TELECOMMUNICATION NETWORK INTEROPERABILITY

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Summary

Telecommunication networks interoperability is a topic of increasing importance, because it is the main enabler for the vision of service convergence. We first strive to define interoperability in technical terms, not a consensus definition to start with. We then explain why interoperability is important, or why failure to interoperate becomes a problem with the proliferation of heterogeneous networks and environments due to convergence. The main part of the article deals then with how interoperability can be achieved, and what are the different types and environments of interoperability. Included is also an overview of the European Union's policies for convergence, and finally the future research challenges posed by the need for interoperability.

1. Introduction

For some time now, we have been witnessing the twin forces of convergence and deregulation modeling the telecommunications landscape. Contrary to what could have been anticipated, these trends have not produced a simplification or reduction of infrastructure and scenarios: on the contrary, the result of this transformation is an explosion of heterogeneity, an explosion of the number and types of:

- Networks
- Services and applications
- Operators and service providers

This world of heterogeneous elements exerts a pressing and critical demand for the concept of interoperability and its variations (see Figure 1):

- Interoperability of networks and of network management systems
- Interworking of applications and transparency between services
- Interfacing among operators and service providers, exchange of *Quality of Service* (QoS), *Service Level Agreement* (SLA) information and accounting rules.

Interoperability is one of the most critical issues in communications to be solved in the 21st century.

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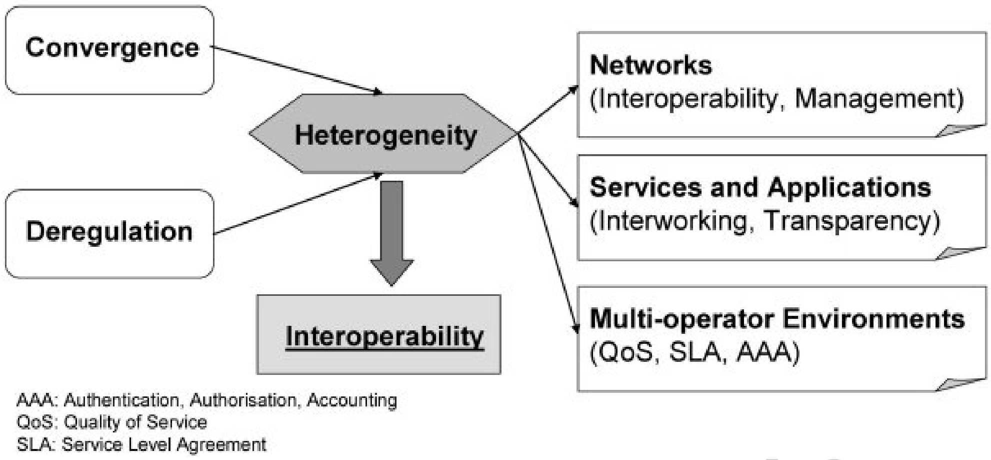

Figure 1: Emerging Context

1.1. Definition of Interoperability

There is no unique definition of interoperability, because the concept of interoperability has different meanings depending on the context, and also because there are different shades of interoperability: what can be interoperable in a given system implementation, may not work with a different vendor implementation. In addition, interoperability can be defined at different abstraction levels. Here we will use the context of technical interoperability, as opposed to regulatory, or market behavior contexts.

The glossary of telecommunications terms, from NTIA's ITS [1] defines "*interoperability 1*" as "the ability of systems, units, or forces to provide services to and accept services from other systems, units or forces and to use the services so exchanged to enable them to operate effectively together", "*interoperability 2*" as "the condition achieved among communications-electronics systems or items of communications-electronics equipment when information or services can be exchanged directly and satisfactorily between them and/or their users. The degree of interoperability should be defined when referring to specific cases".

1.1.1. Network View

EICTA [2] defines Interoperability as "the ability of two or more networks, systems, devices, applications or components to exchange information between them and to use the information so exchanged".

1.1.2. Customer View

According to the IEEE Communications Society [3], Network Interoperability (NI) is "the continuous ability to send and receive data between interconnected networks providing the level of quality expected by the end user customer without any negative impact to the sending and or receiving networks".

Specifically, Network Interoperability is the functional interworking of a service across or between multi-vendor, multi-carrier inter-connections (i.e., node-to-node, or network-to-network) working under normal and stress conditions.

