eMobility

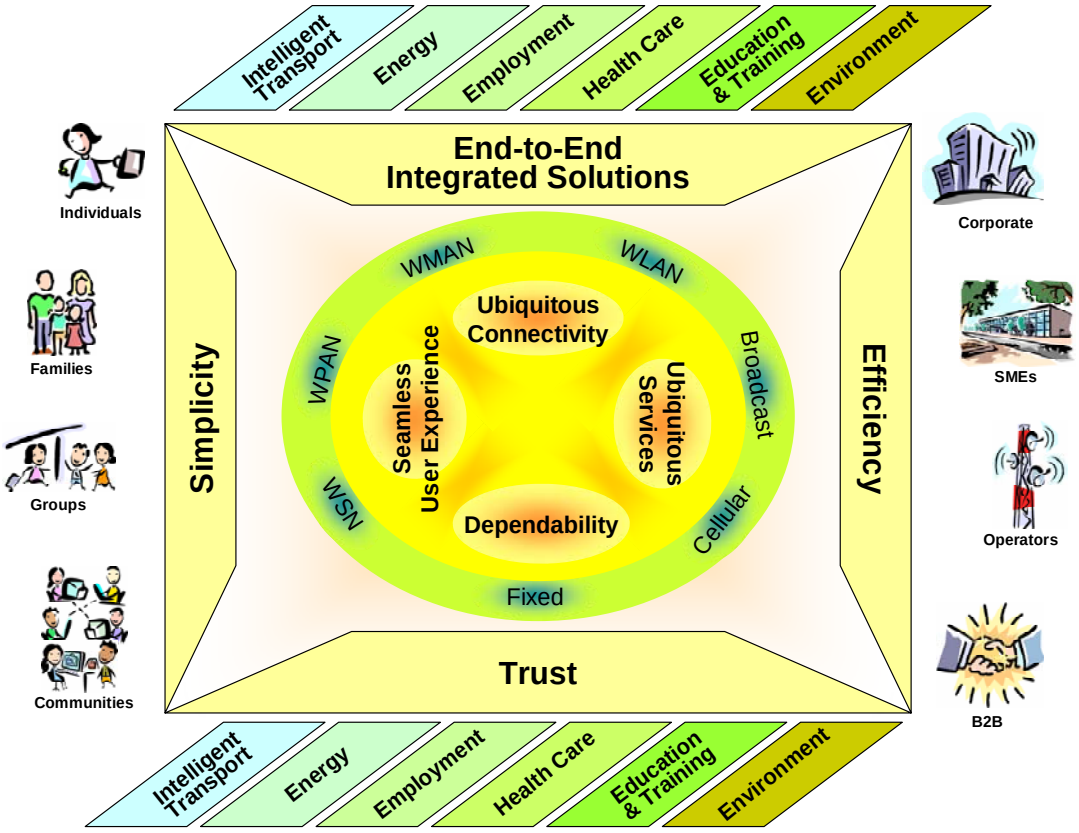
Mobile and Wireless Communications

Technology Platform

Strategic Research Agenda

Staying ahead with SET

Version 7, December 2008



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List of Acronyms

AAA	Authentication Authorisation Accounting
API	Application Programming Interface
BAN	Body Area Network
BWA	Broadband Wireless Access
CAPEX	Capital Expenditures
CD	Communication Device
CMOS	Complementary Metal Oxide Semiconductor
DMB	Digital Multimedia Broadcasting
DoS	Denial of Service
DRM	Digital Rights Management
DTN	Delay Tolerant Networks
DVB-H	Digital Video Broadcasting-Handheld
EC	European Commission
FI	Future Internet
GHz	Giga Hertz
GM	Genetically Modified
ICT	Information and Communications Technologies
IETF	Internet Engineering Task Force
IMS	IP Multimedia Subsystem
IP	Internet Protocols
IPR	Intellectual Property Rights
IS	Information Society
IST	Information Society Technologies
IT	Information Technology
ITS	Intelligent Transportation System
MBits/s	Mega bits per second
MBMS	Multimedia Broadcast Multicast Service
MEMS	Micro-Electro-Mechanical Systems
MIMO	Multiple Input Multiple Output
MPEG	Moving Picture Expert Group
M2M	Machine-to-Machine
NEMS	Nano-Electro-Mechanical Systems
NoC	Network on Chip
NQoS	Network Quality of Service
OMA	Open Mobile Alliance

OPEX	Operational Expenditures
OS	Operating System
PAN	Personal Area Network
PC	Personal Computer
PDA	Personal Digital Assistant
PN	Personal Network
PQoS	Perceived Quality of Service
PSS	Packet Switched Streaming
QoS	Quality of Service
QoSA	Quality of Service Adaptation
RAN	Radio Access Network
R&D	Research and Development
RF	Radio Frequency
RFP	Request for Proposal
RFSIM	Radio Frequency Subscriber Identity Module
ROI	Return of Investment
RTOS	Real-Time Operating System
SDR	Software-Defined Radio
SIM	Subscriber Identity Module
SLA	Service Level Agreement
SME	Small and Medium Enterprise
SoC	System on Chip
SPIM	Spam over Instant Messaging
SPIT	Spam over Internet Telephony
SRA	Strategic Research Agenda
TCP	Transport Control Protocol
UI	User Interface
WAN	Wide Area Network
WLAN	Wireless Local Area Network
WMN	Wireless Mesh Network
WSDL	Web Services Description Language
WSN	Wireless Sensor Network
W3C	World Wide Web Consortium
XML	Extensible Markup Language

Executive Summary

By the year 2020, mobile and wireless communications will play a central role in all aspects of European citizens' lives, not just telephony, and will be a major influence on European economy, wirelessly enabling every conceivable business endeavour and personal lifestyle. The following sentence articulates the essence of the future aims and vision: **"The improvement of the individual's quality of life, achieved through the availability of an environment for instant provision and access to meaningful, multi-sensory information and content."**

Realisation of this vision demands a major shift from the current concept of "anywhere, anytime" to a new paradigm of "any network, any device, with relevant content and context in a secure and trustworthy manner".

The future systems will be complex, consisting of a multitude of service and network types ranging across Wireless Sensor Networks (WSN), Personal Area, Local Area, Home Networks, Moving Networks to Wide Area Cellular Networks. The increasing dependency of society on such communication infrastructure requires considerations of new applications and requirements into their design as well as new research methodology to realise them.

Research methodology proposed here is based on Europe's unique strength and approach to research and development of telecommunication systems. It is captured in a new concept called "SET Concept" that underscores the need for a 3-dimensional vision of research activities that will deliver Simplicity, Efficiency and Trust, strongly advocating "integrated" research and "end-to-end" solutions. The "Simplicity" is to enable simple use of services, service deployment and enhancement and simple and self-optimising operations, maintenance and upgrades. The "Efficiency" emphasises on efficient use of networks' all types of resources and more importantly the energy efficiency contributing towards a greener environment, whereas the "Trust" considers the new requirements and needs of modern societal dependency on use and full availability of such systems in carrying out their daily lives with robust security and resilience in face of variety of natural and man-made disasters.

Several strategically important technologies and non-technical barriers have been identified and justifications provided for their considerations into future national and European research programmes. The technological related chapters are complemented with further work on "Flexible business infrastructures", demonstrating different business models and business interfaces that are envisaged in future.

1 Vision of the Future Mobile and Wireless Communication

By the year 2020, mobile and wireless communications will play a vital role in all aspects of European citizens' lives. The industry sector will contribute substantially to the European business prosperity. Technology will greatly evolve from the current concept of "anywhere, anytime" to a new paradigm of "any network, any device, with relevant content and right context in a secure and trustworthy manner". This stretches the art of mobile communications beyond radio and computer science into new areas of biology, medicine, psychology, sociology, human sciences and nanotechnologies. The following sentence articulates the essence of the eMobility aim and vision:

"The improvement of the individual's quality of life, achieved through the availability of an environment for instant provision and access to meaningful, multi-sensory information and content".

An **Individual** person is in the focal point and reinforces the idea that users will have a much stronger role in defining their own communication sphere, for example, effecting personal preferences independently of network, device, location, operator and service. This also means that network and service provision should be based on users' needs and interests, namely the establishment of group communications. User communities including; families, friends, friends of friends, and associates, are also considered, since communities activate people on a daily basis, implying availability and responsiveness. The increasingly important role of PANs and ad hoc networking will catalyse the emergence of online communities.

Improvement, in parallel with novelty, constitutes one of the basic reasons for R&D, i.e., the ultimate goals are achieved not only by inventing and proposing new things, but also by improving existing ones, which, in the end, serve as enablers for new products and services. However, one must also recognise the possibility of disruptions that can totally change complete businesses; disruptions will most likely also shape the face of communications and impose completely new business models in many cases.

Quality of life is a major human goal, and eMobility contributes to it beyond the very basic provision of a communication means. The starting point of future system and service design is a person's basic needs and interests, which span one's personal, family, professional and private

lives. Technology needs to improve the quality of life in terms of not only wealth creation, but also education, job skills improvement, health enhancement, security and safety. Machine-to-machine communications is an example to be taken into account, because it helps in increasing system intelligence and hides complexity and technology from the user. Furthermore, it is also about enabling and allowing European business to grow and prosper by building and fully utilising the communication environment.

Achieving through the availability implies tangible benefits through an integrated system made available. The user will pay for usage, devices and services, but the cost needs to be justifiable. Users might take things for granted, but this emphasises the need for security and trust. Furthermore, systems and networks should be waiting for the user, not the other way around, i.e., constant high efficiency. This leads to dynamic solutions, resource harvesting and borrowing. Seamless connection between private and public services, local and long-range communications, will be a major enabler in the future communications.

Environment means that the users will strongly interact with the environment that surrounds them, e.g., by using devices for personal use, or by having the location as a basis for many of the services to be used. This implies a totally different structure for the networks. Also context recognised by the system and it acting dynamically on the information is a major enabler for intelligent applications and services. This also means that sensor networks and RFIDs are increasingly important. The number of devices that people carry (knowingly or unknowingly) will increase. Furthermore, the increased interaction between devices will consume power. Therefore, the problem of power consumption, and the limitations thereof, will continue to be of importance.

Instant communication, as perceived by the user, is the essence of the game, in the sense that the user will be capable of communicating how, where and whenever needed, as well as, capable of using more than one system or network simultaneously to carry the information.

Provision and access carries the two-way communications as we know it, but it goes beyond that, as the users will be provided with and have access to content and information they want in a useful way, namely concerning transmission speed. In the future, much of the user information may, indeed, be local, as opposed to information that does not take location into account. Moreover, peer-to-peer communications will play a key role. The provision of, and access to the “right content” at the “right time” is perceptual, and should be provided when a user is ready to receive it, in a format that considers user privacy and present context, by using any available means and network. Sometimes the user requests the information, i.e., “user access to information”, while other times it is the “information that accesses the user”, based on user’s

personal or community profiles. The success of such a vision depends very much on simplicity of access and use of services and on operation of the devices. Another important factor is the cost of a service, which is the reflection of capital and operational costs of a network borne by operators and content providers.

Meaningful is key in the vision. On one hand, undesired information (e.g., unsolicited advertisements, spam, and viruses) and privacy are growing challenges of today's communications. On the other hand, it means that information filtering is very important, so that the users really get what they want. The users need to be aware (if they so desire) of information and content that are of interest to them. The information accessed or provided to users has to be devoid of unnecessary, irrelevant and redundant components.

Multi-sensory is related to all the users' devices and surrounding environment cooperatively capturing a users' presence, context as well as virtual presence. Using such valuable captured information enables provision of services to a user based on his/her truly characterised context in an appropriate modality. This would enable service provisioning to a user as natural and private as interpersonal communications or direct communications in a non-invasive and context-aware manner. This extends the mobile and wireless communications beyond radio and computer science, into new areas of science, like biology, medicine, psychology, sociology, and nano-technologies, and also requires full cooperation with other industries not traditionally associated with communications. Finally, the information should be multi-sensory and multi-modal, making use of all human basic senses to properly capture context, mood, state of mind, and, e.g., one's health state. Clearly, the realisation of this vision of mobile and wireless communications demands multi-disciplinary research and development, crossing the boundaries of the above sciences and different industries. Also, the number of electronic sensors and RFIDs surrounding us is quickly increasing. This will increase the amount of data traffic.

Information and content signifies the growing importance and volume of data and information needed and provided relative to voice telephony. This vision cannot be complete without the definition of future application scenarios and users. A good starting point from which one should draw trends is to consider children and grand children as potential users. They will be the active population in the next 15-20 years' time.

2 Research Methodology

Many steps are required to turn the future vision into reality and from the establishment of this macroscopic vision, many tasks and challenges need to be identified, and solved, at the microscopic scale. The remainder of this document deals with this latter aspect, providing for each of the identified areas a specific vision, its rationale and objectives, together with a list of the research priorities. Besides these main areas, others that can be considered close to basic research are also identified, together with some initiatives that should be implemented as potential projects dealing with these specific areas.

It is not, however, sufficient to only define a list of isolated but strategically important technical and non-technical issues and projects. There is a great need to define a suitable framework providing a common and complementary research policy, goal and strategy. Adoption of this common research strategy by all projects within national and European research initiatives guarantees their outcomes to be complementary and of high relevance and value. Emphasising this in European research context is a new concept called the “SET Concept” that underscores the need for a 3-dimensional vision of research activities that will deliver **S**implicity, **E**fficiency and **T**rust.

2.1 SET Concept

The SET Concept is designed to overcome potential technical, business and psychological barriers to the adoption and acceptance of new technologies and services. It takes into consideration the interests of users, network operators, service providers, and manufacturers, and provides a challenging research agenda for all.

Simplicity - It emphasises research into new solutions for managing complexity seamlessly on behalf of service providers and for hiding complexity from a user in accessing, using and creating services. Complexity is delegated from a user to the communication system which must adapt to the individual’s life stage preferences and situation, and a variety of other contexts.

Efficiency - Solutions which result in efficient use of spectrum and network resources towards greener environment, and higher throughputs, through appropriate energy aware cooperation and adaptation techniques. The new target is not necessarily higher bit rates as in the past. Autonomous self organisation is needed to continuously operate at the optimum point under dynamically varying conditions, as well as capabilities to easily incorporate (as yet unconceived) future services and requirements.

Trust - Wireless communications will enable an always-connected environment, facilitating services to support private and professional life of individuals, families, and special interest groups. Intelligent services will be based on sensitive personal information, context and profiles traversing different network types, and multiple business and administrative domains. Any successful adoption and use of future services and networks in all walks of life, imposes the creation of a trust environment. This is necessary to overcome possible psychological barriers through building a sense of trust in the integrity, privacy, security of information and networks, as well as to protect society against malicious, criminal or terrorist activity.

2.2 Research Challenges

Simplicity

- Ubiquitous connectivity and session continuity through auto-connectivity between legacy and new types of networks: WSN, PAN, LAN, Home Network, Moving Networks, Wide Area Networks and techniques which facilitate self-(configuration, organisation, healing) and management of heterogeneous and dynamic networks and services.
- A network agnostic service execution platform that interacts with networks and terminals and also facilitates the deployment, adaptation and management of services on the various (including mobile) devices.
- Innovative services based on a user's ambient intelligent and streamlined context classifications methodology.
- Enabling techniques for user-created content facilitating peer-to-peer communication.
- Smart user interfaces and interactions with learning capabilities to evolve with a user interests and age, for all types of users and in particular elderly with emphasis on portable personalisation of services and networks.
- New mobile device form factors, included embedded wireless chip connectivity.
- Radically simplified mechanisms and technologies for context capturing, processing, distribution and integration into intelligent services.
- New and efficient search engines with automatic zero-configuration and complexity management (including the management of privacy and trust).
- Intelligent customer care and provision of smart support in real-time in case of technical difficulties.
- Seamless user experience for all age groups with emphasis on portable personalisation for both the services and the connectivity.

Efficiency

- Joint optimisation of coverage, capacity and quality techniques through cooperation and adaptation techniques.

- Efficient mechanisms for joint exploitation and operation of available diversities in time/space/frequency/code/power domains.
- Investigation of alternative deployment concepts and system architectures beyond the classical cellular approach.
- Efficient cross-layer operation and optimization.
- Intelligent resource (frequency, battery, power, hardware, software) discovery and management techniques.
- End-to-end content and media adaptation techniques such as time-shifting, intelligent catching, opportunistic transport/transmission, rate/quality adaptation.
- Centralised and de-centralised self-organising network topologies for both operator-based and operator-less radio access network concepts for special application areas (e.g., disaster relief and campus networks).
- Seamless convergence between fixed and mobile at both service and network levels, exploiting broadband optical technologies.
- Innovative transceiver architectures and jointly optimized RF and baseband hardware designs, matching the nano-electronics roadmaps and exhibiting new degrees of scalability, flexibility, security, energy-aware performance, cost efficiency and design productivity.
- Evaluation of Network Information theoretical limits of cooperative and self-organising networks and research into advance coding design and signal processing schemes to achieve these limits.
- Investigation of the impact of new frequency bands for future systems on the radio propagation and specification of appropriate output power levels to ensure compliance with relevant guidelines and regulations related to human exposure to radio frequency electromagnetic fields.
- New methods of frequency usage, coexistence, cooperation and sharing techniques for/between exiting and newly identified frequency spectrum and radio access technologies, based on cognitive and spectrum-agile radios to select the most appropriate radio access technology for a given environment.

Trust

- Secure data management, and synchronization and private exchange of user profile and context information.
- Efficient encryption and cryptographic mechanisms and algorithms suitable for different types of devices and networks.
- Identity management & privacy.
- Secure and dependable end-to-end network protocols and applications enabling a simple-to-use trusted transaction environment.

- Unified Digital Rights Management.
- Transparent and flexible Service Level Agreements.
- Combined multi-layered mobility support and authentication/authorization across diverse networks and support of simultaneous use of multiple access technologies.
- Secure software and execution environment including O/S.
- Device and network protection against (virus, trojan, DoS attacks) and intrusion detection.
- Safe and secure software download enabling networks and device re-configurability.

2.3 Mapping Research Challenges to Research Areas

Seamless User Experience for All Ages

- Smart user interfaces with learning capabilities reflecting the user needs and abilities
- New Mobile form factors
- Automatic zero-configuration and complexity management
- Efficient search engines
- Intelligent and efficient real-time customer care

Trust, Security and Dependability

- Secure and dependable end-to-end network protocols and applications
- Safe and secure software download mechanisms
- Advanced authentication techniques
- Robust, secure end-to-end self-(configuration, organisation and healing) techniques
- Metrics for TSD performance analysis

Ubiquitous Services

- Network and Device agnostic service execution platforms
- Ambient intelligence capture and awareness
- Innovative context-based services
- User created content platforms
- Peer-to-peer communications support
- Unified digital right management support

Ubiquitous Connectivity

- Auto-Connectivity between legacy and new types of networks
- Joint Optimisation of coverage, capacity and quality
- New deployment and self-organised system architectures
- Intelligent resource discovery and Management
- Multi-layered mobility management

- New network architectures and protocols for post-IP next generation internet
- Full delay tolerant networking
- Collapsed protocol stack into an efficient and minimum protocol framework
- Innovative transceiver architectures
- New coding design and signal processing for cooperative networks
- New frequency bands and Spectrum sharing schemes

New and Flexible Business Models

- New modelling approach and practises that includes worldwide stakeholders (both traditional and new)
- A practical modelling tool for helping understand what constitutes value and how value can be optimised and leveraged on a daily basis
- Prototyping and piloting vertical market-specific light-weight value-oriented networks
- Research into value networks based on non-monetary compensations (e.g., social agenda for end-users, brand lift for manufacturers and operators, etc.)
- Specific research into impacts of peer-to-peer mobile e-commerce
- Comparative techno-economic analysis of new competing radio technologies and their specific environments (e.g., local, wide-area, residential, sensor-based)

2.4 Building on Europe's Strengths

As was achieved with GSM, the SET Concept offers new opportunity for Europe to be the leader in adopting a holistic and balanced approach to realisation of the future mobile/wireless communication system. The SET Concept will result in efficient and usable technologies and was developed taking into great consideration users' interest/needs as well as recognising the important role of wireless communications in Europe's economy. The research programmes will need to be focused on enhancing the axis of research (Simplicity, Efficiency, Trust) in the SET Concept through innovative techniques and technologies and targeted towards a system that comprises multiple network types. The SET framework offers a useful means to measure the relevance and output of research programmes, also facilitating faster standardisation processes and reducing time to market. Supporting measures to evaluate the evolving European policy environment against the SET framework are also needed, if effective and timely research exploitation is to be secured.

