues by outlining the role of the regulator, and examining the traditional model of the telecommunications, broadcasting and IT industries. Thereafter follows a description of convergence and the issues faced by the regulator, and recommendations on how to face these issues. The subsequent section deals with spectrum management in the converging environment. Some emerging technologies are described, including the challenges they pose to the current spectrum management model, and recommendations are made to the regulator in the interests of assisting with dealing with such challenges.

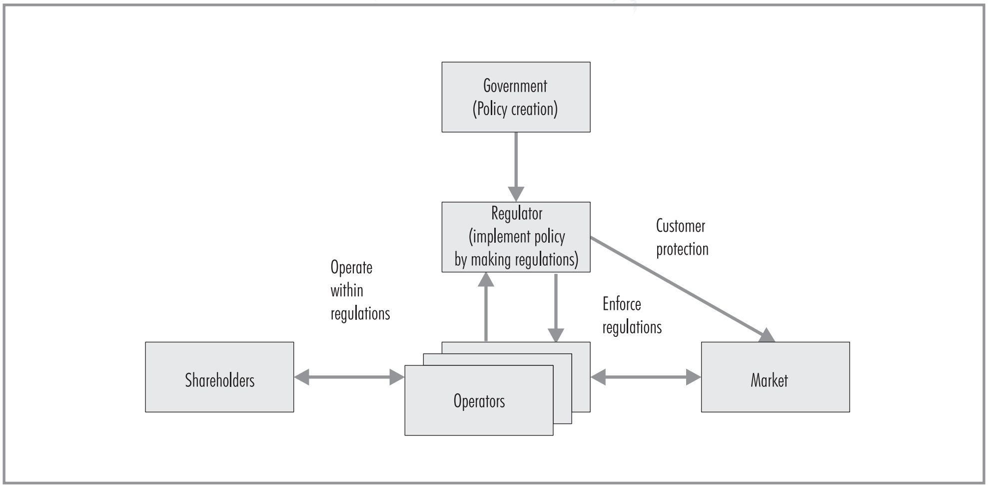
The incumbent operator has not been allowed to embrace converged technology for providing what customers really need. It is forbidden by the existing regulations for Telkom SA to use the best cellular/wired solution to deliver entertainment/educational content or carry converged services such as High Definition television and digital radio to viewers/listeners/consumers/“learners”.

However, telecommunications regulators must satisfy the customers’ needs within a changing market. With the ITV’s 50th anniversary this year, South Africa should be able to see (with retrospective wisdom) the benefits of an independent commercial service in competition with the Government service. Today’s customers want to access the content of their choice when they want to. This is the beginning of interactivity. So, what is required is an information society approach. The operators (and hence the regulator) need to realise that the economic delivery of interactive digital services requires that as many services as possible be delivered by a converged network.

The South African situation is particular in that the distances are large and rural communications therefore suffer from low revenue streams, low traffic, and an expensive lack of scale. Thus, to ensure viability, economies of service must be substituted for economies of scale. Technological advances now offer *economies of service* between telecommunications, broadcast and IT services but regulatory initiatives here have still not removed the legal barriers separating the three industries. South Africa is still limited by the silo-structured management of the incumbent operator, the heel-dragging of the regulator, and the long delay in selecting and announcing the second network operator.

Role of the regulator

In a liberalised environment the main role of the regulator in the communications industry is to ensure that the providers in the markets can operate efficiently so that residential and business consumers and the economy benefit from the services. Being an authority that is nominally independent of Government and industry players, the regulator is concerned with implementing the telecommunications policies and enforcing the legislation laid down by the Government. However, regulation of the industry is not entirely an economic issue; there are usually social and political dimensions to regulation, and these socio-political issues are raised by the Government. This is shown in the regulatory model depicted in Figure 5.1 below (adapted from Melody, 1997b).



Adapted from Melody (1997b).

Figure 5.1: Regulatory model

Vertical integration of the communications industry

Until recently, the telecommunications, broadcasting and IT industries existed with little interaction across the industries. Telecommunications companies (telcos) and broadcasting companies offered services that were tightly coupled to their underlying infrastructure, as shown in Table 5.1, below (Hanrahan, 2004). As the services offered in the different industries relied on the underlying infrastructure, the industries are referred to as being vertically integrated.

It can be seen from Table 5.1 below that telcos traditionally were involved mainly with the provision and operation of the physical infrastructure. Services offered by telcos were implemented by the intelligent network infrastructure, which was an overlay of the traditional network. The content delivered by the telcos' networks was predominantly voice. Voice and messaging were delivered by the mobile networks. The telcos offered the

	Telecommunications			Broadcasting	IT
	Fixed networks	**Mobile networks**	**Data networks**		
Content	Voice	Voice/messaging		Broadcast programs	Software based content
Applications				Broadcasting applications	Software applications
Service	IN Service control points	IN Service control points	Managed network services		Internet service-AAA, DNS, DHCP
Switching	Circuit switching	Circuit/packet switching	frame relay/IP/ATM		
Transmission	SDH, microwave, optical	SDH, microwave, optical	SDH, microwave, optical	Satellite, microwave, optical	
Access	Copper loops, concentrators	Air interface, Base station subsystem		Transmitting stations, cable/air interface	Dial-up/xDSL/LAN
User terminals	Plain telephones	Cellular telephones		TV/radio receiver	Computer

Source: Hanrahan (2004).