1.1.3. System View

Quoting the Institute for Telecommunication Sciences ([1], 2000 Technical Progress Report) "Interoperability involves consideration of how information is exchanged (through networks of networks) and used (through user-based (A, B, C... N) and network-based (a, b, c... n) applications and services). Interoperability issues involve, for example, specification of protocol suites, provision of basic and enhanced services, secure information exchange among authorized users, user selection of transit networks and content providers, connection admission control, end-to-end quality of service, network management, and user data element format, processing, and storage/retrieval" (see Figure 2).

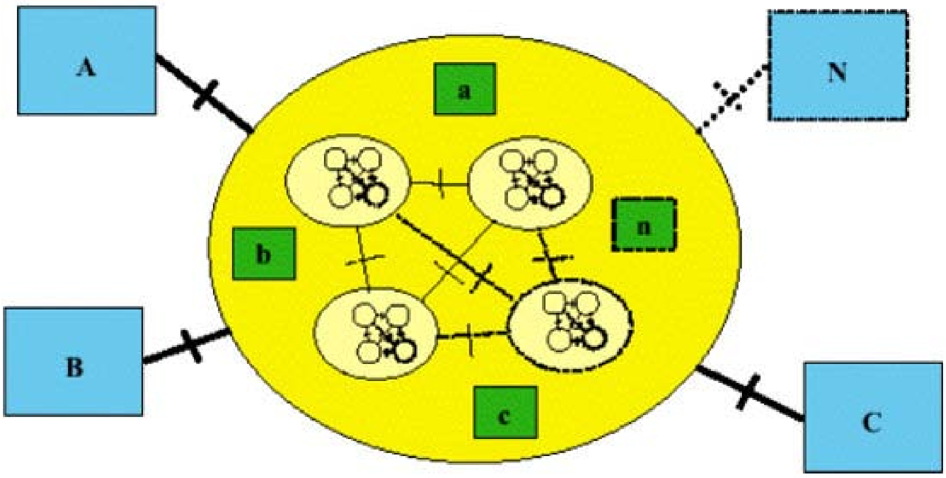

Figure 2: Interoperability of Systems [1]

Therefore, interoperability is the ability of a system or a device to work with other systems or devices without special effort on the part of the user. An adequate level of interoperability is necessary at various levels:

- Device to device
- Device to network
- Network to network
- Service to service

1.2. The Need for Interoperability

Network interoperability is indispensable in order to achieve end-to-end connectivity. The miracle of being able to call anybody in the world using the old *Public-switched Telephone Networks* (PSTNs) is due to interoperability. The same applies for the ability to call any *Global System for Mobile communication* (GSM) phone in the world, or to connect to any computer via the Internet. The more and more diverse networks exist, the greater the need to ensure that they can interoperate, so that end-to-end communication is possible. At the same time, the more difficult the problem becomes.

Interoperability is of benefit to all actors of the value chain:

- *The user* benefits because he can communicate with whom he wants or needs anywhere and anytime, with a single terminal.
- *The network operator* benefits because it can select the best equipment from different manufacturers according to the best price and performance.
- *The manufacturer* benefits because it can sell the same equipment to different countries or operators, and benefit from economies of scale in fabrication and marketing.
- *Public authorities* benefit because they can coordinate responses from different critical infrastructures networks. Recent examples such as the New Orleans flood showed how important is to be able to interoperate between different emergency networks, satellite, fixed and mobile. In addition to safety issues, providing the interoperability to enable systems to work across different authorities and countries is also crucial for security policy: protection against terrorism and crime, coordination of utility grids, disaster management.

1.3. How to Achieve Interoperability

Network interoperability being the ability of two networks to communicate, can be achieved in two ways, just like there are two ways of communicating between people: either by speaking a common language, or by using an interpreter. Interoperability can be achieved either by having the two networks conform to a common protocol standard, or by defining a standard interface to which all networks need to adhere, or by providing a gateway between them that translates between the two protocols.