As a further step to ensure such exploitation, the most relevant research results should be integrated and demonstrated in an open infrastructure for research and education purposes that facilitates joint optimisation of different sub-systems under the same conditions. These include, for example, use of different and new frequency bands, new spectrum sharing methods, interworking and seamless mobility solutions, new security techniques, cognitive paradigms,

ambient intelligence, and new usages and context aware services. This infrastructure is expected to act as a European showroom of advanced mobile technology and services highlighting achievements from leading projects, and an open testbed to host SMEs and students through partnerships with Universities, research centres and through international cooperation.

3 Seamless User Experience for All Ages

In the near future, mobile technologies will support people in their daily life in a flexible and non-intrusive manner, and become a part of the environment in which people fulfil their daily tasks. The instantaneous and on-demand ways in which users interact with mobile devices, and devices interact with each other, offer the possibility of novel approaches for providing services that are simply not possible with traditional server and PC-centric computing. Furthermore, flexible displays and printable electronics offer opportunities for new innovations, as current physical restrictions are gradually disappearing.

Ultimately, it is the overall user experience that drives the adoption of new services. The User experience is a widely used term in telecom but different people understand different things by it and also use it to mean slightly different things. One view would be “user experience” is a combination of *Utility, Usability, Aesthetics, Availability,* and *Offline* issues. Thus, service platforms and enablers need to match the growing needs of the users, which originate from a wide variety of different sectors, covering both enterprises and the consumers. A special target group for new services and experiences is the ageing population in Europe: within a decade or two the expected rise in population age will pose serious demands to the whole European economy. Another group is the business people, who could be considered as early adopters of new and emerging technologies – thus paving the way for mass-market solutions.

Removing barriers to mobile application experimentation will result in the development of a myriad of new end user targeted experiences and services that Europe can be well placed to take advantage of. To be successful in the marketplace, European companies need to understand users’ needs, and the interaction between users and the mobile information and communication technologies environment. This means that there is a requirement to involve the concept of the user from the very beginning of activities, and to an increasing extent to establish a user-centric design process that will enable user requirements to be derived in a systematic way.

Unlike the current communication chain paradigm, the evolution of ICT (Information and Communication Technologies) in the future envisages a communication loop that consists of Individuals requesting and providing services to a seamless Network (comprising heterogeneous networks), through multiple Communication Devices (CDs) not necessarily related to the Individual that uses them. This scenario highlights important trends of future ICT, such as the migration from a CD-centric Network to a Individual-centric Network, the paradigm of the direct communication between Network and Individuals (invisible CD) and the necessity to converge to

a procedure in which information about Individuals and surrounding context is used for the optimization of Network management (Network experience) and improvement of Individuals experience.

The implications of the SET Concept to the seamless user experience lie within the users' interpretation of simplicity, efficiency and trust. These are briefly summarized in Table 3-1.

Research Areas	SET	Contribution to SET concept
User experience and acceptance	S	For the user, it needs to be simple to arrive to the objectives that she sets out to achieve. Simplicity means hiding the underlying technology from the user and shifting seamlessly between accesses and devices without having the session break down.
	E	Efficiency translates mostly to the user to not having to wait for the services and finding easily the searched items. Any charges need to be related to the utility value and perceived value-add.
	T	Trust is key to the user, as it determines the willingness of the user to use the communication systems for obtaining the goals. The level of trust is related to the degree and amount of any personal data revealed to the system and the services used.
Smart user interfaces and interactions	S	The user needs to experience intuitiveness of use and familiarity with the interfaces that she encounters. The look and feel should stay the same when possible and any personalisation information needs to be stored in a private and pervasive profile.
	E	Efficient interfaces will only ask of the user the bare minimum, and learn from it so that the required interaction is also minimised in time. A suitable interaction mode is selected based on needs and resources available.
	T	Flexibility and fault tolerance create trust.
Future mobile device form factors	S	The new device form factors will minimise juggling between devices.
	E	Efficiency increases when it becomes possible to achieve more tasks with less unique devices.

Table 3-1 SET Concept and seamless user experience

This chapter identifies specific challenges that need to be fully addressed in realising the vision of eMobility from a user's perspective. These are:

- Understanding user experience and acceptance
- Provision of smart user interfaces and interactions
- Mobile device form factors

3.1 User Experience and Acceptance

3.1.1 Rationale and Objectives

The aim of involving the users in research and development processes is to create meaningful and useful products. User-centric research focuses on identification and design of relevant concepts, prototype development, and usability and feasibility tests. Researchers and developers increasingly recognise the need to cross the barriers of disciplines to create products that match the future demands of users. A more multidisciplinary approach to the development process opens up to new possibilities, perspectives and methods. The possibilities and constraints of future mobile technologies and applications are dependent on user evaluations in the context of their everyday lives. Such research considers relevance to social and cultural practices and provides a framework for cross-European studies of variations in user's needs and expectations of mobile technologies and applications.

Key issue in the user experience is that the research should be done continuously: users' habits, trends, competences and levels of acceptance change over time. Likewise, the research and testing activities need to follow a dynamic process.

Improved and extended multimedia communication services – richer, higher quality, ubiquitous and context-aware, while being affordable – will be a key driver for eMobility and for the future communication infrastructures. One should understand the users' preferences and requirements regarding future multimedia communication services in different contexts, and map these preferences down to requirements on the underlying technology.

Incorporation of the above issues would impose new requirements on network configuration technologies, as well as, on mobile service design, creation and deployment methodologies.

3.1.2 Research Priorities

To expand research and development on mobile technologies to embrace a broader social and cultural context is a challenging task that requires direct involvement of users with wide range of requirements and cultural backgrounds and abilities, in the process of research and development. The testing of technical solutions in real-life settings can help bridge the gap between different disciplines, as well as, technological development leading to successful market implementation.

Accessibility for all is an important vision for future mobile solutions. This provides increased availability, access and usability of content and application for different user groups (e.g., children, disabled, elderly) through multi-modal user interfaces. New mobile technologies can overcome the digital divide and increase cultural, social and political participation and

understanding. However, security and privacy issues need to be carefully handled due to potential deployment for surveillance and control purposes.

Contribution, cooperation and collaboration are key characteristics driving new types of user experiences, where user becomes a part of a community. Media on demand, rich communication, education, online games and other individual content, activity, and service contribution are based upon collaboration between users and activity-associated software agents. Collaboration and (user) community aspects may be main drivers for future services and mobile experiences, but they still need to be understood better.

Users demand interactivity anywhere, anytime and with any device or associated to any service, be it, e.g., push or pull. If we define interactivity as whatever mechanism that enables the users to send or receive information, participate, contribute or communicate with any kind of service or with another user, interactivity is perhaps one of the most differentiating aspects and values which can be added to present and future services. To achieve the goal of adding interactivity to present and future services, it is necessary to research horizontal and standardised platforms to support the rapid creation and deployment of interactive services covering a wide range of scenarios (mobile TV, radio, etc.), devices, services and technologies (PSS, MBMS, DVB-H etc.). These platforms must consider aspects, such as:

- Enriching principal content (e.g., TV or radio) with auxiliary (e.g., interactive) content
- Rich Media capacities and interactive content production and adaptation
- Relations and synchronisation between principal content and auxiliary content
- Distributing and delivering interactive content on several devices
- Defining new and innovative interaction modalities including collaboration (e.g., user contribution and communities)
- Interfaces with operator infrastructures, content providers and with other agents in the value chain
- Standardisation (3GPP, DVB, OMA, MPEG)
- Location-based interactive services

Coming back to the fundamental user research questions, advanced technical solutions should be justified by users' needs and requirements in order to guarantee success. The fundamental questions that need to be investigated are:

- How to ensure and improve the acceptability of services? How to define "User experience" and what is the bench mark for assessing it? How to take into account the ageing population and their needs? How to address the needs of business users? How to involve the public sector?

- How to develop software production processes to fully take user requirements into account at an early stage? How to improve user-centred research methods to better answer the new research challenges – together with business people and software designers? How to find out and improve the measurability of the user-centred research results?
- How to enable natural human-system interaction, for access to services and use the devices?
- What are the users' preferences and requirements regarding future multimedia communication services – what is the influence of aspects like basic media quality, richness and accompanying information on perceived service quality for different contexts?
- How to provide in distributed and heterogeneous environments with many functional and business relationships a defined and adequate service quality to the end-users or the enterprise customers?

This whole research setting calls for strong participation and involvement of human sciences research community, where one collects and analyses needs and requirements from actual users and iteratively validates results.

3.2 Towards an Individual-centric Network Experience

User experience is used in the context of human-to-system interactions as a way to measure the user satisfaction when using a system and its services, in terms of expectation, performance, transparency or ergonomics. However, research on user experience is required beyond the pure interaction design. Roles are evolving. The relation between network and individuals is not unidirectional anymore. The concept of user is not exclusively associated to human beings. Individuals are becoming not only passive consumers of services but active service providers for other humans or for the network itself. The interaction between an individual and the surrounding ICT environment is a key factor for the acceptance, adoption and experience of ubiquitous services of any kind. They will depend on the individual characteristics and role, the interaction device(s) and the system capacity to predict needs, to learn and to perform tasks in the optimum, trusted way.

Besides other considerations that are explained next, the roles of future communication network entities will evolve and so will the terminology to name them. The terminology used in this paper considers these new roles and renames some of these entities according to their new functionalities:

- The “networks” concept as a bunch of separated networks becomes a seamless “Network” consisting of heterogeneous networks cooperating.
- The users concept to designate human beings requesting services from networks, evolves to a more complex entity, that encompasses from a single human being to communities not only consuming, but also providing services. The term “Individuals” or “Individual” for one entity is used in this paper considering this beyond-user new role of humans.
- The end-terminals to designate the devices carried by human beings to enjoy services from the networks, become Communication Devices (CDs) that can operate not only at the end of the communication chain (as means of any user/provider relation between Network and Individuals), but also in the middle as Network resources.

Unlike the traditional unidirectional approach where networks serve humans through their terminal devices, future communication networks approach envisages a bidirectional relation between the three actors in a communication loop (Figure 3-1 bottom diagram): Network, Individual and CDs. The traditional communication chain (Figure 3-1 top diagram) is inflexible and not optimized, whereas the future approach, is a communication loop rather than a chain, with interaction and feedback between all the actors, continuously optimizing the performance of the Network and consequently the services to Individuals and so forth.

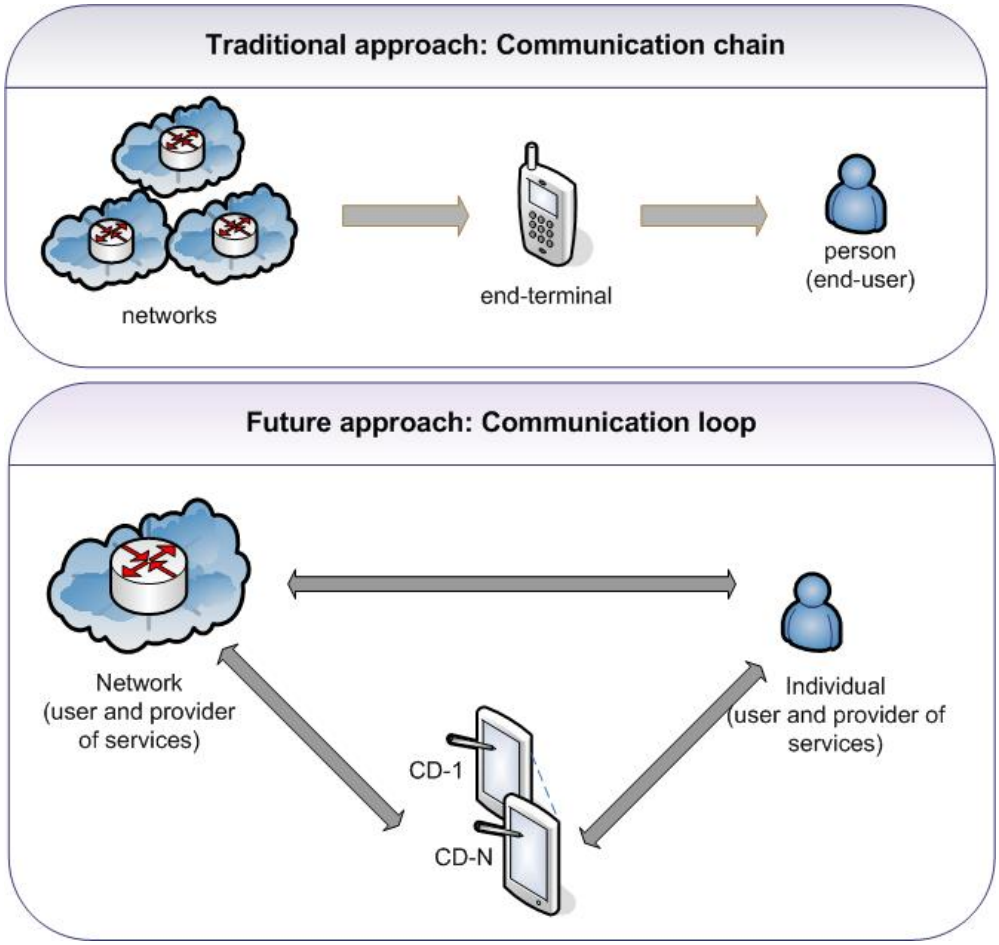

Figure 3-1. Evolution of the communication network concept

Both Network and Individual are users and providers of services, and the CDs serve as bridge between both entities. Figure 3-1 depicts these relations at the bottom side, where a Individual is associated to many CDs and through them in contact to the Network, or even connected directly, emulating the ability of the Network to communicate/recognize a Individual without a strict bond to a specific CD (all the relations are bidirectional). Nevertheless, in future ICT, Individuals become even more than users or service providers for the Network. Future technologies will let Individuals express their creativity through the creation of contents and services for other people.

The following sections go in depth into the relationship among these three actors (Network, Individuals and CDs) in future communication networks, to highlight what it is expected and to point out the challenges and research priorities.

3.2.1 Network experience

Future communication networks will be heterogeneous in terms of technologies, operators, communication models and new stakeholders that will come up, all of them working together in harmony in such a way that the whole picture becomes a seamless Network.

So far, networks have been tools to offer services to human beings. As mere resources, networks are deployed to cope with their requirements in order to serve them adequately. Due to the increasing variety of services available and to the expansion of networks to areas such as households, entertainment locations, as well as remote areas, communication networks have to cope with increasing complexity in aspects such as traffic management (over-provisioning…) and communication model management (different technologies from different operators). Thus, their performance is managed following an uncontrolled and non-optimized procedure. The role of the Network as user of services/information provided by Individuals is a new trend. Such a role relies on the fact that Individuals are not only passive consumers but also active improving both the performance of the Network (service to the Network) and even improving the services oriented to them (service loop).

Within such a context, this Section is about Network experience, i.e. how the Network can profit from information of Individuals and their surroundings as a mean to optimize Network services. The aim is not to describe services but to set the procedure to improve them, whatever they are or will be.

The new trend concerning Network experience relates to Individuals behaviour, especially in those types of architectures where Individuals are not just being served by the Network, but they become active part in Network service providing and even becoming part of the physical resources of the Network. This is the paradigm of infrastructure-less networks such as user-provided networks, MANETs (Mobile Ad-hoc NETworks) or VANETs (Vehicular Ad-hoc NETworks). Individuals as potential mobile entities have a clear impact on the Network performance, so characterizing and even modelling their behaviour is of paramount importance for the Network.

But even beyond the behaviour of Individuals, indirectly they can serve very valuable information to the Network, not about themselves but about the environment in which they move through the CDs they carry. It consists in generalizing the Context-aware concept, i.e. besides CDs being aware of the environmental context where they are located, the Network should be able to sense the environment where Individuals are roaming, and then extract information concerning the communication link or any other interesting information of the surroundings. This information, together with Individuals behaviour, and other potentially interesting information, can lead to the possibility of the Network to foresee the channel behaviour of Individuals, hence, optimising the use of resources. For the sake of simplicity, any information coming from Individuals, either about them or their surroundings is regarded as Individuals information along the article.

3.2.1.1 Challenges and research priorities

No matter the type of information required by the Network, the whole process of Individuals to improve Network experience can be summarized in five steps: collection, storage, processing, use of information and trust management.

Collection of Individuals information

Profiling consists of a first stage of collecting Individuals information everywhere and anytime. This collection of data and their nature are highly dependent on the type of CDs that Individuals use and the interests of the Network. Tracking information stands out as key information in profiling to serve better and more efficiently. The Network requires a constant tracking process, whose main challenges fall on CDs and the way they interact with Individuals in terms of heterogeneity of wireless technologies and even coexistence of communication technologies with pure location technologies such as GPS.

Example: if location information is required, the information retrieved could be from geographical coordinates if the CD has a GPS receiver, to proximity data if the CDs don't have GPS receiver or they are indoors (the type of information reported in this case could be "CD x connected to Base Station y"). Other types of interesting information could be physical activity with a Body Area Network (BAN), communication activity (when the Individual uses the Network), type of services used and so on.

Any potentially interesting information for the Network is collected, either by the Network directly or by the CDs at a first stage, that later will provide this information to the Network.

Research priorities

- Develop techniques based on collecting interesting information from Individuals when the Network requires it, and transparently for them. Depending on the type of information required, the type of technology and even CDs, the techniques required are different: from centralized ones, where the Network is responsible of collecting data, to fully decentralized, where the CDs are responsible of getting this information and even store it temporally.
- The CD concept will expand to comprise many nodes interacting with a Individual (Body Area Networks (BAN) or surrounding Wireless Sensor Networks (WSN) for instance). It is necessary to develop procedures of collection of data when these data come from many nodes, data aggregation, redundancy techniques and real time data retrieval.
- Develop tracking techniques able to deal with very different technologies and approaches (from techniques based on power strength, to time delay or angle of arrival, indoors and

outdoors and so on). Consider location multi-technology approaches, i.e. location techniques where more than one technology (CDs are expected to be multi-technology in the future) work together to get the location of individuals.

Storage of Individuals information

The Network collects Individuals data continuously. This huge quantity of data has to be stored somewhere. The storage can be local and temporal in CDs or directly in the Network.

Research priorities

- Develop a new Network architecture that comprises a Individuals Data Storage Entity (IDSE) as a container of information coming from Individuals roaming different technologies. Such architecture should be agnostic to operator as well as technology or CD in use.
- Analyze different implementations of the IDSE depending on whether the IDSE is centralized or distributed, the expiration time of the information, the type of information, the type of technology and so on.
- Providers are fond of keeping any information of their networks confidential. It is necessary to work on a procedure that would assure their privacy but at the same time would let them inter-work fluently to become a whole Network at least in the sense that they share information of Individuals when they roam their particular networks.
- Come up with techniques to classify the collected information based on what it is about, whose, when it is obtained and from where.

Processing of Individuals information

The type of information coming from Individuals is different depending on the technology used to collect it and even can be duplicated if a Individual is connected to more than one technology at a time. Example: A Individual carrying a CD with GPS receiver and UMTS or WiMAX will collect simultaneously both geographical coordinates and proximity data (CD x connected to Base Station y).

Two processing stages: one for preparing information of the same Individuals coming from different technologies and formats and another one depending on the usage desired for this information. The latter depends on the service or application that will use this information.

Research priorities

Develop processing techniques able to deal with huge quantity of data coming from many Individuals in different formats. The processing can be distributed or centralized but at the end,

information coming from the same Individuals should converge. It is very important to develop data aggregation and mining techniques able to deal with a lot of redundant data in order to speed up the process as much as possible.

Use of Individuals information

The processed information becomes Individuals profiles with their history. This information is very useful for many services, some of them oriented to Individuals but some others targeted at improving Network performance. Whereas the former depends on the nature of the service, the latter consists mainly in foreseeing future events based on Individuals previous history, and rearrange Network resources based on those expectations with a final goal: Network optimization instead of the current over-provisioning trend.

Research priorities

- Develop a procedure to use Individuals data, in such a way that any upper service needing information of Individuals can request it from an Individuals database. Requests will come from heterogeneous networks (as part of the whole Network) and providers. Privacy is a key aspect in this procedure.
- Develop a Network management procedure to optimize Network performance based on Individuals expected behaviour. It can be considered a decision-making process. Two possibilities:
    - On-the-fly: make online decisions according to the information obtained at that time.
    - Offline: make decisions based on longitudinal patterns (friendship, geographical, time, use of the Network, etc.).