Table 5.1: Vertically integrated telecommunications, broadcasting and IT industries

data networks, which were used to provide services like virtual private networks to organisations such as banks and airlines. The content delivered was not regulated, as it was considered private.

In the broadcasting industry, the content was provided by the broadcasting corporations or purchased by the broadcasting corporations from other suppliers. Access to the consumer was either by cable or by radio waves over the air interface. The broadcasting networks are naturally designed for one-to-many transmission. In the broadcasting industry, the content was regulated in the interest of implementing the Government's objectives regarding pluralism, preservation of culture, and the protection of certain social groups (such as children).

The IT industry has been the least regulated. In the IT industry, the Internet services such as Domain Name Service (DNS) and Authorisation Authentication and Accounting (AAA) are undertaken by the Internet Service Providers (ISPs). Content producers are independent of the ISPs. Regulation has predominantly involved the issuance of licences to the ISPs. There has been no technical regulation regarding quality of service, as the Internet is a "best-effort" network, made up of autonomous networks around the globe.

Originally there were different regulators for the telecommunications and the broadcasting industries, who controlled market entry, pricing, frequency spectrum management, and other technical aspects of service delivery in their respective industries.

Convergence

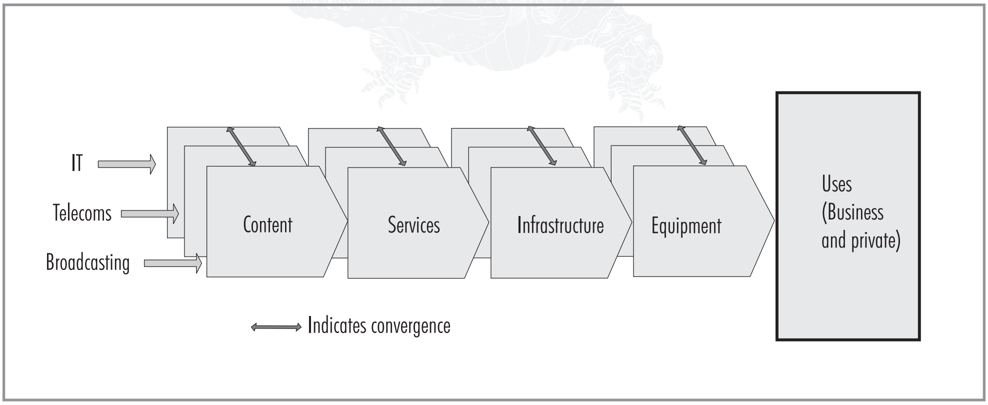
This section describes convergence and considers how it has impacted on regulation.

Areas of convergence

Convergence is taking place in the entire value chain of content and service delivery to end users. The areas that are converging, according to Gillwald (2003) are:

- content delivery;
- services;
- infrastructure; and
- end user equipment.

This is shown in Figure 5.2 below.



Adapted from Henten *et al* (2003)

Figure 5.2: Convergence in the entire value chain

Digital technology has led to the development of more efficient encoding, decoding and compression algorithms. This has enabled content that previously required wide bandwidth now to be transferred over a low bandwidth infrastructure. An example is the Motion Pictures Expert Group (MPEG) compression format. Content such as films and television programmes have become platform-independent and can now be downloaded over low bandwidth telephone lines.

In the legacy networks of the three industries, services were dependent on the underlying infrastructure. In delivering services, the network operators today are able to abstract their infrastructure and offer Application Programmable Interfaces (APIs), on which services are being built. Standards such as the Open Service Access (OSA) and Parlay are used to abstract the underlying network so that service providers can offer their services without having to know the technical details of the network.

Convergence in the infrastructure is taking place in the access networks and the core networks. Access and core networks in telecommunications are evolving to high bandwidth, high capacity networks. In the access networks, the fixed telecommunications networks' copper loop evolved to give rise to the x-Digital Subscriber Lines (xDSL), which offer higher bandwidth to users. Voice and data can therefore be offered to consumers.

Mobile networks have evolved from the 1st generation (1G) that was analogue, to 2G and 2.5G digital networks that are currently in use. Due to the development of more efficient modulation schemes, such as Orthogonal Frequency Division Multiplexing (OFDM), access networks offering higher data throughput to users are being developed.

In the evolution of core networks, the use of Internet Protocol (IP) in the core network enhances its efficiency. In 4G networks, the access networks are envisaged to work together with an all-IP core network to provide ubiquitous access to consumers. Efficient mobility management techniques will ensure the seamless hand-over from one access network to another.

The lack of a return channel in the broadcasting networks was their impediment to providing interactive services. With the emergence of digital TV, there is a return path and the broadcasting systems can be used for interactive services. Cable television (CaTV) providers have also upgraded their infrastructure to provide two-way services such as telephony and other interactive services. The convergence in the telecommunications and broadcasting network infrastructure, being an evolutionary process, does not imply that one infrastructure will integrate all services. The various services and content will be delivered to the consumers using the most appropriate platform or the consumer's platform of choice.