Interoperability can be facilitated and enabled at different stages of the development process through the following methods:

1. Before any implementation or standard creation, several barriers to technical interoperability can be avoided or minimized. These barriers include non-open or proprietary standards, increasingly complex structures due to the convergence/proliferation of multimedia services and infrastructures, competition among standards bodies (previously independent but now due to convergence dealing with the same issues), explosion of the number of operators due to deregulation and competition. Useful approaches involve careful network planning and design including migration strategies, technology forecasting and assessment, evaluation and improvement of standardization processes, research on new communications technologies that are interoperability-friendly.

2. The next step is to concentrate on a correct standardization approach. In order to enable interoperability in a multi-vendor, multi-network, multi-service environment, the standardization specifications should properly cover the requirements, architecture and protocols. The more precise the requirements, the easier will be to produce good standards. Good standards should leave little room for options and should be universal, produced in consensus with other interested bodies. Of course, this needs time, so the

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need to strive for a proper balance between quality and speed, as a standard that takes too long to produce becomes obsolete.

3. The last step is testing: conformance and interoperability testing, the proof to check not only that the equipment and network conform to the standards but also to provide feedback into the standard itself and its process.

An example of this last step being run by a standards organization is the *European Telecommunication Standards Institute* (ETSI) Plugtests^{TM} Service, a professional unit of ETSI specializing in running interoperability test events for a wide range of telecommunications, Internet, broadcasting and multimedia converging standards (http://www.etsi.org/plugtests). In these events, companies can test interoperability and performance of their latest developments against each other in an engineering environment, enabling the speed-up of the standardization process and the promotion of universal interoperability through an open and market-driven process.

1.4. Interoperability and Standards

In practical terms, standards are the tools that make possible the design of interoperable systems. Actually, to speak of interoperability is to speak of standards, and vice-versa.

An *interoperability standard* is a document that establishes engineering and technical requirements that are necessary to be employed in the design of systems, units, or forces and to use the services so exchanged to enable them to operate effectively together.

There are several organizations, some established by governments and some by industry initiatives that create standards. The key standard groups dealing with telecommunications networks interoperability are listed in the table below.

Standards and agreed specifications are clearly important, but manufacturers, operators and users will be confused if new specifications are introduced too frequently, are contradictory, or have not had enough practical validation and pre-service trailing.

	Key Areas of Standardization	**Key Technologies/Focus Areas**	**Sponsor**
International Telecommunication Union - Telecommunications Sector **ITU-T**	Telecom	Broadband, IMT-2000, IN, TMN, SDH, Multi-media, Satellite, Fiber Systems, Radio systems, Broadcast Video	United Nations' ITU
European Telecommunications Standards Institute **ETSI**	Telecom	electronic communications networks and services, and related areas such as intelligent transportation and medical electronics	European Commission
Committee T1-Telecommunications **Committee T1**	Telecom Network Interfaces;	Broadband, PCS, IN, TMN, SONET, Multi-media; Network	Alliance for Telecommunications Industry Solutions

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	Interoperability	Reliability, NII/GII	(ATIS)
Institute of Electrical and Electronics Engineers **IEEE**	Electrical and Electronics	Local Area Networks, Software Languages, Test and Measurements	IEEE
Internet Engineering Task Force **IETF**	Internet	TCP/IP and its Uses to Transport Information -Telnet, FTP	Center for National Research Initiatives (CNRI)
Network Management Forum **NMF**	Network Management	Service and Network Management	NMF
The 3rd Generation Partnership Project **3GPP**	Mobile and Wireless Communications	3rd Generation Mobile Systems, Radio Interfaces	ETSI and others

Table 1: Key Telecommunications Standard-related Groups

2. Levels of Network Interoperability

Inter-operability between different types of networks encompasses the following aspects of inter-working [4]:

- *Physical level* (e.g. opto-electric-radio)
- *Network level* (e.g. signaling and control functions in homogeneous and heterogeneous networks; inter-operability between fixed & mobile networks, and optical & electrical networks; interfacing with service-provider networks)
- *Application level* (e.g. interfacing with content providers; user QoS)
- *Management aspects* (e.g. inter-operability between network management systems; accounting schemes; guarantee and preservation of QoS).

Fixed and Mobile Broadband networks have the inherent capacity to carry all types of services. Their interoperability offers benefits to:

- *Network operators*, who want maximum network utilization, smooth network evolution, and simplified network management
- *Telecommunications equipment manufacturers*, who can reassure their customers with future-proof solutions, backed by promises of interoperability
- *End-users*, who will benefit from the access to more sophisticated services, and (in principle) lower call charges through the more-efficient use of the resources belonging to the network operator.