Trust Management

Current communication models embody a well-defined splitting between networks and end-terminals, as well as users. For the specific Individual-centric approach, CDs can be considered part of the Network. Consequently, Individuals misbehaviour will be tragic to both Network and Individuals experience. Trust management is highly dependent upon mechanisms capable of quickly developing a network of trust. This is a hard task to achieve, particularly given the nomadic lifestyle of Individuals and the difficulty in providing detailed accountability.

Research priorities

- Develop mechanisms based upon human behaviour that can automatically aid in building networks of trust. Such mechanisms must be de-centralized and able to cope with a dynamic Network growth (given that CDs are not static entities). Starting points may be

grass-roots trust models and/or Web of Trust (WOT) schemes, given that they offer the means to rely upon widespread cryptography tools (such as Pretty Good Privacy (PGP)) to develop networks of trust.

- Consider Individuals beliefs (information) but also surrounding context and the level of confidentiality that the Individual expects on a specific moment and for specific applications. In addition, systems that aim to fight back selfishness of peers (fight back the tragedy of the commons) have to be considered.
- Reputation mechanisms should be considered to monitor past actions of Individuals towards the Network.

3.2.2 Individuals experience

Individuals are the cornerstone of ICT. Everything is set up to serve them. Their characteristics and necessities are the benchmark for the evolution of future communication networks. Individuals habits, trends, competences, levels of acceptance change over time, what requires any process based on them to be also very dynamic. Such a changing nature requires a very detailed and fitted analysis of Individuals behaviour and a procedure to extrapolate these features in terms of technology requirements. Individuals experience and satisfaction will make a technology or service success or fail. Therefore, to understand their requirements and preferences is critic. Individuals are heterogeneous, from different cultures, religions, age, groups and so on, but their social nature makes them associate. Despite this tendency to socialize, a human being becomes first at all a unique entity in the world, with his very specific characteristics (not only physical), that requires a personalized treatment and understanding.

New technologies should leave open the possibility to express humankind creativity, innovating their own ways to use technology, create and share usage practices. It should go beyond just offering solutions. Individuals should be allowed to make their own decisions on how and to which purposes they are using ICT, i.e. reduce the current limitations as much as possible. Individuals should enjoy services without being bounded to a specific network technology, provider or CD.

Challenges and research priorities

Toward a Individual-centric Network

The possibility to use any CD to enjoy services, irrespective of where, when and whose is the CD, is undoubtedly a desirable aspect that will improve Individuals experience. In order to have this flexibility, the Network should be able to recognize and address Individuals by their true identities, no matter the CDs used to connect to the Network. Individuals comply with the basic requirement of addressing, i.e. uniqueness, since there are not two similar Individuals in the world, so the

problem is reduced just to a matter of recognizing them. This implies challenges mainly at recognizing and addressing aspects.

Example: an Individual whose mobile phone runs out of battery could use someone else's mobile phone to run their calls with no charge for the owner (even she could temporarily "rent" one if hers is broken, forgotten or not available during some time). The Network would recognize her voice no matter the mobile phone she is using and automatically adapt the phone to her profile (rate plan, agenda, and so on) and would charge the call to her account according to her special rate plan. This information is part of her profile already stored (and continuously updating) in the Network.

Research priorities

- Develop techniques to set up Individuals profiles that let them be distinguished as the unique entities they really are. Two possible ways:
    - Profiling based on their previous history in the network: where and when they usually are, with whom, services they usually use and so on. Key: behaviour patterns.
    - Detection based on unique characteristics of Individuals: fingerprints, eye, DNA, voice, etc.
- Develop addressing techniques specially oriented to address Individuals. This procedures will cope with:
    - Mobility: no matter where the Individual is, he is the same entity, and so the Network recognizes him.
    - Network heterogeneity: no matter the type of network in which the Individual is, the network recognizes him.
    - Device heterogeneity: no matter the type of CDs the Individual uses, even someone else's CDs, the Individual is recognized as him.

Individuals as service providers for other Individuals

Individual experience of services includes both utility and usability of the service, as well as the service characteristics that give the individuals pleasure. Pleasure can arise, for example, from social interactions, Individual creativity (e.g. Individual-generated content such as the Web 2.0 paradigm, and interacting with dynamic media contents that Individuals in the Individual community have created. Service usage on different Individual interface platforms need to be designed carefully to offer seamless task flow between Individuals devices.

In addition to the role of provider of services towards the Network, Individuals are becoming providers of services towards other Individuals. An essential element of successful service Individual experience is an Individual-centric design and the related approach of Individual innovation. In this approach, Individuals can contribute to service creation actively and thus will make the service serve their everyday needs. To facilitate this approach, quite a few issues have to be researched.

Research priorities

- Develop a technology-agnostic approach, a guide about how to specify and describe services.
- Develop a procedure about how to enable Individuals to do service creation. Harmonize service creation approaches.
- For each developed service or interrelated set of services, apply Individual-centric design methods to define Individual experience elements, such as means for social interaction, interaction methods with the dynamic media contents, and utilisation of contextual metadata as part of interaction with the mobile services.
- Create guidelines for service developers to take into account the Individual experience design factors for different CDs and in the different phases of usage life cycle. In specific, ease of installing the service is crucial for Individual acceptance and in the active usage phase, means for dynamic content creation for the Individual community should be offered.
- Develop means for active Individual innovation, for example through “living labs” type of set-ups or tools that allow Individuals to participate in service development on line. This will support also the agile development life cycle of services.

Privacy

The future Network will require Individuals profile information even more than they do today. A transparent policy in terms of personal data use is necessary for Individuals to agree on this upcoming technology trends.

Research priorities

- Come up with new legislation fitted to new technologies and their requirements of personal data use. Ethical assessment is necessary insofar as new technologies are developed. This is crucial to make Individuals feel safe.
- Anonymization: Come up with evolved techniques of anonymization of identities since every Individual will be identified originally by his real identity, irrespective of where he is or the technology of connection.

- Come up with technical concepts on how Individuals information is traced and stored in the Network. They would be designed in such a transparent way that Individuals do not have to fear potential misuse by Network providers or 3rd parties.
- Information campaigns oriented to Individuals, stressing the necessity of this information in order to serve them better and the use of this information according to the techniques stated above.

Simplicity and easy-to-use

A reason to make services unsuccessful is the complexity to enjoy them, no matter if the complexity is intrinsic to the service or the technology. Future technologies expect to be more complex but they will be designed to spare Individuals the onerous process of learning the tricks of every new service and technology.

Research priorities

- Develop techniques of auto-configuration depending on circumstances and Individuals profiles and requirements.
- Develop a procedure where no matter the requested service the way of proceeding of Individuals would be similar. For instance, Individuals requesting services through oral explanation and the Network would realize what services are being requested.

Transparency

Whatever the processes running on the Network, Individuals have to be oblivious of them. The Network exists to get Individuals requested services done, but the way they are accomplished is crucial too. Individuals being aware of tricky technology issues can end up rejecting ICT. Just like simplicity, transparency aims at isolating Individuals of the complexity of the network. Transparency reflects in the following aspects:

- Individuals aware only on the user-part of the services they require.
- Individuals completely oblivious of the background network processes that can be required either for the sake of the requested services or for Network management aspects.

Research priorities

- Devise transparent data extraction techniques. Individuals should be oblivious of the procedure of data collection. This doesn't mean to collect information of Individuals without their consent, but to get this previously agreed information transparently.

- Develop techniques to shield Individuals from Network processes. Complex aspects of networking such as mobility and its impact on services, heterogeneity of CDs and networks need to be redesigned with one goal: seamless services.

3.2.3 Communication Devices

CDs are of paramount importance in communication networks. So far the link between networks and the user enjoying services has been a terminal device (Figure 3-1 top diagram). Services flow from the networks to the user through the terminal device and the relation between them is univocal, i.e. a terminal device identifies a user in such a way that addressing the terminal device means reaching the user. So, terminal devices assume not only the role of bridges between networks and users but to some extend supplant their real identities. Some applications need no personalization at all, but especially those that require billing (mobile telephony for instance) establish a strict bond between the terminal device and the user. Is that link necessary? Is it limiting? For the time being, this univocal association is necessary mainly for security reasons, but at the same time is very limiting because in order to enjoy many services the only way to access to networks is through the corresponding terminal device previously assigned to the user.

The future Network (Figure 3-1 bottom diagram) will consider CDs as mere bridges between the Network and Individuals, relying on the reliability of new technologies to identify Individuals no matter the CD used to access to the Network. Unlike current networks, the future Network will be completely Individual-centric in the sense that any interaction between the Network and Individuals is addressed to the real human entities they are in the world, not to the CDs they can be using (it relies on the principle of uniqueness of humankind). Such an Individual-centric approach makes CDs very attractive in the sense that any CD is suitable to serve anyone. In this sense, Context-aware and Individual-aware functionalities in CDs stand out as crucial aspects for the sake of flexibility and adaptability to different situations.

In addition to the capacities to capture outside information, CDs, as mere presenter of services have to fulfil other requirements in order to improve Individuals experience, such as simplicity, intuitiveness, easy-to-use, ergonomics, and so on. Seamless connectivity implies both smooth roaming with networks of the same nature and at the same time, the capability to interact with heterogeneous networks what requires multiple communication technologies coexisting in the same CD.

Challenges and research priorities

CDs based on Individuals experience

Individuals acceptance of services is critical for their success, and the acceptance is a matter of both the content and also the container and the way it is presented, i.e. the CD. Such devices should consider aspects related to appearance, ergonomics, easy-to-use and simplicity (Zero-configuration concept).

3.2.3.1.1.1 Research priorities

- Analyze the trends of Individuals preferences of CDs in terms of ergonomics, use, and appearance, in the future.
- Enhance current CDs interfaces (displays, etc.) and devise new interaction interfaces according to the new trends and new technologies.
- Research on technologies and CDs toward the Zero-configuration goal, i.e. the situation where Individuals do not need any interaction with the CDs in terms of configuration.
- Development of new revolutionary materials and concepts in the design of CDs to cope with the dynamics and preferences of Individuals: flexible and malleable materials, multi shape CDs, distributed/ubiquitous CDs, etc.

Multi-technology CDs

The Network will consist of heterogeneous networks working together for the sake of quality of services. This heterogeneity is also extensible to the CDs that will implement multiple technologies to access to different networks.

Research priorities

- Develop more advanced techniques to comprise multi wireless technologies in the same CD. Analyze and evolve possible approaches such as Software Defined Radio (SDR).
- Develop decision-making strategies at CDs to use one or another technology based on the available networks, the services requested and specific cost functions. Cognitive radio research field is also applicable to this trend to fit CD radio characteristics to specific environments.

Pervasive computing: towards the invisible CD. Total transparency

The concept of a CD as a compact device expands to comprise many distributed tiny devices. The concept of WSN will completely emerge as not only collector of Individuals information but also providing new and amazing sensations. The paradigm of distributed CD would be the invisible CD, where a fully distributed and ubiquitous CD focused on the Individual and/or all over him or even his surroundings, complies with the necessary functionalities to provide services without being detected by the Individual. The Individual-centric communication Network paradigm

will be achieved: communication between Network and Individuals without CDs (this is obviously not true since the CD will be spread, but this is how Individuals would sense it).

Research priorities

Open a new research field in ubiquitous CDs that would at least comprise the following interesting areas to investigate:

- Scalability of distributed CDs. The CD consists of many spread tiny nodes working together. The number of nodes can be variable depending on the situation and scenario, but the system should be able to deal with a huge quantity of nodes without degrading its performance.
- Node discovery mechanisms.
- Addressing and routing mechanisms that are based on functionalities (for instance "connect to the nearest temperature sensor").
- Build applications that may automatically discover and connect nodes (sensors…) that fit the requirements of a given context.
- Develop efficient data mining techniques to be applied to WSN.
- Environment-matching techniques, to hide the tiny nodes comprising the distributed CDs.
- New materials and techniques to develop wireless sensors taking into account aspects such as durability, size, weight, and other features to boost the deployment of such a concept.
- Networking aspects due to the necessity to make a bunch of very constrained devices work together.

CDs, Context-awareness and Individual-awareness

Context-aware applications are fundamental for future mobile applications and systems to provide rich and consistent experiences for the Network and Individuals. The CDs are the devices in contact with the environment and in charge of extracting the required information.

Individual-awareness stands out as a revolutionary concept in future networks. The ability to address Individuals by themselves no matter the CDs or location opens up a vast new field of possibilities. The CDs are the devices carried by Individuals or surrounding them (invisible CD) in charge of extracting Individuals required information, such as their identity, location and so on.

Research priorities

This issue includes the invisible CD topic and beyond, so in addition to the networking challenges and research trends aforementioned, these are the main challenges and research priorities of this issue:

- Develop new ubiquitous technologies able to extract information from the environment in a transparent way.
- Progress in quick and reliable interaction techniques between CDs and technologies to extract Individuals information. An example could be a BAN in the Individual clothes communicating with a Central CD (a mobile phone for instance) with higher processing capacity to process the information retrieved from the BAN.
- Develop new addressing techniques that relate Individuals with the CDs they are using at a specific time. Individuals identity is always the same so the identifiers of the CDs used by the Individuals (his or someone else's) should consider it.

3.3 Smart User Interfaces and Interactions

3.3.1 Rationale and Objectives

The user acceptance of services and systems is critical for their success. There, the user interfaces (UI) and interactions play a major role, since they are often the only part that the user sees – they are the display window for all future communication systems. The expectations are not modest: the user interfaces should be simple, self-explanatory, easy-to-use, multi-modal, intelligent, context-aware, situation-aware and adaptive.

In multi-modal UIs, interaction modalities depend on the context in which the device is used. Interplay between contextual and interaction modality is critical to facilitate seamless use of the device. Smart UI technologies for mobile will open up great opportunities to meet the needs of the mobile user on personal basis in terms of simplicity and intuitiveness of use and based on one's own preferences and interests profile. Also, virtual and augmented reality with future displays and input-output-devices enable whole new opportunities for user interfaces and more comprehensive interaction.

From the enabling-technologies side, context-aware applications are fundamental for future mobile applications and systems to provide rich and consistent user experiences. This requires also interfaces with learning capabilities and adaptation (content, interaction modality, user interface) based on the context and situation. The research and development challenge is to create a flexible context-modelling framework with efficient means of presenting, maintaining, sharing, protecting, reasoning, and querying device, user and network context information.

In this new environment, we will have multiple devices with differing capabilities that can automatically establish their local communication, and provide the user with multi-modal interaction with multiple services. Users will also need to access their services via an increasingly heterogeneous communications infrastructure, either via fixed communication links, but in

particular via wireless communication links. Automatic, multi-modal, and simultaneous access to multiple services is expected to enhance the user experience and also minimise the user's effort needed to arrange the communication and allow the user to focus their attention on essentials. In the same way, contents (typically multimedia) will be accessed from different channels and devices, and the user experience will be enhanced if these contents have the ability to adapt to device and context limitations, in a transparent way. However, the multi-dimensional heterogeneous usage environment poses several important challenges with respect to zero-configuration and hiding complexity from the user. Machine-to-machine communication and sensor networking technologies and RFIDs are also required to enhance the future user experience. When devices can communicate in an invisible, secure and trusted manner to simplify and make life more convenient for the user, they can significantly contribute and add value to life.

The borderline between the technologies that deal with interaction with the user and the underlying enabling technologies is not a clear one. In order to meet the multiple challenges, the user interface and interaction technologies research and development have to be coupled with the underlying technologies and platforms. The user-driven approach needed in designing new user interaction solutions poses new demands for the whole software and systems design and engineering process – co-design and collaboration is needed in a multidisciplinary fashion.

3.3.2 Research Priorities

Key challenges in user interfaces and interaction are to be able to design simple and natural multi-modal user interfaces (voice command, text to speech, gesture recognition) with enough features for different users in different situations. The interaction mechanisms should make use of all senses and modalities in communicating with the user – speech recognition as a starting point. In particular, 3GPP and ETSI have developed an intense standardisation activity for the promotion of speech-enabled services over the last years whose benefits must be reaped in the near future.

The systems and user interfaces described above should be able to adapt to the expertise and capabilities of the user, as well as to the context and situation of the user (exploiting all kinds of sensor information). In general, this requires systems and interfaces with learning capabilities and adaptation (content, interaction modality, user interface) based on the context and situation. Specific important aspects within this context-awareness and adaptivity challenge are privacy and security; i.e., ensuring that persons' data do not end up in wrong hands.

Devices and services with autoconfigurable and interworking interfaces complement the list of main user interfaces and interaction challenges by enabling zero-configuration and hiding complexity in multi-dimensional heterogeneous usage environments.

Enhanced rich-media services are those services which aggregate in a single interface any kind of content (graphics, text, audio, and video) and client server real-time interaction. Rich media technologies will contribute to the creation of improved multimedia services in different contexts as it addresses some key characteristics like interactivity for driving new types of user experiences. Research challenges in this area include:

- Identifying services in which rich media technologies can add value improving the user experience (mainly from the point of view of interactivity)
- Defining and developing rich media value added services
- Contributing to standardisation and optimisation of rich media and enhanced rich media services (with W3C, MPEG and OMA) in those aspects not covered

In summary, multi-modality and context-awareness in user interfaces create fundamental research challenges leading to better user experience. Some major ones are listed below:

- Explore how context-awareness can provide rich and consistent user experiences for future mobile applications and systems
- Define architectures and technologies to provide access to contents, which are transparently adapted to device and context
- Invention of radically simplified mechanisms and technologies for context capturing, sensor communication, context classifications and new efficient and robust user-centric application design processes based on better understanding of usage model of services and devices
- Enhance current user interfaces with learning capabilities and adaptation (content, interaction modality, user interface) based on the context and situation
- Study the interplay between contextual and interaction modality for seamless use of the device irrespective of the access network
- Research new interaction ways and modes together with virtual and augmented reality technologies, future displays and other input-output-devices, and bring new opportunities for user interfaces and more comprehensive interaction
- Enable automatic zero-configuration and complexity management in order to make it easy and simple for users to find and utilise services with minimal effort
- Mechanism for evaluating and ensuring user’s acceptability of UI’s for example speech recognition

3.4 Future Mobile Device Form Factors

3.4.1 Rationale and Objectives

So far, mobile device design has been limited because of materials and communication technology limitations; for example, display devices have suffered limitations in size and resolution, and mobile devices themselves have been mono-block units with certain similar components (display, electronic components inside, etc.) limiting the innovations in design and functionality.

New manufacturing materials and methods – including flexible displays and printable electronics, open new doors not only for innovation but also for new ways of enhancing the user experience. The disappearing computing paradigm may become closer to a normal user, if her devices or their components are, e.g., being integrated into the clothes or other wearable materials without adding to the bulk.

Another dimension driving the form-factors, is the way people use their devices: are they for a single purpose or for multiple purposes? Is there one device for private life and professional use? Should one give more emphasis on small size compared with feature-richness?

3.4.2 Research Priorities

The form-factors research includes:

- How the new devices can help getting the best possible user experience in the future communication systems environment?
- New devices: design and impact of new materials
- Multi-purpose vs. single-purpose devices
- Distributed devices (including sensors and RFIDs)
- Usability and simplicity of the new devices
- Displays

In eMobility, future mobile device form-factors research is strongly connected to ‘User experience and acceptance’ and ‘Smart user interfaces and interactions’ areas. Within the former, one studies more the non-technology-oriented aspects, while in the latter one can cover the more technological interaction and interface possibilities.

4 Trust, Security, Dependability and Privacy

In this section, the concepts security, trust, dependability and privacy are briefly discussed from the point of view of mobile and wireless communications. These abstract concepts set objectives that should be reflected to actual technical STDP solutions to be developed.