In the user terminals, convergence is taking place as manufacturers are producing devices that can carry out more than one function. An example is the production of TV cards that are slotted into computers, enabling the computer to receive TV broadcast signals. Another example is the set-top box that can be used for TV programming and Internet services.

Convergence has an impact on the lifestyle of users and the wider economy. In mature economies, convergence results in users having access to the same services or content by multiple means, hence increasing competition in the industry. In developing countries, convergence will enhance service penetration, as the different carriers of services will complement each other. Many countries have perceived the potential benefits of convergence and have merged the individual regulators for the telecommunications and broadcasting industries into one regulatory authority.

Regulatory issues

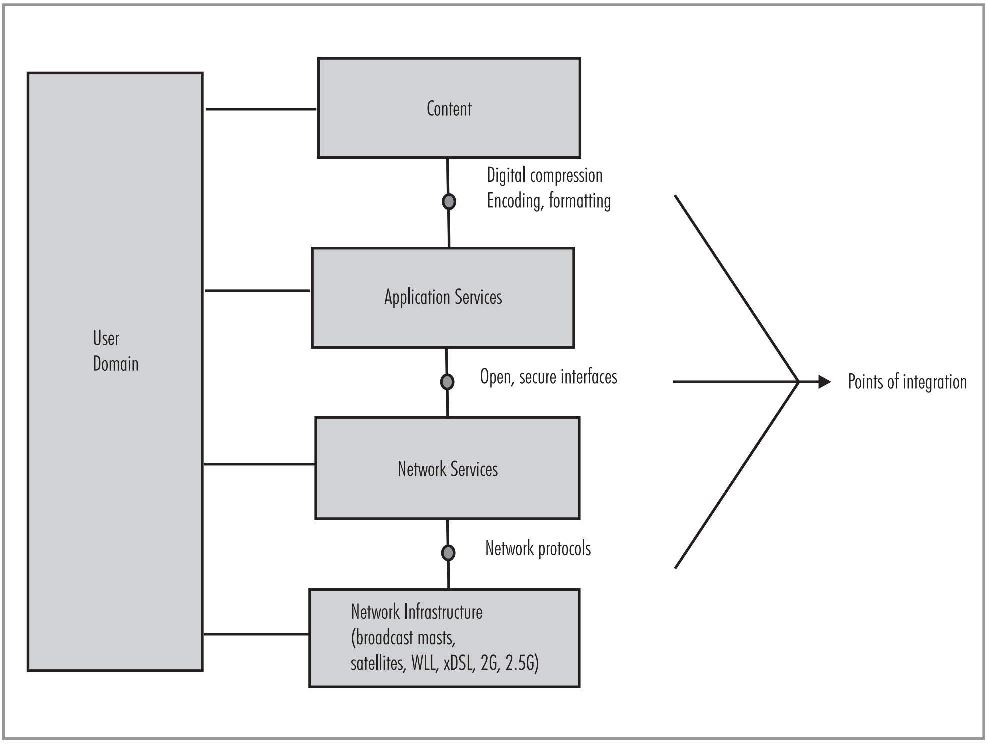
The traditional regulatory regime has been using the vertical integration model of the three industries. With convergence, and the merger of the broadcasting and the telecommunications regulatory bodies, issues of consistency of regulation arise. As a result, the following issues are faced by the regulator.

Technology-neutral regulation

In the past, technology-specific regulation was sufficient, as content, services and applications were tightly coupled to their platforms. As convergence involves content, services and applications being offered on any platform, technology-specific regulation is not efficient. The technology-specific approach would be too detailed in the converging environment, would lead to a slow licensing process, and would retard competition in the industry. A robust technology-neutral regulatory framework is therefore required to regulate the newly converged environment. Services should be considered from the perspectives of consumers. For example, whether cable or satellite is used to provide a broadcasting service is of no consequence to consumers; they receive the required service and content in either case.

As stated earlier, to regulate services and content, the underlying network infrastructure needs to be abstracted. To carry out the abstraction, a horizontal layered model for the converged environment is required to separate the infrastructure from services, applications and content. This is shown in Figure 5.3 below, adapted from Hanrahan (2004). The users are able to access all the services, without the knowledge of the underlying technical details required for delivery.

The network infrastructure layer from the telecommunications and broadcasting industries is classified together in the infrastructure layer (central bottom block in Figure 5.3). The users' terminals, access and core network infrastructure are included in this layer. Typical components in this layer are broadcast masts, satellites, Wireless Local Loop (WLL), Synchronous Digital Hierarchy (SDH) loops, xDSL, 2G, 2.5G and 3G mobile infrastructures.



Adapted from Hanrahan (2004).

Figure 5.3: Horizontal layered model for convergence

Moving upwards in Figure 5.3, the network services layer has generic services required to support communications (Hanrahan, 2004). These services include circuit and packet switching, call control including the set-up and clear-down of connections, gateway control, DNS and AAA and mobility management.

Still moving upwards, the application services layer has applications that increase the value of the communication services or the content delivered to the end user. Examples of these services are web services, and the telco's Operations Support Systems (OSS). Application may be broadly classified as (Hanrahan, 2004):

- Content applications: These provide access to content that is made available by content providers. An example is the content of a radio web-cast.
- Communications applications: These applications are IT applications but are invoked by using the data in the network services layer.
- Network applications: These add value to the generic network services messaging services executing in the service layer.