The concept of a Converged Broadband Communication network continues to be an objective for many developers. Ultimately, it could be deployed and operated by public network operators, value added service providers, corporate network managers and end-users. Network evolution trends indicate, however, that for many reasons, a single implementation of a universal network is unlikely to be ever implemented. Rather, a number of components of this converged world will be operated either in isolation, or most probably, in conjunction with existing voice and data networks, television and the Internet.

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As individual networks become capable of supporting multiple services, the interoperability issues will increasingly be relevant to the higher layers of the traditional protocol stack. Interoperability implies adaptation, and every adaptation has a financial cost and causes a loss of quality, due to processing delay and the inclusion of additional overhead. It is therefore vitally important that the complexity associated with interoperability is minimized. Ideally, interoperability should be inherent in the design; and in practice, interoperability will be one of the key technical and policy issues in the next few years.

2.1. Network Convergence – Next Generation Networks and Beyond

The landscape in telecommunications is changing and among the major drivers for this change are technological possibilities (especially IP-technology and IP-applications), the convergence of media, computing and telecommunications and the market success of mobility.

The basis for the bright future of a plethora of converged services is the emerging next generation network. This will consist of

- *Various next generation access networks*, which will allow true platform competition,
- *Global next generation core networks* with nearly unlimited bandwidth in the backbone and
- *Next generation service control*, which will provide the framework for intelligent and convergent service creation.

There is no common definition of the term *Next Generation Network* (NGN). However, today the industry would appear to settle on the ITU-T definition, which defines NGN as a packet-based architecture fostering the provisioning of new/emerging services through a loosely coupled, open and converged communications infrastructure.

The evolution to next generation networks is built on a foundation that requires operators to evolve their infrastructure in three areas: the core, the access and the service provision/control platform.

The core needs to evolve to a next generation core which is in substance a converged IP infrastructure capable of carrying voice, video and data services. This is basically the evolution from a “one network–one service” approach to a “one network–many services” approach. The access needs to evolve to a next generation access reducing any bandwidth bottlenecks that may exist today at the access level: this evolution is not related to any one single access technology but to characteristics of an access infrastructure capable in providing higher and scalable bandwidth, better symmetry and lower contention. Finally, the management and provision of services needs to evolve to a next generation service control capable in providing features such as Identity Management, Policy Management, Mobility Management, Dynamic Session Management – allowing the operators to provide personalized services on a per user basis and develop innovative services supporting nomadicity and mobility.

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The sequence and timeframe of the development of these three functions – next generation core, access and service control - will depend on different rationales such as obsolescence of the existing infrastructure, competitive pressures, willingness to bring to market convergent and innovative services and the like. The sequence in which this evolution will be addressed will be translated into different benefits along the line.

2.2. Fixed-Mobile Convergence – The IP Multimedia Subsystem

The objective of *Fixed-Mobile Convergence* (FMC) is to support the seamless provision of basic and advanced services across fixed and mobile environments. Benefits can be foreseen for manufacturers, operators, service providers and potential users.

Issues are:

- Definition of network internal interfaces according to the architecture proposed by ETSI for the *Global Multimedia Mobility* (GMM)
- Guarantee of security functions in interworking networks
- Analysis of existing mechanisms for transparent service provision
- *Intelligent Network* (IN) versus client/server solutions
- Mutual re-use of "network functions".
- Impact of mobility functions on the internet (switching capabilities, control functions relevant to mobility, usage of the *Internet Protocol* (IP) and related protocols, etc.)
- Integration of IN with IP
- Security aspects.
- Requirements on service architecture to support mobility
- Definition of an all-IP based wireless network as compared to the historically disparate voice, data, signaling, and control network elements according to the *IP Multimedia Subsystem* (IMS) proposed by 3GPP ([5]).

The 3GPP vision to create standards for so-called All-IP networks at the end of the 1990s was driven by three trends in industry and academia. Because of the majority of the data traffic worldwide being IP traffic, motivation has increased to adapt non-IP traffic to IP to reduce cost with a common transport. Additionally more and more applications rely on IP, so that IP can be seen as a service enabler for IP multimedia services supporting both telephony and data applications. The third trend can be seen from a global perspective, especially regarding the 3GPP2 standardization that has set the direction of new IP-based standards for cdma2000 voice, data and multimedia.