4.1 Trust

The concept of trust will become more essential in the near future. Trust is a complex concept that is composed of many different attributes, such as reliability, dependability, honesty, truthfulness, security, competence and timeliness, which may have to be considered depending on the actual environment. It must be noted that trust is directed, highly subjective, context-dependent, dynamic and conditionally transferable. It also depends on history. Trust is usually non-monotonically changed with time, and may be refreshed periodically or may be revoked, and must be able to adapt to the changing conditions of the environment in which the trust decision was made. Trust can no longer be assumed in the emerging and future wireless and mobile communications. There is a need to differentiate between trust and other security-related concepts and understand trust relationships better. **Trust should be obtained, perceived, assessed, measured, ensured and communicated.**

User trust in technology and mobile services includes perceived reliability of the technology and the information and functions provided, reliance on the service in planned usage situations, the user's confidence that (s)he can keep the service under control and that the service will not misuse his/her personal data. The users may have unrealistic expectations that may cause unfounded trust or mistrust. User trust and the actual trustworthiness of the mobile solutions need to be in balance. Usability problems are often related to missing information on the available services and how to deploy them. The user population of mobile devices and services is growing, both in the consumer market and in professional use. User abilities and skills vary, and many users in the developing countries may even be illiterate. This poses increasing challenges for usability and user trust.

We should be able to build **trusted systems**, Trusted Computing Platforms (TCP), trusted devices and the communication itself has to be trustworthy. There is a need for solutions that provide justifiable trust that the system or device will function according to its specification.

4.2 Security

The security of mobile communications has, and will continue to be, a core issue of high practical relevance. Without adequate protection devices, networks, applications, services and personal data, trust and confidence in mobile systems would quickly vanish, as has been the case with so many Internet-based services. With the fourth generation of mobile systems envisaged as resulting in a full merger of traditional mobile systems with VoIP and data services and a full integration with many other Internet-based services, the traditional Internet-based threats will become highly relevant for mobile systems. A seamless transition between heterogeneous networks and services that have so far been kept separate also means that perimeter- and gateway-oriented security paradigms will have to be supported and eventually even be replaced by a new generation of security mechanisms. User-managed and system-controlled security elements will have to work hand in hand. From the application layer down to the physical layer of network infrastructures and from the basic operating system to the applications run on future mobile devices, security will have to be ensured in an end-to-end mode.

4.3 Dependability

Dependability can be defined, e.g., a system property that addresses many attributes such as availability, reliability, safety, confidentiality, integrity and maintainability. As the dimensions of security are confidentiality, integrity and availability, it is a sub-dimension within dependability. In addition, dependability has overlapping objectives with trust and privacy.

The performance and compatibility of protection systems for mobile devices is still defective and perception of the whole environment is important in the design of security solutions. One cannot assume that inputs to mobile devices are well defined, correct and harmless. The **dependability of the software is becoming more and more critical**, as well as its ability to filter out deficient data coming from its environment.

Nowadays the market sets tight time schedule requirements on R&D, in many cases resulting in a low quality of implementation. Poor quality increases the number of vulnerabilities and other dependability problems. Threats include the great number of different software versions, unsatisfactory maintenance of software (e.g. updating anti-virus software and backup of information) and the more risk-prone open programming interface of new mobile operating systems.

4.4 Privacy

Privacy is an inherently important part of the user's trust in mobile services.

Information processing and storage capacity have increased remarkably and will continue to increase in the future. It is possible to collect a lot of personal information from the Internet and other electronic sources. While a single source of information may not be a threat to privacy, combined information from different sources can be. The lifespan of information is vastly different in the ubiquitous environment, and it becomes less controllable as it is recorded and mediated. Thus, it is becoming far easier to automate the collection and processing of information, and the users are interacting with a multitude of other users and entities without always realising that.

Privacy protection should cover storing, collecting, using and transferring personal data. From the service providers' point of view, their customers' privacy is one of the core business assets. A correct and careful response to the privacy requirements is imperative: inadequate privacy solutions will lead to lost opportunities and serious financial implications. However, the providers also have incentives to gather information on their customers' behaviour in order to keep up with the current trends and maximise the cost-efficiency of their offerings. Naturally, the providers still need enough identity information for billing purposes. In addition, the regulators and authorities set their own requirements for the identification of users. The user should be given the possibility to control the usage of their own personal information. One possible approach is the user centric identity management that gives the users the keys to dictate the level of information disclosure. However, the usability issues become critical when the users wish to use the services in an unobtrusive manner and do not want to have to make a privacy decision at every step. User centric identity management can be seen as one of the Privacy Enhancing Technologies (PET) that are providing a research direction for privacy solutions in the ubiquitous environment.

A challenge for privacy in telecommunications will be to find a balance between two often opposite demands, traceability and anonymity. This balance cannot be implemented using technical solutions alone – legislative guidelines and regulation are also needed. Privacy management and enforcement cannot be done without technology, but technology alone cannot solve all the issues.

4.5 Some Threat Trends in Mobile and Wireless Communication

4.5.1 Increased Complexity

Because of the digital convergence, the **complexity and number of interfaces in devices is increasing**, resulting in an increased need for management of the system as a whole. New security threats are introduced when mobile devices become more versatile and more complex. A great number of conventional PC threats already concern mobile devices too. Cross-layer, cross-spectrum and cross-network operation is becoming more and more common. Data services with a connection to networks such as the Internet are especially plentiful. At the same time, the user has more responsibility for his/her device, which could be difficult to follow. The users are likely to have many devices, both single and multipurpose, and there is a lot of device-to-device communication. One should also take into account that not all devices are for personal use only – some are in shared use by a group of people.

One can learn from the history of technological development that architectures and platforms (or at least parts of them) such as communication networks and user devices are often **re-used** for purposes for which they were not originally developed, **causing major security problems** in many cases.

Simple and unambiguous architectural solutions could increase security. In addition, they should be designed to answer the security, trust, dependability and privacy needs of the target use scenarios. A remarkable challenge is that smart phones are being used as platforms for applications and services that cannot be foreseen during the platform design.

4.5.2 Increased Connectivity

The **expanding wireless connectivity** to individual devices and networks, which increases their exposure to attack, is one of the key areas of concern. In dynamic, hybrid or all-wireless network environments, the traditional defensive approach of securing the perimeter is ineffective because it is increasingly difficult to determine the physical and logical boundaries of such networks.

4.5.3 Wirelessness

Wireless networks share common security threats; however, some of them are more pronounced than others. From the service providers' point of view, fraud and theft of services, malware, business image problems and bad publicity relating to information security incidents, and loss of privacy of their customers are the main causes of worry. The end users are concerned with hijacking of connections or capturing of credentials, loss of integrity in the terminal, and eavesdropping. Wireless networks also have other kinds of threats – they are not protected or bound by the natural physical access control in fixed networks. Malicious users and radio

interference are weakly traceable, and tracing them often requires special hardware and surveillance.

4.5.4 User Devices

The physical device itself must be well protected in order to avoid loss of stored data and to ensure that confidential data cannot be accessed even if the device gets into the wrong hands. Mobile device security includes physical protection, platform security, device access control, storage protection and protection of connections. Threats targeted at the user have increased due to the increase in mobile device use and their increased multiformity. For example, the use of mobile devices as tools, as personal information repositories and as a channel to access services is causing mobile users to puzzle over many practices familiar from the Internet world, such as certificates, passwords and configuration settings. Incidents involving spamming, Denial-of-Service, virus attacks, content privacy and other malicious attacks have become a growing problem. Consequently, security needs to be built into the platform instead of dealing with various separate add-on features. **New platform security solutions** for user devices should support device STDP management, reduce the complexity and offer means to manage add-on components and applications from STDP point-of-view.

The impossibility of physically protecting the devices in a wireless network, as well as the still limited processing and storage capacity of battery-driven mobile devices, are challenges for the implementation of STDP solutions. The traditional approach of securing the network perimeter must be replaced by securing the network connectivity, network nodes and network services, since no fixed perimeters exist. New threat models for mobile devices are constantly evolving.

The storage capacity, performance and applications of mobile devices increasingly resemble those in a personal computer environment. Smart phones contain a lot of personal and business-critical information and they easily get lost or stolen. This poses new challenges for trustworthy **data storage and backup**, as well as protection of data if the device gets into the wrong hands. Storage protection of a user device should include online integrity control of all stored program code and data, confidentiality of stored user data and protection against unauthorized tampering of stored content.

In addition, it is very difficult for the user to realise the differences between professional and personal use of the mobile device. The information security needs for these two ways of use are different. In the PC world it has long been common practice to utilise a separate device to protect information meant for professional use.

Some novel technologies and local communication solutions, integrated to user devices, may create special security and privacy threats if not properly integrated to the threat analysis and use scenarios of the device. These technologies include biometrics, Near Field Communication (e.g. RFID) and device-to-device communication solutions. Traditional security solutions are too heavy to be implemented at reasonable cost to the cheap and simple RFID tags. Unprotected RFID tags are seen as a privacy risk. Ignoring these risks can slow down the adoption of the technology from plain industry use to everyday life.

Availability is very poorly addressed by security solutions in devices today. Most devices with security monitoring have a definitive reaction after detection of a problem, such as clearing memory, erasing cryptographic keys, etc. These kind of reactions could be used, e.g., for Denial-of-Service type of attacks. More attention should be paid on availability and survivability of devices, services and applications.

Identity management is a major challenge in current and future devices and networks. For instance, usability of IP addresses depends highly on the application. For instance, the IP end point model is clearly not suitable for sensors or RFID carrying out environmental monitoring.

4.5.5 Network Management, Roaming and Routing

Operator networks are incorporating many features similar to the Internet network. They can be compared with companies' intranets, accepting only desirable traffic. At the same time, operator networks inherit threats from Internet networks. The servers in operator networks are targeted by unsuitable and malicious network traffic, both from the Internet and from the mobile users. It must be noted that in the future, in addition to operators small "mini-operators" can be involved in the business. Non-repudiation will be more important in this kind of dynamical environment. Management of roaming security, e.g., mutual authentication of a user device and the access network is an important challenge. The unpredictable and dynamic topology of mobile networks is not only a source of routing complexity but also a routing security problem. Secure routing starts with route discovery protection and requires a secure routing protocol in the presence of malicious network nodes. In addition, a secure and fault-tolerant data forwarding scheme is needed.

4.5.6 Automated Operations in Applications and Services

Applications and services are using more automation to provide better user experience. Applications may establish automated connections to a variety of information sources from where the desired data will be fetched. This automation can cause surprising costs to the customer when, e.g., the mobile device decides to fetch incoming emails over 3G connection when the user is travelling abroad. Consequently, it is important to validate the target of such automated operations. Context-aware applications can also require connection to external sources for

acquiring context information. The authenticity of the source and the validity of the data should be verified prior its use.

4.6 Research Priorities

In the following, we introduce research topics that we think are important in mitigating the near future threats and answering to the security, trust, dependability and privacy challenges introduced earlier.

4.6.1 Proactive STDP Solutions

Security, trust, dependability and privacy issues should be analysed and built in to the system starting from the very early stages of its development in order to be able to develop proactive architectural, technology selection and system-level solutions.

The Internet has become a crucial element of our economy and society. Its evolution and how it has to respond to future challenges is at the core of continuous global discussions. Today is the correct time to affect the **Future Internet architectural and technological choices** from the point of view of security, trust and dependability in a proactive way.

An important cross-discipline task is to establish a generic, widely accepted and unambiguous trust model that can be implemented in technical architectures and design. The trust model should define the trust relationships and liability issues, and ensure enough security and privacy.

In the current communication architectures, attackers often have many asymmetric advantages over defenders, such as powerful tools and readily available resources. If security is not taken into account in some of the layers of the communication architecture, attackers can easily take advantage of it. The current security, trust and dependability solutions are not multi-level enough. Classical paradigms for security use the multistage or multiple barrier idea. Information and communication technology based systems should follow the same philosophy. It must be noted though, that non-malicious threats will continue to account for the biggest business impacts.

Complementary to the protection provided by the affirmative security mechanisms, **defensive mechanisms and processes are needed** for the detection of and response to certain attacks and malfunctions. Nowadays there is ongoing provision of protection against malicious agents – such as viruses, worms, Trojan horses – and Denial-of-Service (DoS) attacks. Most malicious agents are dependent on inadequacies in widely used components. In addition, defensive measures are required to detect and counter intrusion and disruption attempts and other emerging threats, as well as unforeseen and unauthorised by-products of otherwise legitimate

functionality. The design of the protection of the system's operation and services must also include attack-resistance and fault-tolerance.

4.6.2 Usable, Scalable and Built-in Security, Trust, Dependability and Privacy for Mobile Communications

Security, trust, dependability and privacy are clearly system-level problems. Most of the requirements for these characteristics arise from the mobile services that utilise the system-level features. Consequently, one cannot accurately determine the STDP requirements outside the context and environment of the system and use scenarios. Building STDP requirements is often a process of making trade-off decisions between high STDP, high usability and low cost. **The STDP solutions should be as usable as possible**. They should respond to the requirements of future services that may be critical. From the user point of view, STDP solutions need to be easy to understand, easy to take into use and easy to monitor and control. Poor usability may actually turn the solution into a threat as the users either refuse to use the solutions or use them in the wrong way. The current security solutions in telecommunications often suffer from poor usability. A specific problem is that the users do not understand the solutions and often just choose to rely on them.

An important part of the low usability of the current security solutions is that they are not scalable enough. **Scalable and reconfigurable security solutions** are needed to answer the needs of actual use cases. STDP solutions should not be designed as separate services or add-ons. They should be built into the actual architectures and should be addressed from the very first phases of the development. A holistic perspective on the system and STDP design that integrates the set of common and interoperable technological solutions is clearly needed.

Further development of hardware support for cryptographic algorithms and for the key management, required by these algorithms, is needed because of the capacity limitations of mobile devices. The potential of the emerging cryptographic technologies for wireless and mobile networking should be explored and deployed. The current algorithms are robust (from the point of view of current needs) and have been thoroughly explored by mathematicians, cryptographers and other computer scientists. Security solutions based on cryptography are therefore attacked with phishing, other social engineering techniques, and through vulnerabilities in the key management. Widely diffused systems, with the user (and the attacker) having physical access to it, cannot be considered as fully secure. The key management can be improved by proactive avoidance of implementation vulnerabilities and by improved key management functions. A number of cryptography research topics are relevant to the entire digital environment. They include fundamentals such as ongoing cryptographic research, including flexible and scalable

low-cost cryptographic protocols and STDP mechanisms for low power devices, the general issues relating to identity and privacy provision and management.

Development of suitable **security policies for wireless and mobile communications** is needed. Security is formalized using “security policies” paradigm. There is a lot of work dedicated to the development of methods and tools to express analyse and prove security policies. However, security policies formalize normal behaviour (protocols, access rights, etc) and do not take into account attacks based on a physical access to the device (side channel attacks, fault generation, modifying the environment). Detection of attacks and effectiveness of security reactions depend only on the competence of the developers. Modelling physical attacks, attack detection capabilities and security reactions, developing integrated tools to express, analyse and prove security policies integrating these features are key elements of the future. Security solutions implementing policies should incorporate sensing and reaction capabilities, evolving from crypto-processor to a security system. Particular challenges are raised by the ubiquitous, pervasive mobile environment: the dynamics, fluidity, and mobility; the polymorphism and heterogeneity; the need for **automatic negotiation and agreement on security policies** and implementation to enable co-operation and collaboration of domains.

The end-user device will have an essential role due to the direct user interaction, the support of application software and the connectivity it will provide to various access networks. The ubiquitous, self-organising and heterogeneous environment brings many new STDP concerns into the picture, and new measures are needed to protect the devices and data stored in them or accessed through them. **Multimodal and context-aware authentication and context-aware authorisation** can be used. There is a need to move up from the current paradigm of authenticating the device in the system into actually authenticating the user. **Secure and trusted application integration mechanisms, as well as trusted execution environments,** are important areas for development. **Protection of security devices** (such as smartcards and dedicated circuits) **has to be improved.** During the last 10 years, there has been permanent and fast evolution of attack methods targeted at them, resulting to a reduction of their life time.

4.6.3 Industrial Strength Methods, Metrics and Tools for Security Assurance, Forensics and Vulnerability Discovery and Management

The increasing complexity of telecommunication and software-intensive products, together with digital convergence, is increasing the need for adequately validated STDP solutions. Different security assurance methods are needed, such as testing, monitoring and evaluation. Testing is not enough in itself, nor is evaluation. Definition of STDP requirements at a suitable level based on threat and vulnerability analysis is a vital stage in security engineering – the requirements guide and control the security assurance activities.

How secure is a software product or a telecommunication connection, or their fusion? And how secure does it need to be in order to be secure enough? Even though appropriate security solutions can be found, their resulting security strength often remains unknown. If appropriate **security, trust and dependability metrics** (or indicators) can offer a quantitative and close-to-objective basis for security assurance, it would be easier to make business and engineering decisions concerning security, trust and dependability.

The field of defining security metrics systematically is young. The problem behind the immaturity of security metrics is that the current practice of security is still a highly diverse field, and holistic and widely accepted approaches are still missing. If the research community is able to develop intelligent and feasible mechanisms for the measurement and information gathering, we might even learn more about the nature of security, trust and dependability. The current limited knowledge of the nature of security-related concepts is hindering us from finding rigorous solutions to the aspects of overall security. Overall, metrics provide four fundamental benefits – to characterize, to evaluate, to predict and to improve.

Even with the best precaution, there will be misuse of the devices and networks in one form or another. In order to resolve the incidents, forensic analysis is required. Gathering a variety of logs and traces can help the forensics process. On the other hand, they can be a threat to privacy. Live monitoring of systems like intrusion detection and intrusion prevention systems can be used to analyse the attacks while they are happening. As the systems get larger and consist of devices from different manufacturers intended for a variety of purposes, security information and event management systems are required. These systems can combine information from different sources and provide a centralized view of what is going on or what has happened in the system. Such systems should be further developed so that enough information is provided for analysis but at the same time the information should not overwhelm the system analyst.

It must be noted that the **perceived security level** is often more important than the “real one”, justifying a higher level of security.

4.6.4 Special Emphasis on Security, Trust, Dependability and Privacy in the Future Internet Architecture

The basis of the current Internet was developed in a closed environment, and its implementation still assumes a domain of mutual trust. Since then, the Internet has grown remarkably and changed its role. The demands for security, trust and dependability are today higher than from the initial environment. Furthermore, **more and more components of societal critical infrastructures depend on global communications like the Internet**. There are security, trust,

dependability and privacy challenges for the Future Internet on many levels: architectural, service, user and various technical levels.

As individuals rely progressively more and more on Internet of Things applications, a new level of trust will emerge in the system. The applications, regularly processing personal data, will have to be (and be perceived as) secure enough to prevent identity theft and disclosure of critical information. In particular, exchange of secure information between different systems has to include new aspects of privacy control. Different schemes for reputations are also needed.

The role of security, trust, dependability and privacy is essential in all parts of the future network architecture. STDP should be integrated into the operation of the terminal, the radio access network, the core network and the service platform and in all relevant layers including hardware, operating systems and protocol stacks. Secure and dependable end-to-end protocols should be developed to meet the changed requirements. The level of STDP offered should be adapted to the needs in terms of user authentication, authorisation, confidentiality, integrity, non-repudiation, privacy, anonymity, global identity management, and content protection. The overall challenge is to maintain seamless, context-aware and transparent end-to-end STDP with an array of different technologies combined in a multitude of combinations in order to provide a flexible and efficient framework for the users to securely and privately enjoy their applications in comfort, while ensuring the trustworthiness of all services.

The STDP solutions in the Future Internet should be **context-aware, scalable and designed for change, evolution and adaptation** to combat unpredicted threats. The user's identity and credentials needs to be protected and there should be better means to protect devices and networks against the malicious intentions of current and future malware. The generation and distribution of information content in the Future Internet should be re-thought with reference to the current philosophy where data is not often distributed in a desirable way.

Secure self-configuration, self-organisation and survivability (self-healing) are important functional requirements in the future network architecture. Dynamic transition and reconfiguration of devices and services set challenges for STDP management.

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5 Ubiquitous Services

5.1 Vision

The potential separation between business related to access provisioning, and business related to services brings about new business models and challenges in ensuring their profitability. The agenda for future services includes creation, adaptation, hosting, provisioning, configuring, and their role in improving the quality of life of the individual(s) who are part of a dynamic and interacting society. In order to realise this, a total of four orthogonal but complementary research challenges are identified as research priorities (RP) and explained in more detail in the rest of this chapter:

- Innovative services (IS): user services that change the quality of life of the individual in a sensor-filled, dynamically changing and interacting environment
- Service Creation process Environment (SCE): realise and ease the creation of services and decreases the time-to-market
- Content and Media Creation (CMC) and adaptation: improve information and content and make available services instantly on various terminals
- Service Execution Environment (SEE): realises the heterogeneous service execution platforms and takes into account the IT and telco convergence, multi-domain operation, network and technology heterogeneity, global roaming and specific requirements for adoption by the industry

The limitations of the service platforms, devices and services of today are main drivers for seeking solutions of tomorrow, working towards convergence of the various network domains, depicted in Figure 5-1.