At the highest level in Figure 5.3 is the content layer, which includes the different types of content offered by various providers – either the network owners or external providers of content.

With such an approach, the regulator will be able to issue the appropriate licences for providers operating in the different layers of the model. Service providers who operate in all four layers will require a licence that spans the four layers. Those operating in the infrastructure, network services and applications layers will have a licence that spans the three. The providers offering the network services and infrastructure will have their licence spanning the two layers. And providers who choose to operate in only one layer will have a licence allowing them to operate in that layer only. This licensing model creates a competitive environment for network operators and Value Added Network Service (VANS) providers.

According to Hanrahan (2002), to implement and maintain technology-neutral regulation requires the regulator to have deep insight into the current and emerging technologies. This is because innovative technologies are continually being developed, and consequently new services are being offered. To avoid problems, network services and application services should be classified into service groups with their attributes and values defined. The services should not be limited to a group but should be benchmarked. This will ease the process of licensing the VANS providers.

According to South Africa's national convergence policy colloquium (South African Government Information, 2003), the infrastructure layer in Figure 5.3 requires tight regulation, and the regulation is reduced with each layer up the horizontal layered model.

This is because the infrastructure layer needs equipment type approval, interconnection management, and frequency spectrum management. As will be discussed in subsequent sections, regulators are faced with numerous issues in frequency spectrum management as networks converge and technologies evolve.

Regulation of content

As already mentioned, broadcast content has been regulated in line with the Government's policies of pluralism, culture preservation and protection of certain social groups that are vulnerable (e.g. children). With convergence, the content providers may be located in any part of the world, and distribute their content via the Internet. Governments and regulators are faced with the difficult task of regulating such content. While some of these policy objectives can be met through self-regulation, content providers may be subjected to certain regulation of their content to implement the Government's policies.

Market regulation

As mentioned above, the objective of regulating the market is to achieve universal access or universal service, and to encourage competition in the industry. The regulator should intervene in the market in cases of market failure, or as necessary to pursue the interests of the public.

Market failure can occur due to anti-competitive monopolistic behaviour of the incumbent operator, which then creates barriers to market entry, and market distortions resulting from imperfect competition (Blackman, 1998). To gain the competitive advantage, the incumbent operators usually attempt to offer all the services in the horizontal layered model shown in Figure 5.3. Policy makers should approach this issue with caution as the incumbent operators may attempt to abuse their dominance. Accounting separation should be used so that the regulator can monitor the revenues from the various services that the incumbent operators offer consumers.

In addition to the dominant operators providing open APIs to new entrants, unbundling of the local loop is necessary to increase the local loop competition. This should be done for CaTV networks, telco networks, and electricity distribution networks in the case of power line communications (PLCs). This is done to avoid the inefficiencies associated with duplication of the local loop infrastructure. In addition, there may not be aesthetic space to erect poles, and physical space for manholes, for every provider. The unbundling process needs to be regulated to ensure that new entrants are treated fairly in the lease of infrastructure, and competition is promoted.

In many countries in the past, cross-media ownership has been resisted. Asymmetric regulation has been applied preventing the telecom operators from providing entertainment or other content and CaTV providers from offering telecommunications services. In the converged environment, these restrictions will inhibit the market penetration of services in developing countries. Therefore, the cross-media ownership restrictions need to be loosened and some degree of market self-regulation needs to be permitted (Henten *et al*, 2002).

Tariff regulation

Traditional and differential application of tariffs for broadcasting and telecommunications and their regulation will be challenged by new, converged systems.

There will be no differentiation between voice and data traffic through telecom networks as the core networks will be IP-based. The cost of voice calls will therefore no longer be on the basis of the distance or even the duration of the call. In addition, there will be numerous providers of voice services. For these basic services, the regulator may regulate the tariffs, taking into consideration all costs that the telecom providers incur to provide services, in order to enforce a fair pricing regime that promotes competition and at the same time offers low prices to consumers (le Roux, 2004). The Independent Communications Authority of South Africa (ICASA) is in the process of implementing this approach to tariff regulation. Tariff regulation of value added services should be left to market forces, and the regulator should intervene only in the case of failure to self-regulate.

Interconnection

In the past, broadcast networks did not require interconnection. The telcos' networks covered vast geographical regions and only required interconnection with other providers across national geographical boundaries. Interconnection was referred to as co-operative since the operators were co-operating only with others in different geographical regions (Melody, 1997a). Operators tried imposing as much of the network costs as possible on the other operators to maximise their own revenues. This issue is still present, and more complex in the converging environment. Interconnection is a problem that continually needs to be monitored and managed in the competitive converging environment. Associated with unbundling the local loop are important interconnection issues that must be addressed by the regulator. These include the extent of unbundling for unbundled elements, local number portability, achieving parity of operations support systems and services, and costing and pricing (Melody, 1997a).