The evolution towards an All-IP network, also called IP-Multimedia network, within the 3GPP is occurring in three steps corresponding to Releases 4, 5 and 6. While the core network modifications in Release 4 are related to IP transport, Release 5 aims to offer operators the possibility of increasing revenue by the introduction of IP-oriented services. The aim is to provoke a user migration from conventional users of speech served by the circuit-switched domain to users accessing enhanced IP-based services using the packet-switched domain. This is realized by the *IP Multimedia Subsystem* (IMS) that overlays the existing architecture. In order to achieve access independence and to maintain a smooth interoperation with wire line terminals across the Internet, the IP multimedia subsystem attempts to be conformant to "Internet standards", e.g., the Session

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Initiation Protocol (SIP) that is known from *Voice over IP* (VoIP) services.

However, IMS services should not only be seen in the context of voice services, but as an enabler for interoperable multimedia service platforms. IMS is currently in trials with over 200 fixed and mobile operators around the world. IMS is an open and standardized architecture for mobile and fixed services. It is used by operators to offer network-controlled multimedia services by combining voice and data in a single packet switched network. IMS is gaining increasing momentum as a key driver of fixed/mobile convergence, especially among operators in Western Europe, with the first roll-out of IMS-based services already occurring.

The evolution of fixed and mobile integration is divided into two major steps:

1. Interworking, where networks are used in their current form without modification of the network nodes and only minor adaptations to the protocols used.
2. Integration, where the fixed and mobile networks converge. The integration could imply the reconfiguration of network systems into a Generic Radio Access Network, a backbone transport network and a service network. This will resolve the former boundaries between various network types (e.g. GSM, UMTS, DECT, ISDN, or PSTN).

The agreed strategy for future telecommunication systems is an evolution from existing networks and services. This involves progressively introducing new components (e.g. a revolutionary air-interface). As the process continues, the definition of network architecture will involve increasing co-operation between the individual players.

Interoperability issues are at the core of IMS, as interoperability is the key enabler for seamless roaming of services across different types of networks and devices. Furthermore, for almost all operators, there is the need for the new IMS architecture (NGN networks) to co-exist and interoperate with legacy systems for a while. Actually, IMS is just the last of a long line of attempts to create an infrastructure that could support a "network of networks", and which has been a long-term vision for the last 20 years.

The IMS concept was first developed by the 3rd Generation Partnership Project (3GPP), but has been adopted by both the ITU-T and ETSI. IMS standards are still developing, and wide scale implementation is still some years away.

Network operators realize that IMS will be essential to provide fixed-mobile-wireless convergence and to enable advanced services requiring presence and location information, shared user profiles, and flexible charging and metering capabilities (see Figure 3). But big challenges still lie ahead in terms of the complexity and interoperability issues from different vendors and from different technologies.

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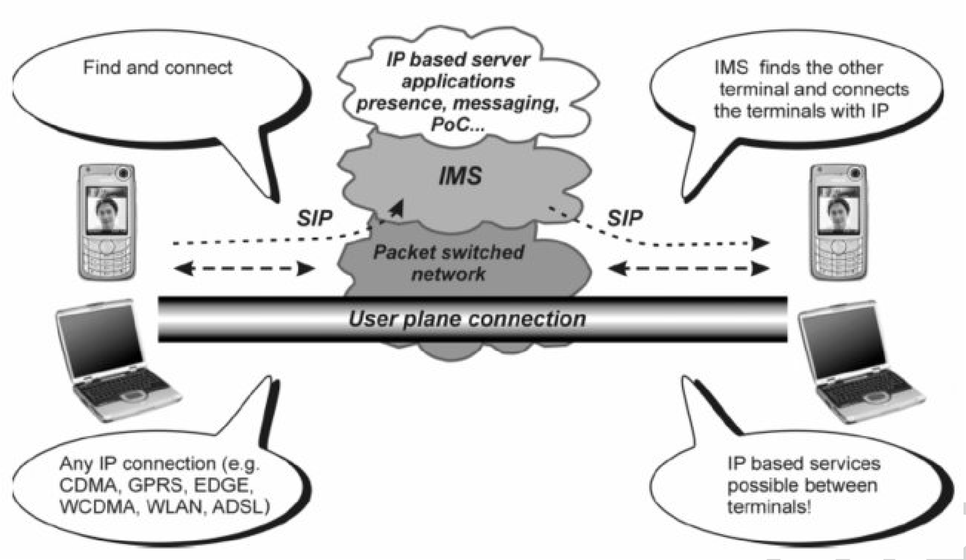