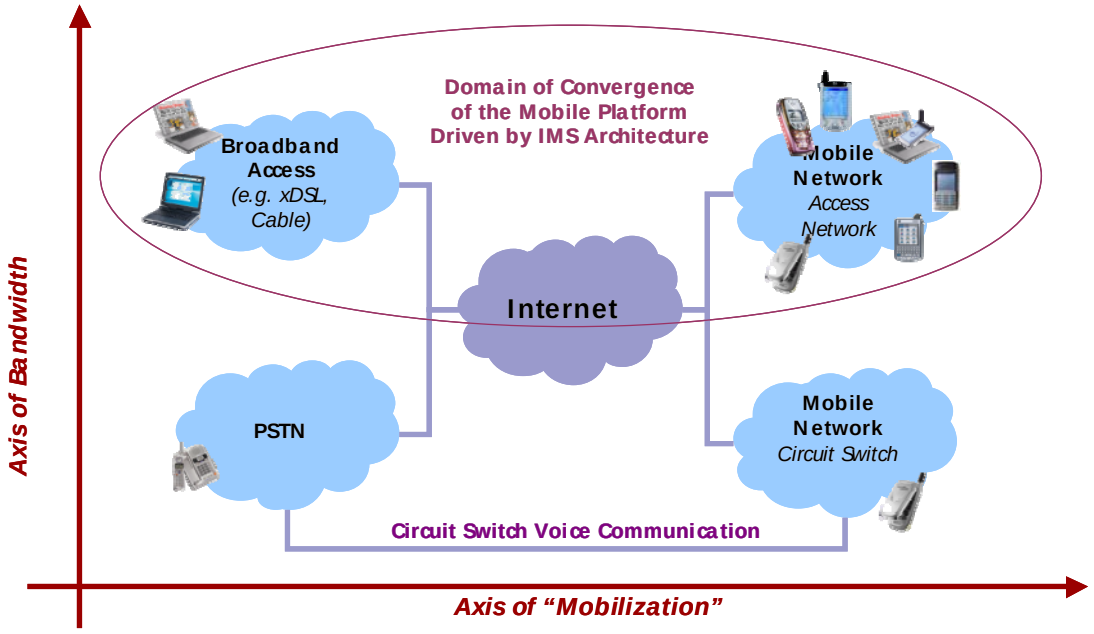


Figure 5-1 Trends in Service Architecture: The Telecom Evolution

The following table (Table 5-1) explains how the Research Priorities (RP) introduced in the following sub-section are contributing to the SET concept.

Research Areas	SET	Contribution to SET concept
IS	S	The research priorities identified in this section will simplify the use of services and the devices enabled by new of type of services that understand the user requirements and capability and adapt to their characteristics (e.g., behaviour, preferences and context) automatically and also hide complexity from them through auto-configuration and software updates of user terminals.
	E	In provision of user services the capabilities of users and their devices should be exploited in determining communication resources needed.
	T	Besides the information security and user's profile privacy it is important to provide a feel of trust to user in using the networks through provision of some level of control over use of their profiles and context.
SCE	S	Provide service creation environment that are more easy to use, even by non technical actors encouraging new players in the market of service and content creations

	E	The service life-cycle should be shortened and time to market shrunk. The RP should provide solutions for automated deployment, client generation over heterogeneous terminals and (semi-)automated service generation. The whole service creation process will gain in efficiency.
	T	Provide a trusted and controlled framework for accessing and sharing of service components by different actors involved in the service creation process.
CMC	S	Better user experience as far as accessing to Content and Media is concerned using context-aware and user-centric content delivery.
	E	Increased efficiency through the use of user terminal capabilities and an optimised use of the available communication modalities.
	T	By delivering the right content, to the right users, at the right time thereby enhancing the feel of trustworthiness and dependability by the users.
SEE	S	The creation of intelligent user-centric services will be facilitated by the availability of intelligent enablers at the SEE and SCE side.
	E	Efficiency in executing services must be provided both at the servers and at the terminals. Also, an efficient service execution environment that provide users with a large set of intelligent mobile services has the potential of largely increasing the efficiency of users in performing their daily tasks.
	T	Service execution environments are responsible of guaranteeing safety, security, privacy, and reliability in accessing and executing the services provided to the users. Their contribution to the trustworthiness of the overall platform is crucial.

Table 5-1 SET and Ubiquitous Services

5.2 User Services

5.2.1 Rationale

The user's communication environment becomes ever richer and is generally composed of various terminals that may vary (e.g., PDA, Laptop, PC, Mobile, embedded computer in vehicles,

communicating objects) dynamically depending on the user's context (e.g., home, work, leisure, vacation, static or roaming). The communication and computation capability of this communication environment is increasing, enabling then the emergence of new brand of innovative mobile services.

5.2.2 Objectives

In order to provide people with the best possible service experience, the set of surrounding pieces of equipment is to be transformed or abstracted into a communication environment that can be easily accessed and used by the technology-agnostic user. To do so, the complexity the terminal capabilities and the heterogeneity of the underlying networks are to be hidden to the user. Assisting the users in such a way they can exploit this inherently complex communication environment without any prior technical training is mandatory to foster the adoption of new equipment, and consequently new services.

Assuming the richness and ubiquity of the communication tools available today, the available bandwidth, and the variety of contexts in which they can be used, a new brand of really innovative services is expected to emerge. Moreover they are expected to answer realistic user's expectations. The new innovative mobile services will have to be intelligent enough to:

- Understand the total situation or context attached to a person (or a group of persons)
- Behave accordingly either reactively – meaning that a context change has been detected and that the service adapts accordingly its behaviour – or pro-actively – the service detecting in advance something the user is not aware of and proposes to adapt its behaviour accordingly
- Anticipate the end-user's goals and intentions
- Optimally exploit the communication capabilities available at the user side for easy of use

This domain of mobile intelligence offers a wide landscape of new possibilities driven both by new mobile equipment capabilities (e.g., sensors, connectivity, multi-media support) and new related usages.

5.2.3 Research Priorities

The research priorities of user services include:

- Personal and mobile gateway automatic configuration mechanisms
- Data management and synchronisation in combination with the growing awareness of context: How to manage the huge amount of user information? How and when to select the most appropriate information according to a given situation? How to handle the underlying complexity before presenting to the user? How to migrate this complexity across different domains and across different terminals and devices? How to fusion different sources of information into a single one?

- How to provide the user at any time and any place with the most appropriate data and service environment?
- Intelligent customer care or how to provide smart support in real-time in case of technical difficulties?
- Improve the service experience understanding and quantifying the quality of experience. This includes understanding the requirements regarding future multimedia communication services in different contexts, possible de-compensation of components to study effects; the influence of aspects such as basic media quality, richness, accompanying information on perceived service quality for different contexts
- New middleware layer supporting the remote execution of services within the communication sphere (exploiting the best of communication modalities, communication channels and execution capabilities available at the terminal side)
- Proposing automated context-aware and semantic-based robots or agents (e.g., mobile reflexes and dynamic services) that provide pro-active or on-demand seamless support in various situations of the daily life
- Proactive services not only taking into account the mobile end-user environment (including the end-user's activity and role) and changes therein, but also able to anticipate predicted (or foreseeable) changes therein. Moreover also anticipating end-user’s intentions and goals
- Multi-modality and augmented reality enabled services that enhance the ways to use mobile services via smart sensors, distributed media restitution and aggregation facilities
- Reasoning capability: while a huge amount of data is available through sensors and devices, and huge amount of information is available, e.g., on the World Wide Web, there is no real flexible way to infer knowledge, i.e., interpreting these data and information according to a given domain (for instance transport or medicine). Research is needed to provide :
    - Large-scale reasoners ready-to-use by mobile application making then benefits of this mass of available information;
    - Light-weight reasoners usable on handhelds ;
    - Combinations of knowledge and data based reasoners;
    - Reasoners capable of handling superfluous, incomplete, ambiguous, vague and uncertain information.
- Managing in an efficient way the huge amount of information either gathered (or pushed) by (to) the user allowing an efficient and accurate aposteriori retrieval of information (knowledge base management, automatic knowledge clustering, contradiction and validity period checking)

Succeeding in this direction is not independent of concerns related to the service architecture. Thus, implicitly new mobile equipment are now not only terminals but mobile gateways as well, with the related issues of capabilities-discovery and automatic configuration. The value brought by the combination of such intelligence along with a diversity of mobile devices may lead to enhanced services and usage for general-purpose end user, as well as, vertical markets (e.g., health, transport, retail, tourism).

5.3 Service Creation Environment

5.3.1 Rationale

While it is foreseen that more and more companies will get involved in the service creation business, it is quite obvious that for profitability concern, the proposed services are going to target the largest audience possible, ignoring then services that are of interest for just a few people. As a matter of fact the service creation power has not been pushed in anyone's hand as the web page creation has already been for a long time. Easy-to-use creation environments (at home or on the move) are therefore needed to enable all users making their own customised services. At the same time, while competition increases, it becomes more and more crucial to decrease drastically the time to market, especially from service creation to service deployment. Then not only the average end-user is concerned with service creation, but the professional is, as well.

5.3.2 Objectives

In contrast to the radio and network technology evolution, with innovation cycles of up to one decade, the design phases and innovation expectations on mobile services are much shorter. Upgrades every few months and major service launches every couple of quarters are commonly expressed expectations already today. Standards in this area are developed iteratively by partner alliances and active involvement of the open-source software developer community. Introducing systems and methods that permit the maintenance of this pace of constant mobile service innovation and rapid time-to-market will lead to a sustainable competitive advantage for the mobile industry. Making novel mobile service creation environments inherently aware of the underlying communication network characteristics and the users' mobile device capabilities will lead to a competitive edge for the European mobile service and network business.

A drastically simplified service creation-, testing- and deployment process, in a merged information technology and telecommunications world, will present one of the biggest challenges required to make the approach pervasive and the vision of ubiquitous intelligence a reality.

In contrast to current information technology style service creation tools and processes, a mobile service creation environment demands, in most cases, on-line test facilities, utilising network resources from different operators and data sources from multiple content providers. Today, no

systems or methods are in place permitting the thousands of software developers, with a background in information technology, to participate in the mobile service creation process. This innovation and business potential is largely untapped, as of yet. The initial efforts made in the 6th Framework Programme need to be substantially expanded during the 7th Framework Programme to rapidly change this situation.

5.3.3 Research Priorities

In order to foster the mobile service creation and deployment business, essential research challenges need to be addressed:

- Research and develop **open mobile service creation and deployment concepts and environments** that do not depend on a specific execution platform that could become unfavourably dominated by a single organisation
- Investigate how the **standardisation processes** can be organised to meet the time-to-market demands of the service innovation life cycles in a competitive environment
- Study the potential of **overlay network technologies** for bridging and inter-operability between different platform solutions from different vendors, as well as, legacy solutions while still permitting independent system evolutions
- Examine how **mobile service creation environments** could be designed to leverage wide-spread **information technology style development tools**, while taking the mobile network specific characteristics and the multitude of mobile terminal capabilities and design factors into account
- Research **mobile service creation methods** that avoid the parallel development of service instances for all types of devices and all types of data transports
- Investigate and prototype **network support functions** that permit the creation of situation-aware services, while still keeping the mobile service logic slim and suitable for mobile devices with their limited processing capabilities
- Explore how **Web Services technologies**, automated code generation tools, XML based data, interface and interaction description languages can be enhanced to permit on-the-fly integration of platform features, services, access networks and devices
- Research **generalised user interface description methods and languages** for fixed and mobile services that permit an automated and on-the-fly generation of mobile device specific clients (like WSDL for service invocations today). This would greatly speed the mobile device and service innovation cycles. Personalised and device-specific user interfaces could be automatically generated once newly designed mobile terminals are introduced into the network and a first service invocation takes place
- Study techniques for **semi-automated composition of services**, based on pre-existing sub-services and network support functions

Assuming that thousands of skilled software developers start creating mobile services for all types of devices and networks, questions such as the following will be asked:

- How can large numbers of developers be provided with online testing facilities in **multi-operator environments?**
- What **business, security and software verification measures** have to be put in place to permit this mass service-creation to emerge?
- How can successfully tested new services be **rapidly deployed** to investigate their usefulness and business potential?
- How can **plug-and-play deployments** of new services be supported from a system design perspective?
- How can mobile service entrepreneurs be supported by automated value-sharing relationships?
- What types of **protection mechanisms** need to be put in place to prevent abuse of a simple and flexible service creation and deployment environment? What new types of business models and relationships could emerge?
- How can such a simplified mobile service creation and deployment environment be used to **gain a knowledge step** for the European society?
- Based on this knowledge step what measures need to be put in place to sustain and further strengthen the competitiveness and the European leadership in the mobility-enabled IS and IT domains?

5.4 Content and Media

5.4.1 Rationale

Improved and extended multimedia communication services (e.g., richer, higher quality, ubiquitous, context-aware and affordable) will be a key driver for eMobility and the future communication infrastructure. Multimedia communication services use digital techniques for capturing, encoding, transporting, storing and rendering information of any form (e.g., voice, sound, image, video, graphics, structured data). They are undergoing a rapid evolution and will create a paradigm shift on how people communicate and exchange and use information. If technology allows, a new level of multimedia communication services will emerge that is richer, of higher quality, ubiquitous, context and access aware while being affordable. This new level of multimedia communication services improves the life of the individual, but it will also improve the efficiency of the European business. Communication will be as good as being there.

5.4.2 Objectives

The objectives are to develop the technologies required to deploy improved and extended Multimedia communication services across Europe. Extensive R&D must be carried out to ensure that:

- The media and service quality is sufficient regardless of context
- The requirements from different communication services, situations or contexts on parameters such as network delay and jitter are understood. Solutions to fulfil these requirements and to predict the quality as experienced by the end-user
- The services are efficient regarding, e.g., network resources, spectrum, battery, regardless of device, context and access network
- The services will work across networks and devices
- The cost involved in launching and using the services is reasonable

5.4.3 Research Priorities

The following research items can be identified as examples:

- **Media formats, media compression**: A continuous development is ongoing in the media compression area for different media (e.g., audio, graphics, still image, speech, video). The required bit-rate is ever decreasing (thereby increasing efficiency) while the quality increases. New dimensions are added (e.g., 3D, multi-channel). A specific challenge is to develop media formats that can be used regardless of access, input and output devices and terminal types while maintaining compression efficiency. These codecs are known as scalable codecs. Such formats would enable the use of one media format for all usages thus removing the need for trans-coding, media conversion and encoding several versions of the same content. The alignment of media formats would overcome the current fragmented situation that hinders fast service take-up over access and device boundaries. It would also reduce the costs involved thereby making services affordable.
- **Media transport**: Defining the appropriate methods and protocols for media transport. This area may include specific aspects like management of congestion situations. Important challenges are group communications, as well as, broadcast over heterogeneous networks and terminals.
- **Media adaptation**: Technology for media adaptation based on terminal capabilities, network and access resources, user preferences, as well as, context should be studied. Media adaptation means both changes within a media (reducing the bit-rate required for a media by, e.g., transcoding) as well as changing media (e.g., video to slide-show, text-to-speech). Basic technology and algorithms, as well as, network architecture should be studied, and should be aligned with the research on new media formats and compression.
- **Terminal front end input**: The development of technology that predicts and enhances the media quality in person-to-person (and group) communication services. Includes ambience suppression (e.g., noise suppression), finding the direction and location of the source and predicting quality of experience based on, e.g., network measurements.

- **Terminal front-end output**: The development of technology that presents the media to the user in the best way includes advanced displays, methods to present 3D sound, graphics, images and video, multi-channel rendering.

5.5 Service Execution Environment

5.5.1 Rationale and Objectives

In terms of innovation for mobile services and service architecture, the objective is to bring it to reality and to take advantage of the progress achieved in parallel in other domains such as radio and networks infrastructure, in order to contribute to a wide adoption of the mobile services, as well as, the fixed ones seamlessly.

To achieve these goals, all the players in the mobile communications field have to make progress in the area of service architecture. The objective is to remove the hurdles which prevent the adoption of mobile services by providing the missing links in addition to the existing standards and components.

5.5.2 Research Priorities in Service Architecture

- Providing a homogeneous and open service execution platform on the terminal side in order to facilitate the deployment, the adaptation, the management and the execution of any mobile services. Today the heterogeneity of software environment such as the operating system on mobile terminals makes this concern very tangible. For instance, a widely adopted open source initiative could bring a very significant improvement to solve the current fragmented situation.
- Overcoming the heterogeneity of mobile and fixed infrastructures at the service level, in order to smoothly educate the market with service architectures that simplify the way to communicate seamlessly in heterogeneous environments. Such a concern is important to manage, in order to move from legacy architectures to new generation ones.
- Providing enabling components that support more intelligent mobile services (e.g., scalable support for semantic publishing and discovery, reasoning, knowledge inferring, learning, profiling, contextual information gathering).
- Proposing a standardised architecture in order to support and facilitate the adoption of a new generation of services by considering the evolution of usage of mobile equipment. For instance, in addition to their standard use, mobile handsets can be used as mobile gateways between sensors, players or others gateways.
- Reconfigurability of IMS nodes, from hardware up to application layers, in order to take into account the different services requirements.

5.6 Mediation Bus for Ubiquitous Services

This section introduces the Mediation Bus (MB) that targets to act as a both long-term revolutionary and short-term evolutionary paradigm for networks and services for new generation communication systems. MB refers to a distributed environment that achieves an optimized operation of Future Internet (FI) by performing mediation operations among the service and network/transport layer entities. In this context, MB enables both service and scenario-oriented end-user treatment by instructing the involved entities to execute the appropriate commands in an efficient and network agnostic way. The section identifies the key features of the mediation bus and the derived research priorities.

5.6.1 Future Internet Services Provision

This section gives an overview of the requirements that are foreseen for the service provision mechanisms in the Future Internet environment.

The service delivery is expected to rely on knowledge. This means that information is based on previous experience (e.g. service provisioning negotiations, training etc) will be taken into account in a dynamic fashion. The embedded cognition will lead to new discovery mechanisms with high degree of personalization, self-configuration and adaptation. Thus, the future service provisioning solutions will be based not only on personal aware communications but on user behaviour models and patterns.

Future Internet services are expected to evolve from mashups, involve and allow the user to become part of the service creation, customization, adaptation and provisioning process thus pushing service and content towards a highly interactive and bi-directional flow. The openness of the underlying infrastructures, the capability to translate and transform user needs into composable services, reusability of service components and modules and service orchestration, intelligent service discovery and the service composition itself are intriguing issues that pose demanding requirements on the Future Internet service provision environment.

Service-Oriented networks will be deployed. A Service Network can be seen as an application level network that leverages a Service Oriented Architecture (SOA) and implement complex but still flexible business models. The Service Network is composed of a number of Service Network Participants and many Service Components. To this end, network clusters will be formatted in order to accommodate specific service offerings. The clustering will be triggered by the service similar characteristics targeting optimal service provision. The clustering may encompass heterogeneous network infrastructures having as common reference target the service provision requirements. In this way overlay and virtual networks targeting the end-to-end delivery of specific services will be accommodated in Future Internet formations of network elements.

The expected service “plurality” will lead to new requirements in both managing and controlling the service provisioning; in this sense, conflicts are expected to emerge due to existing limitations of the current IP networking infrastructure that will need to address the new ways of service provisioning. In this context, the vision is to overcome limitations and allow for management of new levels of complexity. This may need the adoption of a general service framework that will allow the increase of the freedom degree in service composition and provisioning as well as the efficient management of complexity. As a special case, a recognizable party might be needed that will be responsible for overall customer care.

On the other hand, a single user will be utilizing multiple devices with heterogeneous capabilities whilst the ever growing device-to-device communications will require efficient resource management (power, bandwidth, etc). Autonomic mechanisms such as self-organisation, self-adaptation, network self-management, and policy-based management are expected to have large impact on the service provision and the QoS management. A new architectural perspective with self-management capabilities supporting multi-domain and being wireless-friendly (i.e. to be energy and spectral efficient and be capable of supporting a variety of wireless networks, from very low power sensor networks to wide area multi-hop and mobile networks) will emerge. In the same sense, users will expect “joined up” services; a key feature of such a concept is linked to the service continuity that needs to be ensured in a device-independent way.