In the 4G networks, the access networks will be interoperable, and the core network will be IP-based, and will have more open interfaces, since, with IP routing, tables are used to implement the interfaces. Interconnection in 4G will be greater, and the focus on the category of service to be interconnected will increase, compared to focus on the origin of the network (Intven, 2002). This is an issue to be addressed by the regulator. The regulator will also have to address the need of VANS providers to combine network elements from different providers to create platforms for services.

To address the issues, the regulator needs to follow the interconnection rules set out by the WTO (2004), and the World Bank interconnection principles (Intven, 2002). Technical issues of implementing interconnection as required are left to the operators.

Spectrum management in a converging environment

The frequency spectrum is an important asset, one that is scarce due to an increase in technologies and users. Previously, as already mentioned, the military and other state monopolies hoarded bands of frequency spectrum, which they did not use efficiently. The deregulation of the telecommunications industry, and convergence, competition and a high demand for access to services and applications, have led to the development of new technologies, which have created more demand for spectrum. It is the responsibility of the regulator to ensure technical and economic efficiency of spectrum usage (International Telecommunication Union, ITU, 2004b). The regulator is faced with the task of adopting a more flexible spectrum management framework to accommodate the new technologies. This is a reason for the infrastructure and network services layers in Figure 5.3 needing more regulation than the upper layers. With the evolution of access network technologies, technologies are categorised (by Dame *et al*, 2003) as follows:

- personal area access technologies – to support short range connections;
- local area access technologies – to provide wider but still local access;
- last-mile or local loop access technologies – to provide full connectivity between the user and the core network; and
- global area access technologies.

Some of the technologies in the categories above are shown in Figure 5.4 adapted from Dame *et al* (2003).

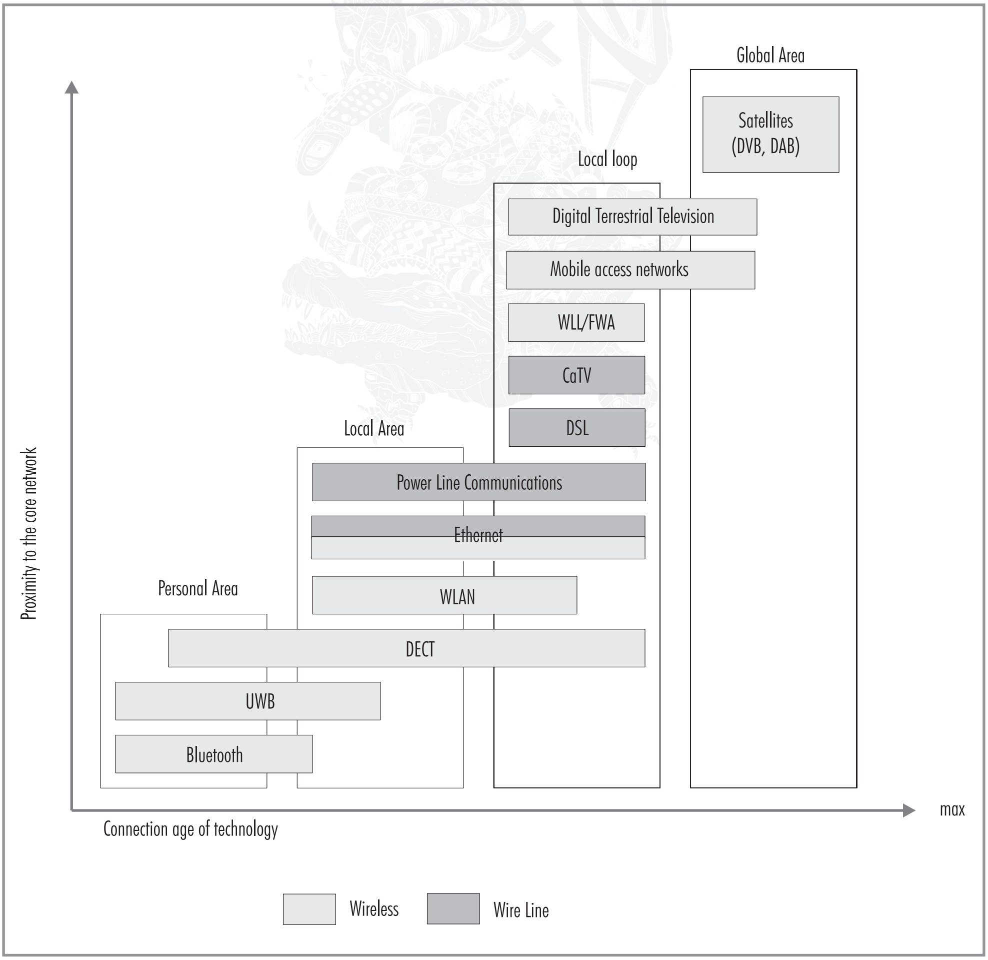
Emerging technologies

As mentioned earlier, with the evolution of wireless networks, different access network technologies will be able to interoperate, providing ubiquitous access to service by the consumer. Some of these emerging technologies are briefly described below. The implications for the current regulation model are also discussed.

Spread spectrum technologies

Spread spectrum technology takes advantage of the fact that the power density achieved by a high powered narrowband signal can also be achieved by having a low powered signal that spans over a wide range of frequencies (Carter *et al*, 1998). Two types of spread spectrum technologies are Direct Sequence Spread Spectrum (DSSS) and Frequency Hopping Spread Spectrum (FHSS).