Figure 3: The role of IMS in packet-switched networks (source: [6])

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Bibliography

[1] Bloomfield, R.S. (1999). Institute for Telecommunication Sciences. *Online Telecom Glossary* and other publications, NTIA, http://www.its.bldrdoc.gov/pub/pubs.php. [Online publications provided by the Institute for Telecommunications Sciences, an agency of the US government. It includes a glossary of telecommunications terms, and yearly technical progress reports]

[2] EICTA (2004). *EICTA white paper on Interoperability*, http://www.eicta.org/files/WhitePaper-103753A.pdf. [Recommendations to governments and industry on ensuring interoperability by EICTA, the voice of the ICT and consumer electronics industry in Europe]

[3] IEEE Technical Committee on Communications Quality and Reliability, http://www.comsoc.org. [Gives a working definition for the interoperability study group]

[4] Potts, M. (1999). *Network Level Inter-operability and Management*, ACTS Guidelines NIG-G1, http://www.cordis.lu/infowin/acts/analysys/concertation/chains/ni/index.htm. [Gives guidelines for best practices on network management interoperability issues, produced by EU-funded research projects]

[5] Stuckmann, P. (2002). *The GSM Evolution*, John Wiley & Sons, 2002, ISBN: 978-0-470-84855-5. [Presents the basics of GPRS and EGPRS including the radio interface and system and protocol

architecture and provides an in-depth description of GPRS, EDGE and GERAN networks]

[6] Poikselka, M., Niemi, A., Khartabil, H., Mayer, G. (2006). *The IMS: IP Multimedia Concepts and Services*, 2nd Edition, John Wiley & Sons, ISBN: 978-0-470-01906-1, [Provides comprehensive coverage of IMS including its concepts, architecture, protocols and functionalities]

[7] Ambrosch, W.D., Maher, A., Sasscer, B. (1989). *The Intelligent Network*, Springer, ISBN:3-540-50897-X. [Presents a comprehensive discussion of the Intelligent Network concept and the capabilities the Intelligent Network would provide the network operator in the deployment of telecommunication services. It shows the findings of a study carried out by Bell Atlantic International, Siemens and IBM which dealt with the implications of introducing new services into the telephone network through the use of centralized logic.]

[8] The Parlay Group (2005). *Parlay/OSA and the Intelligent Network*, http://www.parlay.org. [This white paper looks at how Parlay/OSA works with the Intelligent Network and how Parlay/OSA applications can make use of the capabilities of the IN.]

[9] OECD Working Party on the Information Economy (2006). *Digital Broadband Content.* [The OECD Working Party on the Information Economy is undertaking analysis of the digital delivery of content. This work recognizes that the rapid development of high-quality "always on" broadband Internet services is transforming high-growth industries that provide or have the potential to provide digital content.]

[10] Commission of the European Communities (2005). *i2010 - A European Information Society for Growth and Employment*, COM (2005) 229 Final. [Presents the strategic framework i2010 laying out broad policy orientations promoting an open and competitive digital economy and emphasizes ICT as a driver of inclusion and quality of life]

[11] Commission of the European Communities (2006). *The Networked Future*, Brochure ISBN: 92-79-02366-7. [Testimony of the European RTD efforts in the area of communication and network technologies and of their potential to master and shape the future]

[12] OECD Working Party on Telecommunications and Internet Policy (2006). *OECD Broadband Statistics 2005.* [Presents recent statistics based on world regions including broadband subscription, penetration, deployment and usage]

[13] Niebert, N., Schieder, A., Abramowicz, H., Prehofer,C., Karl, H. (2004). *Ambient Networks – Research for Communication Networks Beyond 3G,* IST Mobile Summit 2004, Lyon, France, http://www.ambient-networks.org. [Describes existing approaches for next generation wireless networks and discusses the associated research issues and first design concepts for ambient networks]