Concerning the provider’s point of view, Future Internet services will need to have the time-to-market reduced through service automation lifecycle that includes service creation and composition, service deployment, service activation, service adaptation, service fulfillment and assurance and service charging accounting and billing. The aforementioned plurality in services and service provisioning may also need advanced service brokerage and the corresponding service brokers for efficient service orchestration and composition.

Moreover, the Future Internet service provision environment has to cater for personal information collection and processing; extensive user profiling mechanisms may be required and new types of personal data. At the same time, the data collection manner may be also impacted in terms of ensuring the invisibility of collection means as well. Whereas collecting these data is the basis for many new valuable services to the benefit of the end user, he or she will only accept this if there is sufficient trust in the technical solution. Methods to provide Privacy and Trust have to be considered as inherent to the Mediation Bus concept.

Fulfilling the above requirements, a long-term revolutionary and short-term evolutionary paradigm for networks and services environments needs to come at the foreground. This necessity is further stimulated by the following factors:

- The end users profile is dramatically changed and in 2020 is expected that a critical mass of elderly people with different needs and expectations will be active users of Future Internet.
- The uniqueness of end user brings to the foreground diverse demands for Perceived QoS (PQoS), Experienced QoS, and QoS Adaptation (QoSA) that subsequently affects the handling of Network QoS (NQoS).
- A large spectrum of services and applications are going to be released to fulfill end users demands in a totally heterogeneous communication environment in terms of terminals, stake holders, bandwidth constraints, mobility patterns and environmental aspects.

The mediation bus targets to answer at the above challenges by converging network and services in the context of Future Internet.

5.6.2 Mediation Bus Rationale

The mediation bus could be defined as a distributed environment that achieves an optimized operation of Future Internet (FI) by performing mediation operations among the service and network/transport layer entities that are plugged into it enabling both service and scenario-oriented end-user treatment by instructing the involved entities to execute the appropriate commands in an efficient and network agnostic way.

The mediation bus operations concern:

- Translation of policies (rules, constraints and requirements of the optimized operation of FI) and context view (e.g., spectrum, energy status, user profiling, etc.) to executable transport workflows (functionalities) optimizing the usage of both computing and network resources.
- Wrapping functionalities for creation (open APIs) and delivery (adaptation, orchestration and execution enablers) for existing and future Internet services.
- Examples of wrapping functionalities constitute generic services enablers/facilitators for searching, negotiating, reasoning, subscribing, publishing.
- Transition path from current application and transport (TCP/IP) layers deployments to the Future Internet one.
- Vertical control and management functionalities for bus optimum operation (e.g., for green aware performance) and self-organization.

The first key research priority is the identification of the location of the mediation bus in the context of the evolving Future Internet approach. Targeting at the convergence of network and services, the apparent place of mediation bus is between application and transport layer as as in Figure 5-2. A first approach could be to keep unaffected the application layer of the current TCP/IP protocol stack, while to pass some of the existing transport layer functionalities at the mediation bus in a more advanced context.

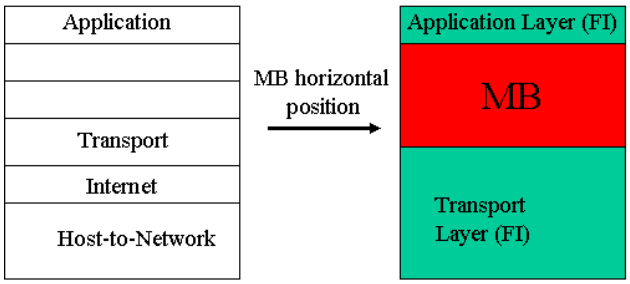


Figure 5-2. Mediation bus between the application and transport layers

The policies actually will constitute the service APIs for the communication of the mediation bus with the application layer, while the workflows will formulate network APIs for the communication of the mediation bus with the transport layer. The combination of this with the necessity for future communication systems to be self-organized entities, clearly explains why the mediation bus is not simply a layer but a vertical environment that handles also control and management operations. The backward compatibility with current TCP/IP protocol stack could be achieved by putting again the mediation bus between the existing application and transport layer. Figure 5-3 illustrates these two layers.

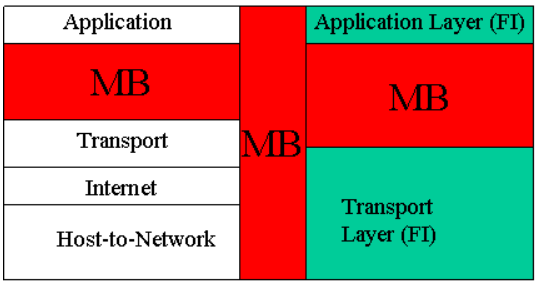


Figure 5-3. Mediation bus as both vertical and horizontal layer between the application and transport layers.

Furthermore, as the adaptation of the mediation bus to both application and transport layers is not going to be something static but it is going to be heavily affected by the service, the end user's context and the underlying network capabilities, the mediation bus could be thinned in some cases.

The launching of the mediation bus is expected to extend the "Walled Garden" network-service architectures including IMS making a full range of valuable network services accessible in an open and network agnostic way to all current and future applications/services.

5.6.3 Research Priorities

The presence of mediation bus draws a number of research priorities for the new generation communication systems. The subsequent subsections outline those research priorities, which actually derived from the features of the mediation bus.

5.6.3.1 Adaptation/context aware

The extremely dynamic nature typical of ubiquitous computing environments, the very heterogeneous and differentiated capabilities of user access terminals, the need of tailoring service provisioning and networking to user location, attributes, and characteristics, are only few examples of the challenging issues still waiting for solutions in the design of ubiquitous services.

Ubiquitous Computing scenarios can hardly be supported by traditional service management approaches, because new requirements introduce challenges that ask for new guidelines and solution strategies. In fact, only new middleware level solutions can autonomously and dynamically perform ubiquitous service management operations tailored to the current context. In a principle perspective, there is a variety of literature in the ubiquitous computing field that define context, but we intend context as the collection of information that can be used to characterise the situation of an entity, where an entity can be a person, a place, or a physical or computational object. According to a support point of view, it is particularly important to make context information available to all interested layers, up to the higher application level, for eventual tailoring and adaptation.

Along this line, the Mediation BUS should provide a rich set of tools to represent and gather context information, to process and aggregate it according to the application requirements and to propagate its visibility to all interested entities. The Mediation BUS should rely on context information for the autonomous configuration and its dynamic reconfiguration of services. As a consequence, the Mediation BUS should also support the description and the enforcing of service management policies, e.g., reconfiguration policies, access control policies, together with any other requested one. In addition, context information visibility should be propagated up to the application level to adapt applications accordingly.

Challenges to be addressed are:

- Structuring and modelling of context information/knowledge and modelling of knowledge (this encompasses community driven ontology management as knowledge modelling should result from a consensus).
- Global context/knowledge frameworks integrating sensor and actuator networks incl. body area networks, smart and virtual objects (dealing with the Internet of Things)
- Context reasoning.
- Human behaviours and subsequent patterns: this encompasses modelling of end-users through observation, learning and generation of behaviour patterns or more global elaboration around human activities, how they relate the one another and how to make use of them for the sake of content/service delivery.
- Frameworks for context-aware multi-modal content adaptation/delivery and related supporting multi-media standards.
- Transcoding techniques (cross modality content delivery).
- Adaptation via service composition: Semantically enhanced and context dependent service composition, e.g. depending on content format preferences and on the quality requirements/resources availability (based on business models for traffic and user priority classes). Also exploitation of workflow-related technologies for automating composition decisions and management.
- Challenges coming from dynamicity: for instance how to deal with client mobility and change of locally available middleware adapters? Or how to deal with nomadic mobility of users dynamically changing their access devices?

And the most important one

- Investigation of MB key context concept as a set of dynamic APIs referring to a pool of underlying network services that could be exploited in an open and network agnostic way by MB towards the creation and the delivery of future Internet services.

5.6.3.2 Both inbound (regeneration) and outbound policies

The Mediation Bus will incorporate Knowledge-enhanced and Policy-based Management features; specifically, according to the perspectives under consideration about outbound and inbound policies, the Mediation Bus in the outbound case can be considered as cooperating with external entities for:

- Policy integration coming from various stakeholders.
- Knowledge building based on decision making and policy integration experience.
- Ontology management for exploiting description logics advances and reasoning capabilities for facilitating policy integration.

Alike, in the inbound alternative, the Mediation Bus will embed advances policy management and knowledge management features. Such features will include:

- Policy Generation according to the involved entities goals, and preferences by conceptualizing the underlying network infrastructure.
- Policy Enhancement regarding additional information coming from outside entities and rapid changing environment.
- Policy Evaluation according to operational feedback regarding the provided QoS and efficient resource management.
- Knowledge building according to decision-making, high and multi-directional personalized policy derivation. Knowledge Management key aspects are also incorporated in every policy related logical function.
- Harmonized Ontology management for efficient conceptualization of the underlying and interacting infrastructure.

Quite a few challenges are resulting from the above listing, regarding the policy integration, the personalized policy derivation and communication, the policy evaluation and the conceptualization of the technical ecosystem in the various service provisioning scenarios. All the mentioned advances features must be provided in an efficient/optimized way. This implies the need for a complete investigation of the various mechanisms and approaches that have been or need to be developed and/or extended to address the abovementioned challenges.

5.6.3.3 Workflows

In order to cope with efficiency in service provision in future internet infrastructures, the heterogeneity of execution triggers and actions in such infrastructures should be alleviated by the Mediation Bus. In this direction, the related operations that can be undertaken by the Mediation Bus will focus on the identification of computational, power, spectrum and other resources available for service provision and execution purposes, along with the correlation of alternative resource usage cases for the accommodation of optimal service provision over such heterogeneous networks and devices. The selection operation of the most efficient combination of resources that can match the optimality criteria for both the service provision requirements and the resource usage alternatives will be an important feature of the Mediation Bus functionality.

From the technological perspective, the corresponding resources that are available through the various infrastructures, networks and devices should be identifiable under a common framework, which will enable the association of such resources with specific service provision requirements and alternative scenarios. It is thus quite important to enable the filtering and correlation between resources characteristics and service provision potentials in order to match these (currently disjoint) service execution perspectives under a self-organised series of actions meeting targeted

efficiency criteria. In this context the service provision related execution actions become part of an abstracted workflow that can be mediated to heterogeneous systems and can be translated in system specific actions. The Mediation Bus can undertake this mediation operation while the system specific actions are hidden from the individual application and service developers, and deployers.

It is obvious that this yields major research challenges that correspond to the identification and abstraction of resources characteristics, the translation of efficiency criteria to optimal selection of deployment and service provision actions in heterogeneous systems and networks, as well as the evaluation and triggering of alternative actions in future internet systems in order to meet the efficiency criteria.

The Mediation Bus will be a major enabler for the identification of alternative available resources (e.g., spectrum, power, computational resources) for the service provision and for the efficient usage of such resources. To this end, some important research priorities can be identified:

- Identification of available alternative and heterogeneous resources under a common framework , targeting optimal service provision.
- Efficient spectrum and resources usage for service provision.

It is thus apparent that it becomes quite challenging to investigate the abstraction technologies for the resources identification, as well as the triggering and translation mechanisms that can be applied by a common mediation framework towards the alternative resources and execution potentials in order to achieve efficient and optimal service provision.

5.6.3.4 Deployment model

An important aspect of the Mediation Bus concerns its deployment, more specifically the entity that undertakes the deployment, control and maintenance. Due to its nature, the Mediation Bus should be neutral; that is, it cannot be managed by a single entity. In fact, the Mediation Bus will constitute a policy decision and enforcement point for both inbound and outbound policies, as well as a broker for personal data that are collected and processed in the context of services' provision. Therefore, a fair number of organizations constituting consortia with high level of neutrality should be considered.

This raises a number of challenges regarding the deployment and the business model of the Mediation Bus. From an operational point of view, of particular interest are the issues of distributing the policies and the personal data for ensuring fair operation and privacy protection. On the other hand, availability and performance issues must be taken into account.

From a business perspective, the possible sustainable horizontal and vertical business models should be investigated, along with the motivation, perspectives and opportunities for participation in the collaborative business of the Mediation Bus operation. In this context, the potential participation of public Authorities, such as Data Protection Authorities, should be considered.
The emergence of the Mediation Bus creates several challenging issues regarding its deployment, management and operation that should be investigated:

- What kind of business models the Mediation Bus creates for the operating entities?
- How the desired level of the system's neutrality can be achieved and how the neutrality affects the business aspects?
- What is the optimal policies and data distribution model for operational integrity and fairness, as well as privacy protection and trustworthiness?
- What can be the potential role of public Authorities in the service chain?

5.6.3.5 Privacy/trust/security

The potential impact of Future Internet Services on users' privacy rights is regarded as being among their most evident negative effects. In fact, the Future Internet Services rely to a great extent to personal information collection and processing: personalization, context-awareness, convergence, federation of services constitute only a part of the emerging services' characteristics that motivate as well as facilitate the collection of personal data.

Privacy is becoming a salient issue not only for individuals or other entities that provide personal data, but also for organizations that constitute personal data consumers. From the service providers' point of view, the recognition of the importance of privacy protection is motivated by the business losses due to privacy violations and mishaps that support users' mistrust, as well as by the need for regulatory compliance, since the privacy domain is increasingly becoming a legislated area. Additionally, the emergence of Service Oriented Architectures (SOA) and federated services creates chains of trust and responsibility which complicate the enforcement of fair business practices with respect to personal data handling.

In that respect, the Service Mediation Bus will constitute a personal data avenue, facilitating the collection and circulation of personal data and –therefore– a critical component in the service provision chain from a privacy protection perspective. As a result, not only the Mediation Bus should be a privacy-aware component, but it should be additionally considered to constitute an enabler for the privacy-awareness of the considered services, that is, a "trust broker".
Mediating natively between users and service providers as well as between service providers in the context of federated services, the Service Mediation Bus can be considered for undertaking

the enforcement of privacy-aware access control regarding the diffusion of personal data. In that respect, the appropriate policies should be integrated with the overall policy-based management framework of the bus, taking additionally into account the potential privacy preferences specified by the users. The enforcement of access control should be supported by comprehensive models describing the different types of services, personal data, preferences, regulations, actors' roles and any other information that could constitute "privacy context".

Additionally, the service Mediation Bus can cater for the execution of privacy-related operations, the origin of which can be twofold. On the one hand, there are certain behavioural norms specified by the European data protection legislation, such as the request for the explicit consent of a user before disclosing or processing personal information. On the other hand, the Mediation Bus can undertake the execution of certain processing tasks, such as the obfuscation of information, where applicable. Along the same line, the bus could further offer reusable service components for the execution of privacy-critical operations that could be exploited by the service creators and providers. Especially regarding the provision of ready-to-use components for boosting the privacy-awareness of next generation services, an interesting as well as critical issue would be the adaptation of services in terms of their composition models and real-time components discovery.

Being a distributed system and involving a number of different players, the Mediation Bus should establish the means for security and trust. The Bus should cater for making the circulation of information secure, regardless of the underlying –possibly heterogeneous– network and transport means, while it must be secure itself, in terms of integrity and reliability. On the other hand, in the context of its mediation functionalities, the Bus should provide for trustworthy services and applications in the dynamic environment that the Future Internet Services create. In fact, in order for the emerging models to succeed, both the users and the service creators/providers should have a feeling of trust regarding the peer entities, the services and components of which are using.

The Mediation Bus will constitute a critical system in the service provision chain in terms of privacy, security and trust. Not only the Bus should be aware of them, but in can also be their enabler. In that respect, the recommended research priorities include:

- Semantic conceptualization of privacy/trust/security practices, as well as underlying notions (e.g., personal data and their sensitivity), in order to enable the conceptual integration with the other semantic models of the Bus. In other words, incorporation of the "privacy context" to the description of the contextual situations.

- Investigation of the means for the enforcement of privacy-aware access control, as far as the personal data circulated by the Bus are concerned.
- Exploitation of modern software engineering paradigms (such as Aspect-Oriented Programming and Model-Driven Architectures) for the introduction of transparency and abstraction at the services' design phases, regarding privacy, trust and security.
- Specification of the means for authenticating and validating the trustworthiness of services in the new dynamic environments. This concerns not only the end users, but also the service creators/providers that make use of third-party service components.
- Specification of the security means for setting the Bus itself secure (in terms of integrity and availability), as well as for enabling secure data circulation. Therefore, the definition of abstractions regarding the mechanisms offered by the underlying protocols is necessary, for boosting the desired network-agnostic nature of the Bus.
- Integration of the reasoning procedures related to privacy, security, trust to the overall reasoning and policy-based management framework of the Bus. Consequently, a common language for policies specification should take into consideration the corresponding needs.

5.6.3.6 Common language for policies/federation

As the mediation bus is the mediation among different layers and network components, it needs a language to describe the components involved in the composition of the future internet services, as well as, a language for describing policies that will govern the system.

The flexibility required by the architecture should take into account context, business policies, a knowledge representation of the characteristics and relationships of the evolved entities, etc. For this purpose a common language for describing these policies and resources/components of the federation should be understandable by all system components.

There are many different policy specification languages and service description mechanisms in the literature, but there are still missing a common language that could be understandable among the heterogeneous components involved in the delivering of FI services.

Main research priorities in this point regards the study of available approaches on policy languages in the literature and appropriate NGN service description mechanisms (e.g. ontologies, semantics), in order to find the most suitable one to be used as a common language in the federation (also proposing extensions to the language if necessary).

5.6.3.7 Service life cycle

One of the major constraints in today's telecommunication services is the huge engineering effort that has to be spent both on development and marketing, in order to get a service running and deployed in the market. The MB offers carefree development, deployment, hosting and maintaining of services using smartly combined abstraction and virtualization methods.

By that the MB vision reduces the risk and complexity for service providers to bring new service into market as it takes care of the autonomic deployment on best fitting resources and necessary resource re-arrangement and allocation to adapt best to the current service need. (This is the Service Provider view, whereas the Resource Provider provides resources which are shared and used on demand based on fluxionary resource allocation driven by external conditions/sensors.)
All that without the need of installing, operating and maintaining the physical resources (cpu, ram, disk space, connectivity ...) or worrying about availability, redundancy or backups. The MB prevents on every layer that independent services may influence each other. The user-centricity of services is gaining momentum in the current opening up of telecom service ecosystems. Within this approach, services are created and managed by the end-users themselves, even if they are not technically skilled. Within a user-centric service lifecycle model, users would like to decide, depending on their own preferences, when, where and how their services must be active (for example, an SMS service sending messages of the results of the local football team should only be available every weekend from Friday afternoon to Sunday evening, or a personal friend finder will be activated based on the location context). Since activation in telecom platforms means the real allocation of resources, and therefore expenses to the platform providers, the deployment activities must be planned based on the initial schedule that the creator has decided for the service. On the other hand, at the end of the lifecycle the operator needs to be sure that all allocated resources are released and can be re-used for other services. Therefore withdrawal activities must be carried out after the service has been deactivated, whether the service is going to be activated again (following the user schedule) or if it is going to be definitely removed.

Service developers are disburdened from the detailed knowledge of the underlying network or the computing resources. They just design and characterize (indicating special requirements as link QoS behavior or maximum latency,...) their service components based on an abstract view. During service creation developers, we see here even end users, compose their own services by orchestrating a set of differently rich service components. At the end of this process a service description is generated and stored in a kind of global repository. A new service is created by composing service components (atomic or compound) whereby the service creator can concentrate on the functionalities of the new service (and not on all the implementation, realization and adaptive deployment details). With the MB the service deployment process is an

autonomous platform process to make a service available in the global communications environment. As usually it includes physical installation, provisioning, registration, publication and activation. These tasks must be carried out in a given order. Whenever something fails, the steps already carried out must be undone. Deployment finishes when the service is up and running and ready to be subscribed to by end users. The service components may also include wildcard components where different realization of the same functionality exists (e.g. a transcoding service could be done in hardware or software, and the MB decides which will be used).