- In DSSS, a high speed pseudo-random code sequence is used to modulate the information that is to be transmitted. The transmission is done over a wide range of frequencies. The receiver demodulates the signal using a locally generated pseudo-random code that has the same sequence as that used at the transmitter.



Adapted from Dame *et al* (2003).

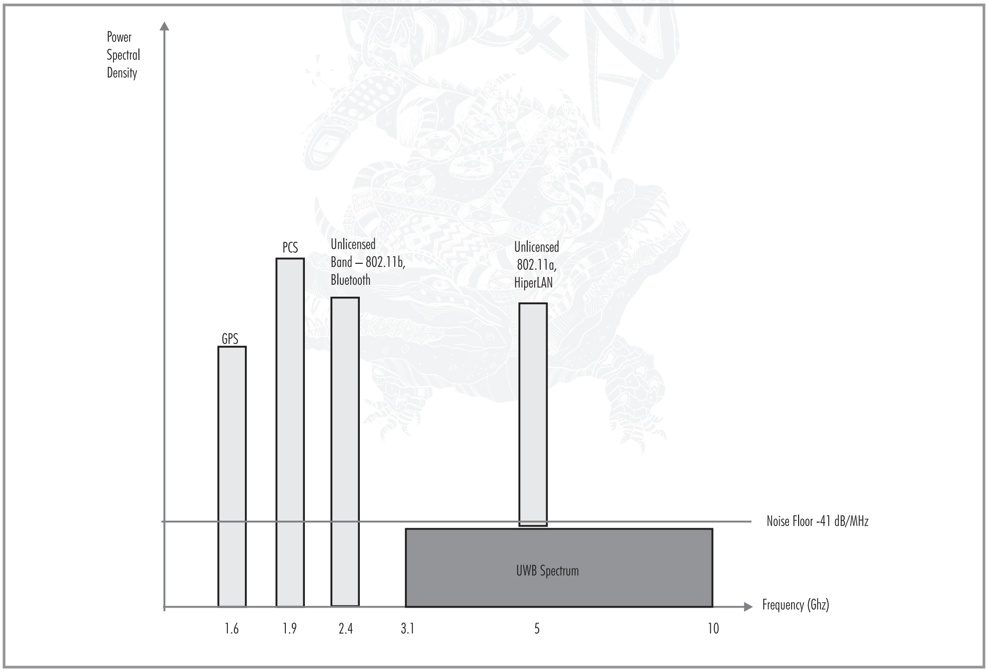
Figure 5.4: Access technologies in their categories

- In FHSS, a high speed code sequence is used to hop the transmitted information from one frequency to another, over a wide band of frequencies.

These spread spectrum technologies have been employed in 3G wireless technologies such as Wideband Code Division Multiple Access (WCDMA), and Wireless Fidelity or Wi-Fi (IEEE 802.11b). Frequency bands for 3G have been auctioned off in several countries.

Ultra Wide Band

Ultra Wide Band (UWB) is an emerging technology that can transmit data at very high speeds. UWB can be used for through-wall motion sensing, creation of personal area *ad hoc* networks, and location and radar systems. It does not use a carrier and instead uses very fast pulses, of the order of nanoseconds, to represent the data in digital zeros and ones. The transmission of these pulses is over a wide range of frequencies, typically from very low frequency to the Gigahertz range (Mihai, 2002). Due to the wide frequency range, UWB signals can penetrate



Source: ITU (2004a).

Figure 5.5: Operation of UWB below the noise floor

objects such as walls and the ground and, unlike other wireless technologies, do not suffer from multi-path fading.

The power spectral density of UWB signals is low. As a result, UWB can operate below the noise floor and can therefore operate in the same frequency band as other licensed spectrum users without causing interference. This is an issue the regulator needs to address, as the technology requires wide bands, and incumbents operating in bands that are already licensed may be resistant to the operation of this technology. How UWB operates below the noise floor is shown in Figure 5.5 above (ITU, 2004a).

Mesh networks

A wireless mesh network is an *ad hoc* multi-hop local area network, in which devices communicate with one another using other devices as intermediaries. This is shown in Figure 5.6 below.

The mesh network offers multiple redundant links so that, if one link fails, messages will be automatically routed through other links. Mesh networks require the use of software radio, since this technology enables devices to configure themselves. Mesh networks also reduce the need for long distance communication since only a signal strength sufficient to reach the neighbouring device is required. This implies that mesh networks can reuse the higher-speed short range frequencies that are currently used for other wireless communications (ITU, 2004a). Regulatory issues arise as users will be able to form their own *ad hoc* networks capable of internal voice and data communications. Also, in congested areas, mesh networks must be able to withstand interference.