[14] Demestichas, P. Vivier, G. El-Khazen, K. Theologou, M. (2004). *Evolution in Wireless Systems Management Concepts: From Composite Radio Environments to Reconfigurability,* IEEE Communications Magazine - Vol. 42, No. 5, May 2004, http://e2r.motlabs.com. [Presents a management system, which has been developed for enabling wireless systems to operate in a CR context and addresses the necessary extensions to the management system for handling the impact of the re-configurability context]

[15] Cordier, C., Carrez, F., Van Kranenburg, H., Licciardi, C., Van der Meer, J., Spedalieri, A., Le Rouzic, J.-P. (2006). *Addressing the Challenges of Beyond 3G Service Delivery: the SPICE Service Platform*, Workshop on Applications and Services in Wireless Networks (ASWN 2006), Berlin, http://www.ist-spice.org. [Presents research on a service platform in a B3G environment, sketches the key issues of such a service platform, discusses current technological solutions, and describes the specific SPICE approach to address these challenges]

[16] Cerf, V. (2006), email communication.

[17] OFCOM NICC website, http://www.nicc.org.uk. [The Network Interoperability Consultative Committee is a pan-industry body that acts as a co-ordination forum in which key players in the telecommunications sector (communication providers, service providers, manufacturers, the regulator, etc) address and agree necessary technical arrangements for interconnection and interoperability for networks and services in the UK.]

UNESCO – EOLSS SAMPLE CHAPTERS

[18] Hill, J. (2005). *A Conceptual Model of ICT Interoperability*, SUN Microsystems, http://www.etsi.org. [Addresses the lack of a common definition of interoperability, proposes a formulation for an index of interoperability and recommends extensive academic research focus on the nature, requirements, methods, and confirmation of interoperability].

[19] Falch, M., Henten, A., Saugstrup, D., Tadayoni, R. (2004). *Convergence - A Challenge for Broadband Development*, ICETE Conference, Setubal, Portugal. [Addresses the different layers of convergence and its regulatory and policy impact]

[20] Commission of the European Communities (2003). *Communication on Barriers to Widespread Access to New Services and Applications of the Information Society through Open Platforms on Digital Television and Third- Generation Mobile Communications*, COM (2003) 410 Final, Brussels. [Identifies barriers to open platforms, and other issues that influence the roll-out of 3G mobile services and digital TV]

[21] CompTIA White Paper (2004). *European Interoperability Framework - ICT Industry Recommendations*, Brussels, http://www.comptia.org. [Recommendations by the ICT industry for the role of governments in promoting interoperability and enacting related regulatory policies. CompTIA is a global industrial trade association involved in developing standards and best practices]

[22] ETSI, Background papers. *Standards, OpenSstandards and Interoperability*, http://www.etsi.org/sos_interoperability/Background%20papers/BackgroundPapers.htm. [Collection of papers dealing with network interoperability strategies and standards, including some referenced here]

Biographical Sketches

Paulo de Sousa was born in Huambo, Angola in 1947 and received a Lic. degree in electrical engineering from the University of Luanda, Luanda, Angola, in 1971, and a Ph.D. degree in electrical engineering from the University of Missouri, Columbia, Missouri, USA, in 1976.
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He is currently Project Officer with the European Commission, Directorate-General Information Society and Media, where he is involved in European Research Programme Management. Before joining the European Commission in 2004 he has occupied several engineering and managerial positions both in industry and academia. From 1999 until 2003 he has served as a Research Engineer at the Chair of Communication Networks of Aachen University, where he has led the research group "Mobile Packet Data Services" and has been responsible for several research projects funded by the German and European government and clients from industry. From 2003 on he has been working with AixCom GmbH as a Project Manager responsible for the product group "Radio Network Planning Tools". In 2004 he has been with France Telecom R&D as a Project Manager responsible for research activities in the area of radio interface engineering.

Dr. Stuckmann is the author of the text book "The GSM Evolution", Wiley & Sons, 2002, 2 book contributions, more than 20 journal and conference publications and one patent. He is member of the IEEE and the German VDE/ITG.

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