After service deployment a service is managed automatically without required action of the service developer/provider, i.e. the MB enables fully autonomous network wide operation. With growing number of customers or service load/requests a service is dynamically rescaled in a transparent way and remapped to better qualified resources. Resources may be re-arranged to always be best adapted to the current service situation and to ensure optimal usage of resources (e.g., resources are automatically re-arranged if required due to changed geographic customer concentration). In service maintenance the service execution status is permanently analyzed. This information will help to improve the service based on monitoring and usage statistics, to optimize the resource usage spent on that service and to identify errors and other runtime problems. A refinement procedure observes the occupied resources of a component during execution and performs a refinement of the component characterization. The objective is to improve the characterization from a first perspective view to a more and more application reflecting version.

If the service is going to be substituted or evolved, or will not be used for a while, it must be replaced in operation or stopped. Then, when it is no longer needed it must be cleared up from the platform. Service withdrawal consists of deactivation, withdraw the publication, deregistration, unprovisioning and physical uninstallation. As the services and their components are stored persistent in a kind of global repository, new concepts to manage service withdrawal have to be found. Version control and ageing concepts to avoid service component garbage have to be provided.

If required for service execution the MB can incorporate any type of new resources like sensors, cameras, or whole computing clusters. The integration of external sensors into a service can have influence on the location where the service is executed. Furthermore, external sensors may influence the resource allocation or service execution location.

5.6.3.8 Green/Energy aware

One of the biggest challenges facing the world is to reduce energy consumption and carbon emission while fostering economic development by research into disruptive technologies that decrease the telecom energy footprint in the face of rapid expansion. As far as the proposed Mediation Bus is considered the research priorities that need investigation in order to guarantee energy awareness include:

- Design energy-efficient network architectures.
- Design of power adaptive to the current requirements architectures.
- Energy efficient schemes for statistical multiplexing of computing and data storage.
- Transform from always-on to always-available.
- Create infrastructure for virtualization of services, applications and computing.
- Integrated approach universally handling the resources on all layers: transmission, access network technology, switching, routing, server, operating systems, etc.
- Designed for global and everywhere use, for every user and every application.
- Efficient in discovery and allocation of universal resources, end-to-end.
- Priority management and policing to assign guaranteed resources to rivalling parties.
- Assuring integrity and privacy of the data and processing.
- Inherent robustness and self management.
- Global resource sharing asks for new business models, we will only fly when resource providers have the right incentives and users get their fair share, 100% fulfilling their current demand.
- How the bus utilizes the physical/energy resources in order to obtain a green behavior for the entire infrastructure?
- Human affection through radiation pollution.
- Design of simple and fast “wake up” and usage adaptive modes of network.

5.6.3.9 Vertical management and control

Defining the vertical management and control notably asks for a holistic architecture with optimal support of all types of services - and that as an open and scalable, but still lightweight approach. Target is an access-independent Internet-based resource management that provides the opportunity to unify control and management of both wireless and wireline access next-generation networks. This new concept, which can be applied in flat and open architectures, and even in cellular environments, implies key challenges such as scalability of the architecture, performance of mobile routing algorithms, and the stability of link metrics.

New virtualization concepts for the transport layer of fixed and wireless networks are seen today as fundamental for creating the new Internet. However, new concepts beyond the virtualization approaches known today are required: not only the network resource as such, but also the transport capabilities, mainly bandwidth and quality parameters have to be controlled. In particular for wireless networks the dynamic behavior of these parameters has to be handled. Learning from data records, considering location and other simulative patterns, the MB is even able to act even in a proactive manner.

The following questions have to be answered:

- Which resources and parameters have to taken into consideration.
- What is the architectural concept providing the best support of the required information flows with maximum abstraction between transport and MB realm.
- How is it possible to derive strategies for the configuration of services and functions from the transport characteristics, and that based on the actual demand.
- Besides the simple transport resources, there are further potential network resources to be considered: e.g., packet forwarding enhanced with multi-/any-casting functions or content-related application support functions like caching or new semantic resp. cognitive concepts at the transport layer.
- Dynamic interaction between (self-organized) local control within the transport realm and global control by the MB has to be considered.
- Privacy and priority management to assign guaranteed resources to third parties and assuring the privacy of the data and processing.

An often disregarded topic is the use and interplay between offering of different network qualities and access/usage control. Generic rule: no QoS without policing/metering! However, the flop of signalled ATM shows that a simple application interface is a key. Presumably more successful should be implicit fairness models and simple tariffs, respective charging models preventing from misusage and ensuring network wide compensation of costs. Related measures should be considered as an integrated approach from the beginning.

6 Ubiquitous Connectivity

6.1 Vision and Rationale

There are several networking challenges presented in the vision chapter. A key consequence is that of scale. In pervasive wireless applications and services, the users will use a truly substantial number of wireless terminals and devices and networks. People and all their "things" communicate: there will be a transformation from one transmitter per thousands of persons (as in the broadcast case) via one transmitter per person (as in the mobile telephony) to hundreds of tiny wireless devices per person (as in the ubiquitous networking world). The networking technology will need to undergo a transformation, from a highly visible, “hi-tech technology” to a “disappearing technology” that everyone can afford, use and deploy, and which utilizes only minimal amount of resources (like energy). A truly pervasive technology is taken for granted to work and needs to be extremely reliable and dependable. Electric power is a good example of such a technology. An invisible technology needs to be:

- Auto-everything and self-x anything (no conscious user interaction to configure, install and operate network elements and terminals)
- Reliable, secure, **trusted** and **simple** to use
- Simple to add and develop new services also by users themselves and to select service providers
- Extremely low cost and energy efficient

The networking world will become a world consisting of **wide-area networking** including moving networks and a **local networking** including wireless sensor networks, RFIDs, personal area networks, local area networks and home networks.

- **Wide area domain:** It is one of today’s public systems providing fixed broadband and wide-area mobile cellular connectivity. “Natural monopoly” economics rule in this domain, and public operation with few competing market actors is the natural evolution. “Any-time-any-where” communication is what a user expects. Hence the demand on reliability is very high. Interworking will provide full connectivity between legacy and new types of networks. A common service support over all these networks makes the services ubiquitous anywhere over any access with the potential to use a multitude of different end-user devices.
- **Local area domain:** One key issue forgot in designing current and even emerging wireless networks has been to focus on the user: in which situations and where the user needs different types of services. We might argue the key environments for e.g. broadband services to be: home, office, public areas, commuting and other

transportation. In this world there will be a large number of competing and complementing technologies that will cater for reliable access and large capacity at low cost. This world will also be characterized by a higher degree of direct device-to-device communications through ad hoc and opportunistic communications solutions where non-infrastructure networks form and reform dynamically at different time-scales primarily dependent on mobility patterns and other contextual factors. Here new wireless terminals and infrastructure components are zero-maintenance and self-configuring. These local access networks can be deployed in minutes without requiring highly skilled and trained personnel. This will radically lower the entry thresholds for new actors in the infrastructure field creating new business opportunities and competition. Facility, shop and restaurant owners and even private persons can provide both wireless access to global services, as well as, to value-added localised services. The infrastructure components will form an integrated part of the wireless grid accessible to the public. The large diversity and efficient competition between providers of network and service elements or combinations thereof will provide seamless service according to user preferences.

The architecture of such systems will be mainly characterized by following features:

- **More intelligence in the end-points – not in the transport infrastructure:** Moore's law is applicable to electronic devices - not for infrastructure since infrastructure costs are dominated by the system deployment costs (like site rentals, wiring, installation, maintenance etc). New user equipment and servers can appear on the market in a matter of months, whereas large-scale infrastructure deployment takes years. Therefore appropriate technologies are needed that enable inherent flexibility and intelligence through reconfiguration, adaptation and self-x functionalities at the end-points (user devices, access points, PANs, and network elements like servers and gateways). In access independent IP-based transport network the end-to-end principle applies to all services. In order to provide this flexibility the transport network has to provide sufficient capabilities such as high enough throughput to be prepared for potential future developments at the edge systems and to avoid bottlenecks in the less intelligent large-scale infrastructure. However this should not preclude the introduction of advanced mechanisms in the transport network that will intelligently optimise the available resources with respect to the capacity demand. A further driver for the increased intelligence is the increased energy efficiency which this can facilitate.
- **From "Single system for all needs" to navigating in the "Wireless mayhem":** No single wireless access solution or radio technology is capable of providing cost-effective wireless access in all scenarios and for all user needs. Large

investments are already made in existing networks and technologies which already provide cost-efficient solutions for certain applications, e.g., wide-area voice and medium data rate wireless, or wirelss local area networks. Instead, future wireless access will be provided by plethora of systems forming a heterogeneous wireless environment. New access technologies will appear (e.g. IMT-Advanced, future evolutions of IEEE 802.11 and 802.16, gigabit-per-second short range systems, BWA) and many of these will be successful in limited scenarios, thus complementing existing technologies rather than replacing them. More advanced radio access networks (RANs) (e.g., for high speed mobility with quality of service (QoS) guarantees) will need to coexist with simple local access solutions (e.g., best-effort nomadic connectivity), and modern infrastructure will coexist with the legacy infrastructure. Multi-service capability and mobility over multi-access networks (fixed and the mobile networks) enables true connectivity for all and everywhere.

- **Multimode access for cooperation and competition:** Multimode terminals adapt to both new services and new wireless access technologies in a much faster and flexible way than the corresponding infrastructure. Significant cost gains are derived from multimode terminals and efficient use and reuse of access resources. The fact that full coverage is not necessary for all access options is probably a key factor for new radio access technologies. Infrastructure can be deployed incrementally and cost-efficiently where needed. Effective access competition will provide additional benefits for the end-users.
- **Networks that automatically "compose" and manage themselves:** The heterogeneity between the network administrators will increase, ranging from the typical non-technical personnel, providing local wireless access, who expects the systems to work flawlessly and will spend only minimal time on managing the systems, to the experts managing the large networks of today. Furthermore the dynamics within and between these systems will increase, and the large providers can spend less money on management due to increase competition and cost pressures. This implies that the management systems must be more self-managing, they need to be able to cope with most situations autonomously, and when interaction with an administrative person is required, present the problem as abstractly as possible and provide easily understandable tools to remedy the situation. These autonomous functions have to work also on the network control layer, enabling the negotiation of agreements between networks, as well as, their efficient verification and enforcement.
- **New information acquisition schemes leading to new internet architectures:** Current internet is based on IP addressing. In the future ubiquitous wireless environment information gets outdated very fast and cannot be stored to

servers, but is shared between network nodes and users. Information search must be content based. This calls for new architecture for future internet. Hence, it is justified to say that future mobile wireless networks will be the key driver for the development for the future internet. In fact, the ubiquitous wireless environment sets strict requirements for future internet in terms of e.g., number of connected devices, node mobility, bandwidth availability and variability, utilizing of new features like position information, variability of devices processing power and energy availability, security and trust on vital information exchange etc.

- **Energy consumption aware networking and services:** As the CO2 emissions must be reduced in all sectors of society, ICT field must also pay special attention on energy consumption and other environmental issues when developing new technologies or improving existing ones. Due to expected explosion of the number of wireless devices and network entities, energy consumption should be minimized in any technology developed in the future. This will create new design criteria e.g. for wireless network architectures and will foster e.g. heterogeneous networking development to the direction “All ways minimum effort and energy connected”.

The following table explains how the Research Priorities (RP), introduced in the following sub-sections, contribute to the enhancements of each axis of the SET concept.

Research Areas	SET	Contribution to SET concept
Radio Access	S	Introduction of self-configurable access schemes and reconfigurable transceivers.
	E	Aggressive introduction of novel space/time/frequency transceiver algorithms with minimal extra overhead to the broadband access systems. Power efficiency is crucial at all levels and in all areas. New deployment strategies such as multihop, mesh and cooperative networking.
	T	Always accessible secure wireless connection to the networks without user knowledge of available access schemes.
Networks	S	Automation of Management by using innovative self-x methods (configuration, management, provisioning, healing etc).
	E	Efficient transport. Efficient application development framework. Intelligent resource discovery and Management. Always Best Connected.
	T	Security, Trust, Privacy, network resistance should be well

		integrated in the network.
Platforms and implementation	S	New computing platforms for mobile devices must be simple to use both by users and by developers. The functionalities provided by the platform software (OS and middleware) must reduce the effort and time needed to add new advanced services, and to have them cooperating. Retargeting to multiple product domains and product variants should become straightforward. Efficient tools for energy management of the products need to be inbuilt to the platforms.
	E	Efficient platform is a prerequisite to provide efficient services to the users. The platform software layers need to efficiently scale and adapt to the emerging multi-processor and network-on-chip computing platforms to take benefit of the increased efficiency they can provide. Advanced middleware services should provide innovative ways to efficiently integrate different communication and coordination models. Energy efficiency needs to be addressed at all the levels.
	T	New computing platforms must offer a large set of basic functionalities to easily implement safe, secure, and reliable services for the users
Opportunistic communication	S	New adaptive radio system must be able to automatically adjust the way they operate to obtain the best performance in every possible scenario. Opportunistic communication makes access to spectrum self-evident and transparent.
	E	By increasing spectrum utilization, opportunistic communication has the opportunity to increase communication efficiency solving today's problems and increasing the scalability of the system.
	T	Opportunistic communication should provide reliable communication in situations where today technology cannot be reliable, thus increasing the overall dependability of the system.

Table 6-1 SET and Ubiquitous Connectivity

6.2 Ubiquitous Networks

6.2.1 Rationale

Flexible growth from small-scale, to continent-wide up to global systems and services needs to be supported, enabling a wide variety of both wide area and local area solutions for all the various application offerings, including unicast and multicast services. One key element will be wireless and fixed access with optical transmission integration. A heterogeneous networking environment as outlined in the previous section calls for means to hide the complexity from the end-user as well as applications by providing intelligent and adaptable connectivity services, thus providing an efficient application development framework. In this section we present possible impacts and technical challenges the vision presented in the previous section will have on networks and network architectures.

Fixed-mobile convergence (FMC) of both services and networks play a major role in realisation of our vision, allowing users to be always reachable and having access to their normal personal service environment. A first step towards this is to enable nomadism in the fixed access network meaning the ability to reconnect to the network at new locations and being able to access e.g. the service environment at home and everywhere. The next step is to be able to do the same across different mobile access networks, for example between access networks controlled by different operators and administrators. The last step in the evolution towards a true always best-connected network is the seamless and efficient interaction between the fixed and the mobile/wireless networks. The interworking and convergence between the fixed broadband networks and mobile networks will be a key factor in order to achieve the eMobility vision. The future infrastructure will support multi-service capability and mobility over multi-access networks that enable true broadband for all and everywhere.

The complexity of network management will also increase between the providers of network connectivity. This is addressed through provision of substantial automation for achieving both network composition and cost efficient network operations and maintenance via various autonomous self-x functionalities. The autonomous functions operate also on the network control layer, facilitating the negotiation of agreements between networks as well as their efficient verification and enforcement. This will include policy-based networking within a given business framework to enable maximum and stable use of the networking resources.

The emerging communication systems are oriented towards the interconnection of heterogeneous networks able to provide various types of services, including those with high transmission rates and with quality of service guarantees. The integration of optical and wireless technologies allows an efficient solution to provide multimedia services to the end user in high

traffic density areas, merging flexibility and mobility characteristics of the wireless networks with the high capacity of the fibre.

Applications will have to be supported by intelligent connectivity service taking care of context information and relying on user and application preferences; for instance by increasing the semantic understanding of media flows in the network. The composed connectivity networks must provide predictable and dependable connectivity service to applications with the acceptable robustness in order to be trusted by users and service providers. At the same time, the connectivity service must be secure enough to identify, isolate and autonomously react to any malicious behaviour by, e.g., applications.

IP as a data delivery technology was invented in the time where networks had static configurations and mobility was non-existent. Generally speaking TCP/IP Internet solutions assume a fairly predictable and simple notion of the end-to-end communications. This implies that operational assumption for the TCP/IP depends on the need for availability of at least one permanently functional path between a source and a destination with relatively small end-to-end delay and packet loss. This major assumption does not always hold true in a dynamically varying mobile environment. The emergence of sensor networks, RFIDs, ad-hoc networks, and large mobile networks with high and varying cases of mobility, various degrees of intermittency and burstiness, heterogeneity in many different aspects of networking and diversity of services available questions the very essence that the Internet paradigm was built on. The Delay Tolerant Network Architecture (DTN) in IETF recognises this shortcoming and provides recommendation for a very specific research in the Interplanetary Internet but at the same time introduces interesting notions and solutions for Internet evolution in areas of architecture advancements concerning services, topology, routing, security, reliability and state management. This research offers useful insight in methods of adaptations and enhancements of Internet communications in the emerging communications paradigms. The case being investigated in the Delay Tolerant Network Architectures bases the argument on the specific examples of networks where the end-to-end communication delay is highly variable and large with different expectations on the transit properties and delivery constrains of the traffic. This can be interrelated with some of the abovementioned recent types of emerging communication environments in the Internet and considered as an important challenge in *evolving* Internet communications paradigms and associated solutions.

With advances and lessons learnt in the past 40 years of network architectural designs, combined with in-depth understanding of requirements of current and future wireless systems, there should be a parallel and clean slate (*revolutionary)* approach to the future generation of internet in the

Post-IP era internet. This is differentiated from the evolutionary and patchwork enhancements to current Internet emphasising on the fact that the future trend on devices research is shifting from current practice of e.g., content or a software application process towards networking of mobile/device objects. The Post-IP Internet research includes challenges that relate to the data delivery paradigm or IP itself where routing of datagrams is inefficiently based on addresses of a virtually static and common global infrastructure. The notion of an IP address itself is another reason for inefficiency of IP for mobile/wireless communications and supports justifications for new and revolutionary approach. There is a need for research on a new set of protocols which are more wireless friendly and also provide a smooth migration from current IP to protocols and architectures where mobility, security and mechanisms for quality of service support are the fundamental basis in the design of protocols and architectures in next generation internet in the Post-IP era.

6.2.2 Objectives

The major objectives of the research are therefore to:

- Fixed Mobile Convergence – nomadism and mobility with session continuity with alignment of business models, roaming protocols, user & service management and architecture between fixed and mobile networks.
- Enable the future infrastructure supporting multi-service capability and mobility over multi-access networks (fixed and mobile networks) with heterogeneous devices where privacy, security and safety are prerequisites but need to be easily managed.
- Enable interworking and convergence between the fixed broadband networks and mobile networks to reduce cost and make services available everywhere including full acknowledgement of optical transmission.
- Unbundling: Network architectures that allow for collaborative business models in which complementary providers join forces, as well as for unbundling of the access network to competing service providers in order to achieve the most attractive service offer for the end-user.
- Propose new Post-IP networking and architectures coping with the new and emerging wireless networking requirements in next generation internet.
- New protocol frameworks and collapse of current protocol stack and layering into minimum required protocols in face of widespread availability of fibre optics networks.
- Complement research effort on networking of devices with networking of information, e.g. towards semantic technologies, data fusion etc., to support ubiquitous availability of content and information for all application scenarios (e.g. user-centric, M2M-centric).
- Define a network architecture that supports high-bandwidth real-time services over multiple access technologies

- Understand the evolution towards context-awareness and support of cognitive networks and media-aware networking thus providing the intelligent connectivity services required for efficient application development
- Enable an always-on experience: Information can be accessed anytime, anywhere as if it were stored locally (e.g., music database on mobile players) even in the case of intermittent or fluctuating connectivity.
- Create support for network and system management that are highly self-managing to lower the level of required skills and effort to manage such networks. These management systems will also be highly distributed to cope with the size of and with the high level of dynamics in and between the networks.
- Enable harmonisation of actuations amongst sensors, monitoring and control applications working under critical requirements (e.g., security, availability, reliability, speed of action).
- Develop support of automatic context-aware discovery, selection and composition of devices, networks, resources and services as well as personalised service selection and decision making.