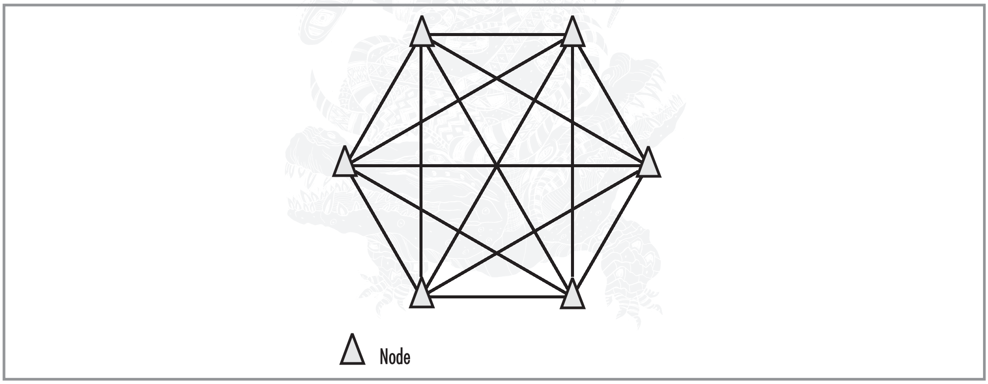


Figure 5.6: Mesh network

Software Defined Radio (SDR)

Software Defined Radio (SDR) refers to wireless communication devices that are made of generic hardware consisting of Digital Signal Processors (DSP) and microcomputers, and use software modules to implement radio functions such as modulation and demodulation (Wipro Technologies, 2002). An SDR can be upgraded by changing the software, and can be re-programmed to accommodate different frequencies, bandwidth and directionality (ITU, 2004a). One specific type of SDR is agile radio. This radio system uses the frequency hopping technique to make use of the inactive frequency bands over a wide range of the frequency spectrum. Agile radio can therefore increase its available bandwidth without requiring new frequency allocations.

In the current regulatory model, frequency bands are allocated exclusively to operators. The frequency use of the agile radio must therefore be addressed by the regulator. A survey (Yang, 2003) shows that the licensed spectrum is usually under-used, and many frequency bands usually lie fallow. The regulator needs to change the spectrum management model to accommodate such technologies.

Power line communications (PLCs)

PLCs rely on the electricity distribution network to provide two-way communications services such as voice and data transmission (Dame *et al,* 2003). Due to the deep user penetration of electricity, PLCs provide the potential for realising universal service.

In the electricity distribution network, there are varying levels of impedance and attenuation due to the switching of electrical equipment connected to the network. Time-variant interference from various sources leads to poor performance and, as a result, transmission capability is restricted due to power limits, bandwidth constraints and the high levels of noise (Pavlidou *et al*, 2003). There are various modulation and coding techniques that are being tested for PLCs. Modulation schemes such as Frequency Shift Keying (FSK), Code Division Multiple Access (CDMA), and Orthogonal Frequency Division Multiplexing (OFDM), have been proposed as appropriate choices for PLCs (van der Gracht & Donaldson, 1985). Spread spectrum is also an appropriate technique due to its robustness against interference.

The radiation emission of power lines is an issue that requires regulation. Sources of emission may be upstream signals at the customer premises, upstream signals adjacent to the customer premises, and downstream signals at the substation (Pavlidou *et al*, 2003).

Spectrum policy recommendations

In the South African convergence policy colloquium report, it is the infrastructure layer of the horizontal layered model of convergence that requires the most stringent regulation (South African Government Information, 2003). Apart from the complexity involved in local loop unbundling, and in the deregulation of the telecommunications and broadcasting industries, a robust spectrum management framework is needed to accommodate operators who will use the emerging technologies. The current spectrum management model involves allocation of frequency bands exclusively to the operators. Some spectrum users such as Government agencies have been allocated large bands of frequency. One shortcoming of this particular spectrum management model is that the efficiency of use of the allocated frequency bands is usually not monitored once the spectrum has been allocated. The auctioning of the 3G wireless bands is one method to allocate the spectrum to the operators who will value it most and use it efficiently. Some authors (including Peha, 1998; and Office of the Telecommunications Authority, 2000) argue that this method may not increase spectral efficiency, as the high prices for the licence auctions may eventually stifle further investment and developments in 3G, and may also lead to consumers being overcharged.

Changing the spectrum management framework is a difficult task, and it needs to be tackled carefully to accommodate the changes due to convergence and emerging technologies. To accommodate the emerging technologies described above, according to the ITU (2004a), the regulator needs to:

Allow transmission underlay: Electronic devices produce radiation, either intentionally or unintentionally, at various frequencies. This radiation, if not controlled by the regulator, can cause interference with other transmissions in licensed bands. To take advantage of emerging technologies such as UWB, the regulator needs to allow transmission underlay. Transmission underlay implies the decisions by the regulator to allow technologies that use low transmission power such as UWB, to be used over frequency ranges that may include the licensed parts of the spectrum. The regulator, therefore, needs to ascertain that the technology is able to operate below the noise floor. In the United States of America, the Federal Communications Commission (FCC) did tests to ascertain that UWB does not cause significant interference with other services such as Global Positioning System (GPS), and has thus allowed its use.

Develop noise temperature measures: To efficiently implement transmission underlay, the regulator needs to define the noise floor, and the level of interference that is acceptable for other services and legacy radios. By defining the noise temperature, the interference can be regulated and devices such as SDRs can detect the level of interference in a certain frequency band and adjust their transmission power accordingly. The current spectrum management model involves limiting the transmission power of the devices in an area as a preventive measure to control the levels of interference in the various frequency bands. With noise temperature measures, different transmission power levels would be allowed in different areas depending on the noise temperature of the area.

These can be implemented in the following spectrum management models to ensure a more flexible framework (ITU, 2004b; Hatfield, 2003):

Licence exempt frequency bands: Licence exempt frequency bands such as the 2.4 GHz Industrial, Scientific and Medical (ISM) bands have been successful in facilitating the development and deployment of technologies such as the Wi-Fi (IEEE 802.11b) and Bluetooth. Users in licence-exempt bands are required by the regulator to adhere to certain restrictions to minimise interference. They are liable for any interference they may cause to other bands but are not protected from interference from other licensed bands. Successful technologies in this band (such as Wi-Fi) use spread spectrum to increase the spectral efficiency. For UWB to be deployed, wider bands than the licence-exempt bands are required for its operation. From the experience in the United States with Citizen Band (CB) radios (Ting *et al*, 2003), the regulator should not expand licence-exempt bands to accommodate new technologies, as new technologies may become a fad phenomenon (like CB radios), and not last for long.

Spectrum sharing and leasing: This refers to a situation where the co-existence of operators in the licensed bands is allowed by the regulator. The licensed operator is allowed to lease out frequency bands to another operator who needs the spectrum. This should encourage the use of technologies such as the software radio and UWB. This method allows fallow spectrum to be released to the market, and technical and economic efficiency of the spectrum is thus achieved. In the frequency sharing and leasing agreements, the regulator should play the role of clearly determining the obligations of both parties. The regulator should also regulate the leasing charges to prevent high costs from being passed on to the consumer.

Spectrum commons: This is a form of open-access spectrum management policy. Frequency bands in a given geographical area are allocated to a group of users who also manage the bands. Other users can gain access to the required bands and they are subject to certain basic rules. With this approach, emerging technologies can be deployed, with the operators not having to suffer long delays associated with the allocation of spectrum.

For other technologies, such as PLCs, the regulator should adopt standards laid out by bodies such as the ITU and European Telecommunications Standards Institute (ETSI). The standards regularising PLC for the different regions in the world are listed in Balázs *et al* (2002).

To come up with a flexible spectrum management framework, the regulator also needs to address the issue of unused spectrum. Some operators and Government agencies are allocated large bands that often lie fallow. The regulator needs to clean up unused bands for re-allocation to other users. In the case of Government agencies, one way of increasing the economic efficiency of their bands is through making the Government agencies pay annual spectrum fees (Balázs *et al*, 2002). The amount to be paid in spectrum fees can be calculated from the usage fees from users of other, similar licensed bands. The regulator must also ensure that the spectrum management database is always up to date to make the management of the spectrum possible.

Conclusion

This article has presented the challenges faced by regulators in general, and the South African regulator in particular, due to convergence and new technology. Convergence is an evolving process and is characterised by an increase in the value added services and content offered to customers on any platform. From the point of view of services and content providers, the notion of scarcity of bandwidth may appear to be unimportant. The primary objective of the regulator is to create a framework that will foster a competitive environment, in which the benefits of convergence will be delivered to consumers. Thus the regulator must approach the issues carefully and with due consideration for the policies of the industry and the Government. The regulator cannot function without highly skilled technical expertise to implement the sound framework necessary for facing the challenges of convergence. For example, to implement technology-neutral regulation, skilled engineers are required, to understand the technologies used in the infrastructure so as to carry out the abstraction required and benchmark services into service groups. The regulator needs to provide incentives such as regular technical training to motivate its staff and to improve its core technical competency and capability.

With the merging of the telecommunications and broadcasting regulatory authorities, content, value added services and infrastructure will be regulated by one body. It is thus important that Government policies for the bodies are taken into account and clear guidelines are followed by the single regulatory authority, in the formation of a regulatory process and practice that will accommodate convergence and the emerging technologies. By using the horizontal layered model for convergence, light regulation should be applied to content and value added services. This will help create a competitive environment, as the regulator will only intervene in the case of market failure. With the use of the horizontal layered model for convergence, it has been proposed that the current cross-sector regulation should be eased to increase competition and consequently deliver lower prices to consumers.

This article has also presented various issues in spectrum management that the regulator faces due to the emerging technologies. These technologies lie in the infrastructure layer of the horizontal layered model for convergence, and require tighter regulation due to the challenges they pose. The account of emerging technologies presented in this article is by no means exhaustive, but the spectrum management solutions proposed are generic and should be able to accommodate the needs of other new technologies. The regulator needs to have a flexible spectrum management approach, taking into account the needs of both the incumbent operators with their legacy networks and the new entrants who will only use the new technologies. Spectrum sharing and spectrum commons may be used for certain bands, while the traditional spectrum management approach is used for other bands. As proposed, the regulator needs skilled expertise that understands the new technologies and their implications for the spectrum management model. The regulator also needs funds to invest in the appropriate equipment to perform spectrum audits and carry out tests of the emerging technologies.

With the challenges posed by convergence and emerging technologies, the regulator needs to take a proactive approach, in order that the economy might gain from the potential benefits presented by convergence. ❑

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