6.2.3 Research Priorities

Today's trend is that large, feature-rich systems tend to become more complex to specify, build and operate. Hence further research is needed on:

- Design of post-IP technologies, specifically novel data delivery mechanisms matching the dynamics of large scale mobile networks and particularly for ad hoc and infrastructure-less networks and network constellations. Richer notions of networked objects including new means for naming, addressing and identification. Layered vs. non-layered stack design, statically or dynamically configured networking stacks should also be included. The solution should operate efficiently over both fixed as well as mobile networks.
- New protocols optimised for packet-only in a public access environment. Especially capacity and latency-effective alternatives to IP and TCP.
- Full delay tolerant networking.
- Radio over fibre influence on new collapsed and minimum protocol framework.
- Scalability and optimization of network and service control technology which can deal with all sizes of networks, from small ad hoc networks up to large-scale corporate and public wide-area networks, employing a common networking concept. Concepts for intelligent distribution of services across multiple access technologies.
- Fixed and mobile convergence with focus on service, device convergence, and network convergence where both the fixed and the mobile network use the same multi-service layered architecture that improves efficiency and flexibility.
- Auto-configuration and self-management mechanisms which are able to autonomously deal with dynamic configuration changes (for example, small footprint networking

technology), including multi-mode multi-band radio, radio resource management, application-based charging, instant network composition and decomposition, automatic roaming agreements, interworking between new and legacy management systems, multi-hop radio networks, software configurable radio interfaces, multi-link phones (terminal, router and repeater functions), flexible quality of service and in particular from user's point of view quality of experience.

- Ability to cope with a wide range of application middleware to support applications with more intelligent communications services.
- Design and development of new network topologies and routing structures to cope with a composition of multitude of networks. Mesh architecture should be validated in an integrated wired/wireless network.
- Alternative deployment strategies and technologies for capillary networks.
- Multi-layered (ISO layers as well as overlaid/underlaid cell layers) mobility support, which enables ad hoc cluster mobility, as well as, user-mobility across networks.
- Delivery of information and media flows to users, adapted to their current access situation, location-dependent interests and preferences.
- Unifying solutions for personal networking (PN), interaction with body area networks (BAN), new types of home networks, vehicle networks, wireless sensor networks (WSN), RFID, deployment and operation of emergency networks, and other network types.
- Security and robustness to sustain malicious attacks with inherent self-healing configuration mechanisms, QoS and policy-based networking (e.g., policy-enabled service on demand), firewalls, authentication and trust management technologies.
- Secure and trusted application environments including damage prevention and control techniques for connectivity (Network security, information and trusted content security).
- True multimedia support: Basic technologies for content distribution over heterogeneous networks and media conversion techniques for multi-modal presentation of content to users.
- Transport network evolution for reliable, cost efficient, easy-to-deploy-and-integrate solutions taking optical and BWA transmission fully into account.
- Solutions enabling efficient OPEX and CAPEX for fixed very high bandwidth multi access networks with scalability for number of users and bandwidth including a variety of first mile technologies such as fibre, fast DSL and BWA.
- Investigations of Traffic Engineering solutions in both the wired and wireless MANs to balance the traffic. The utilization of different traffic engineering schemes to manage specific issues of optical/wireless networks, such as physical impairments, node architecture, routing and wavelength assignment.

- Interaction of the routing protocol with physical, MAC, and transport layer to optimise the traffic engineering schemes.

6.3 Radio Access

6.3.1 Rationale

Extensive and high quality ubiquitous wireless access cannot be managed with the currently established infrastructure or with emerging ad hoc radio network technologies as the traditional radio access schemes will not scale to large collections of nodes and is destined to be plagued with unmanageable interference, and network congestion. To develop such scalable and dynamically pervasive wireless access, there is a need for fundamentally new methods to address spectrum sharing cooperative and adaptive link management, opportunistic access, information routing, and quality of service management.

Current wireless access networks have been developed in a fragmented way, cellular systems with spectrum dedicated to operators being one example. In the future a great deal of flexibility is needed in terms of how networks are constructed and operated, how spectrum is used most efficiently between several operators and technologies for managing the flexibility. The future wireless access schemes should be developed to facilitate flexibility for the allocation of throughput values per user, high aggregate average throughput per area, low latency and high cell edge capacity, as well as high speed access with somewhat modest power consumption requirements and different access range as well as relatively short range techniques having the power saving (lower power wake-up radios etc.) as some of the key driver. It can be foreseen that on top of current networks and architectures several new topologies will be applied. For example local mesh extensions to improve connectivity at e.g. cell edges, public areas, home/office environment, vehicular environment etc. would improve the coverage and capacity of existing cellular networks.

6.3.2 Objectives

In the development of future RANs the **efficiency** will become even more important issue than ever. Operators publicly providing RAN solutions are in a new business model where they need to compete with other operators and access technologies for various applications. New solutions for access technologies (both user and backhaul links) and signal processing methods are needed which result in efficient use of spectrum and network resources, and higher throughputs, through appropriate cooperation and adaptation techniques. Simple and low-cost deployment of access infrastructure is of paramount importance to the overall economy of access provisioning. The target is not necessarily higher bit rates as in the past but *high and uniform* capacity in most of cell coverage such as 85% of cell area. Autonomous self organisation is needed to

continuously operate at the optimum point under dynamically varying conditions, as well as capabilities to easily incorporate (as yet unconceived) future services and requirements.

Radio access network and backhaul system research are part of the overall system design. It needs to be emphasised that radio interfaces for the future should be designed jointly with the overall systems. However, achievement of major advances in, e.g., RAN capacity, power efficiency, distributed network control, new network topologies requires also independent and highly focused research at different layers. This results in an integrated and iterative design process, where the major difference with the past is that the overall system design is much more emphasised. New design criteria such as energy efficiency need to be considered together with capacity and throughput for developing sustainable technologies for the future. Also the development of future Internet from mobile wireless perspectives must be carefully monitored as the wireless component will be setting the most stringent requirements for the development of Internet. Inclusion of sensory data to be a natural part of the wireless networks will set totally new requirements for the networks security matters.

In-band mesh networking (i.e. backhaul sharing spectrum with user access) is increasingly being considered as a solution to linking WLAN access points, but suffers from capacity limitations as traffic levels grow. Out-of-band mesh topology instead promises to cope with the capacity and performance requirements if adequately designed

One major paradigm shift driving the future RANs and backhaul systems development is related to more liberal spectrum allocation policies, leading to **simplicity** in regulation and **efficiency** in spectrum usage. Opportunistic communication technologies based on the concept of cognitive radio must be extensively researched and developed for this purpose. This will be treated in more detail in Section **Error! Reference source not found.**. The flexibility, adaptivity and multi-functionality requirements leading to multi-radio and cognitive radio concepts require new transceiver architectures which will be discussed in Section **Error! Reference source not found.**.

6.3.3 Research Priorities

The target is to develop future integrated systems in a unified manner. The commonalities of different access networks are utilised to support developing a flexible radio for the future whilst maximising the unique capabilities of different types of networks by somewhat independent system optimisation. The identified major research areas pertain to user link (radio access) as well as backhaul links between access points and concerned with deployment concepts, radio interface technologies, reconfigurability, spectrum and coexistence, trials and prototypes as well as regulation and standards.

The Radio access research topics include:

- Joint optimization of coverage, capacity and quality-of-service techniques through co-operation and adaptation techniques involving different layers in protocol stack assisted by information from physical layer and radio environment.
- Efficient mechanisms for joint exploitation and operation of available diversities in time/space/frequency/code/power domains.
- Development of radio access schemes with high peak aggregate spectral efficiency for noise-limited environments and high area average aggregate spectral efficiency values with high cell edge spectral efficiency for interference-limited environments.
- Energy efficiency in future wireless networking and radio technologies.
- Radio access schemes with high flexibility and adaptability of data rate allocation to users.
- Investigation of alternative, low cost deployment concepts, new network topologies and system architectures beyond the classical cellular approach, such as relay-/multihop-based concepts, meshed networks, distributed antennas and radio over fibre for signal distribution.
- Intelligent resource (frequency, battery, power, hardware, software) discovery and management techniques.
- Evaluation of Network Information theoretical limits of cooperative and self-organising networks and research into advance coding design and signal processing schemes to achieve these limits.
- Investigation of the impact of new frequency bands for future systems on the radio propagation and specification of appropriate output power levels to ensure compliance with relevant guidelines and regulations related to human exposure to radio frequency electromagnetic fields.
- Development of radio access and networking schemes for unpaired frequency bands for mobile cellular systems to take full advantage of radio channels reciprocity and MIMO techniques capacity gains.
- Autonomous networking concepts and related technologies for femtocells in home and public areas.
- Networking concepts and information filtering for supporting dynamically changing information for e.g. vehicular networking.
- Development of methods for supporting efficient multicast transmissions in cellular systems with significantly different fading channel conditions for the links to and possibly different levels of meaningfulness of the transmitted information for various recipients.

- Development of the self-configurable user terminal by the software defined radio technology to assure mobility to the final user and an efficient interoperability among different networks. Development of software defined radio technologies for multi-standard base stations and reduce cost by diminishing diversity of hardware platforms.

6.4 Opportunistic Communications

6.4.1 Rationale

The demand for wireless communications will continue to increase at an accelerated pace, which with the current paradigm of rigid spectrum allocation and licensing will undoubtedly lead to a spectrum crisis, even with the development of highly spectral-efficient transmission techniques. Nevertheless, considerable spectrum might be available, especially for local area communications, if both the space and time dimensions are considered. Hence the problem is more a problem of inefficient access to parts of spectrum that are under-utilized rather than actual spectrum shortage.

While such an approach represents a major deviation from the current paradigm of spectrum allocation, the debate on alternative and more efficient spectrum management policies has started in the standardisation bodies and national regulation agencies, but to support the eventual step of going towards a more liberal approach of spectrum management, the decision-makers need proof of evidence of the viability of technologies that would enable the alternative approaches.

Providing novel mechanisms for enhanced and more efficient spectrum usage would support the i2010 initiative of the European Commission towards the Information Society. Opportunistic communications would facilitate the emergence of new business models. For instance, it would support the implementation of much heralded secondary spectrum market, by using or leasing some licensee frequency bands for a limited time period and under some specific constraints on interference level.

6.4.2 Objectives

The development of frequency-agile terminals that can sense holes in the spectrum and adapt their transmission characteristics to use these holes may provide one tool to address and take advantage of the spectrum under-utilization. Although, some current adaptive radio systems already exhibit the feature of automatically adjusting their parameters for a given standard, the development of truly agile terminals requires to go much further, since it is not possible for the designers to foresee all the possible scenarios and then provide deterministic schemes for the selection and reconfiguration.

Opportunistic communication challenges fit in the general framework of the Cognitive Radio research, focusing specifically on techniques exploring mainly the frequency dimension to find and use the best spectrum and space opportunities in a fair manner. Research needs to be conducted on concepts, mechanisms and architectures for cognitive radio terminals and networks. Business advantages of opportunistic spectrum usage in both time and space need also to be demonstrated.

6.4.3 Research Priorities

The main areas of opportunistic communications requiring research advances include:

- Spectrum sensing techniques to acquire relevant information from the radio environment and define the feasible operating region
- Distributed and centralized decision making processes to allow intelligent choice of spectrum access, based on spectrum access policies available or unused spectrum
- Optimisation procedures to define the best waveform when applicable given the environment
- Identification and dissemination of spatial opportunities in opportunistic radio networks and collaboration strategies to efficiently make use of them on a network level
- Adaptable and flexible broadband RF frontends for variable carrier bandwidth
- Adaptable baseband architectures that may efficiently adapt to the radio environment
- Scalable and reconfigurable techniques to support all digital RF flexible transceiver architectures
- System-level studies to evaluate the effectiveness of the proposed techniques in terms of system parameters (e.g., capacity, QoS)

6.5 Platforms and Implementation

6.5.1 Rationale

Pervasiveness of future wireless applications and services will integrate the computation and wireless communication capabilities in a great variety of mobile devices both on terminal and network sides. To achieve wide acceptance, the devices and their designs should exhibit new degrees of scalability, flexibility, security, high level of energy-aware performance, cost efficiency and design productivity applicable for a wide range of products that provide users with intelligent context-aware services via heterogeneous networks.

Digital convergence will combine technologies in products in new ways that force tighter synchronisation of roadmaps between different technology domains in order to ensure the availability of all necessary technologies in time. Different parts need to be specified and optimised jointly to identify common features crossing the borders of the domains. This holds for

antennas, radio frequency front-ends, baseband signal processing, and displays as well as for computing architectures, middleware and application software and user interfaces. Standard interfaces and open communication and computing platforms are needed to facilitate this collaboration.

Future mobile devices will continue to drive the development of many semiconductor product sectors, especially the potential migration to higher frequencies asks for pushing RF CMOS circuits beyond the current limits.

One major requirement for the future platforms and implementation is the need for much higher energy efficiency. This requirement will impact all the components and aspects of mobile devices and wireless infrastructure, and their overall system design.

6.5.2 Objectives

Merging several simultaneous network access schemes, high data rate communications and multiple concurrent diversified applications will severely challenge the scalability of current platform approaches. Future communication and computing platforms need to be based on new modular architectures (e.g., network-on-chip) and design methodology paradigms (e.g., model-based and platform-based design) reusing components over a wide range of products to obtain shorter time-to-market, lower costs, increased reliability and to amortise investments.

The multiplicity and diversity of media access control processing, protocols, middleware, applications and smart user interfaces cumulate to huge complexity in many dimensions including functionality, architecture and internal communication. Computing platforms of mobile devices will require heterogeneous multiprocessing architectures that need to interact continuously with their environment and to transfer and manage large amounts of data. The platform should be capable of accommodating very diverse types of applications, provide them with a secure execution environment and support software download. The ultimate objective is therefore a mobile device computing platform that would allow retargeting to different product domains and product variants. In addition, the envisaged platforms and architectures require major leaps in the design methodologies and tools for specification, design and implementation like model-based design, performance modelling and evaluation and platform-based design.

The basic functionalities provided by the platform software layers (e.g., RTOS, device, connectivity and network management, user interface and application interface) will remain, but the structures need to scale and adapt according to the emerging multi-processor and network-on-chip computing platforms. The key issue to be studied is how this can be done efficiently considering the stringent resource constraints of mobile devices. Offering of open standard-type

interfaces, e.g., in the form of APIs, is essential in order to achieve an open execution environment for envisaged intelligent context-aware services to be offered via heterogeneous networks.

A heterogeneous networking environment will result in more complex systems with respect to signal processing. In addition, requirements on environmental issues and the impact of electromagnetic radiation on the human body have to be considered. Constraints on the power consumption will increase significantly in the future, and the means to overcome the set challenges requires a lot of work. The adaptivity and multi-functionality requirements leading to multi-radio and cognitive radio concepts require new RF front-end architectures. Joint optimisation of the antenna, RF front-end and digital baseband modem will be needed. A flexible-reconfigurable platform optimised by the maximum amount of commonalities would allow retargeting to different products and give possibilities to achieve low costs through economies of scale.

6.5.3 Research priorities

The main areas of **computing platforms** requiring research advances include:

- Platform and architecture concepts that take into account the needs of users, businesses, services, connectivity, and different associated technology domains.
- Network-on-chip and multi-processor system-on-chip architectures, packet-based intra-communications, interfaces and resources.
- Interaction with multiple parallel radio interfaces, co-existence of multiple protocols.
- Design methodology and tools for model-based design, platform-based design, performance modelling and evaluation, power modelling and evaluation, functional validation and verification.
- Facilitation of energy efficient technologies and techniques. Taking energy efficiency into account at all levels.

The main areas of **platform software** requiring research advances include:

- Extensible middleware architectures: dynamic architectures, self-organisation algorithms and strategies, and negotiation techniques.
- Middleware services: automatic and scalable service discovery, adaptive resource management, authentication with dynamic configuration, standard-based light-weight middleware solutions with support for interoperability, heterogeneous devices, software solutions and applications, and self-aware middleware services.
- Performance monitoring and analysis, security modelling and testing, survivability methodologies and mechanisms, reliability and availability evaluation.
- Cost-effective development methods, middleware frameworks and test-automation.

The main areas of **antennas, RF front-ends and baseband processing** requiring research advances include:

- Innovative transceiver architectures and jointly optimized RF and baseband hardware designs, matching the nano-electronics roadmaps and exhibiting new degrees of scalability, flexibility, security, energy-aware performance, cost efficiency and design productivity
- New architectures of broadband and adaptable RF front-ends matching with the microelectronics roadmaps and including advanced technologies and components such as RF MEMS and NEMS (Nano Electro Mechanical Systems)
- Development of simple and cost-effective base station architectures based on the integration of photonic and electronic devices. The base station and the link design should take into account some critical design parameters such as, for example, radio and optical link losses, optical and radio impairments and optical amplifier gain.
- Joint optimisation of the front-end and the digital baseband modem, including analogue and RF behavioural modelling as well as digital compensation of their impairments
- Efficient analogue-to-digital co-simulation
- New design methodology for hybrid devices including micromechanical and electrical components
- Synthesis and verification of reconfigurable architectures
- Synthesis and verification of Network on Chip (NoC) architectures
- System level (System on Chip, Network on Chip) methodology and tools
- Integration of embedded non volatile memories (e.g., MRAM, PCRAM, PMC) on chips
- Design of fault-tolerant chip architectures
- Design of smart memories including data management at the hardware level

The main areas of **power consumption challenges** requiring research advances include:

- Long-lasting and lightweight power supplies for mobile devices, energy scavenging techniques and piezo materials.
- Techniques for low power communication and computing architectures.
- Cross layer optimisation to exploit flexibility in order to save power.
- Improved power dissipation techniques applied to telecom equipment to control difficult climatic conditions.

Reduction of power consumption by using low power technologies and by developing interaction between hardware and embedded software (e.g., monitoring of voltages, clock frequencies and threshold voltages).

7 Green Wireless Communications

7.1 Holistic view, motivation & requirements

In its communication “Addressing the challenge of energy efficiency through Information and Communication Technologies” the European Commission states :
“Information and Communication Technologies (ICTs) have an important role to play in reducing the energy intensity and increasing the energy efficiency of the economy, in other words, in reducing emissions and contributing to sustainable growth. In order to achieve the ambitious targets set and meet the challenges ahead, Europe needs to ensure that ICT-enabled solutions are available and fully deployed, but efforts should be made so that ICT leads by example and reduces the energy it uses — ICT industry accounts for approximately 2 % of global CO2 emissions, but is pervasive throughout all kinds of economic and social activities, and increasing its use will result in energy savings from the other industries”

The European Commission acknowledges the opportunities ICTs have to offer in reducing the energy intensity of the economy but also points out that ICT needs to lead by example in increasing its energy efficiency. When assessing the energy efficiency of a product, the energy consumed for its manufacturing, distribution, use and end-of-life treatment needs to be considered.

Currently, data volume transmitted through networks increases approximately by a factor of ten every five years, which corresponds to an increase of associated energy consumption by approximately 16 % – 20 % per year. Gartner estimates that the use phase of ICT equipment is responsible for 2 % of the annual carbon emissions. Other studies indicate that the share of the use phase of ICT in the worldwide energy consumption is closer to 3 %. This is comparable to the energy consumption of the aviation industry. When incorporating the entire life cycle, the share of ICTs is closer to 4 %. The exponential growth of ICTs, which will be required for reducing the energy intensity of the entire economy, is currently not sustainable.

According to a study of ABI Research, base stations and backhaul networks of the cellular communications networks operators consume approximately 60 billion kWh per year. This corresponds roughly to 0.33 % of the global electricity consumption . Note that the above investigations take into account only the use phase of the equipment. The GSM association estimates that this operational fraction is 90 % of the total use phase energy consumption of mobile communications. Based on these numbers mobile communications entail 15 % – 20 % of the entire ICT energy footprint.

When tackling the problem of the increasing energy consumption, instead of looking just at different isolated aspects of the overall problem, a global optimization approach is required in order not to compromise the quality of the networks. A holistic approach should be considered. This energy efficiency view is relevant not only for networks in developed countries, where it contributes to decrease the electricity bill of operators, but also in developing ones, where the access to power networks is difficult in remote areas (implying alternative solutions). Improving energy efficiency can thus foster the deployment of wireless networks in these regions and help to close a potential “digital divide”.

A first step requires increasing individual energy efficiency of equipments. Power consumptions of the most relevant equipments are listed on Table 7-1. Evidently, by migrating from 2G to 3G, power consumption has multiplied by a factor of 5. Moreover, the radiated power of a BTS or Node B is maximally 50 Watts maximum. This demonstrates that drastic reductions in power consumptions are required and should be feasible.

2G Networks			3G Networks		
Equipment	Power Consumption	Share in cellular network	Equipment	Power Consumption	Share in cellular network
BTS	1200 W	97 %	Node B	6000 W	98%
BSC	500 W	2.2 %	RNC	2500 W	1.5%
MSC	4000 W	0.8 %	UMSC	4000 W	0.5%

Table 7-1. Cellular 2G and 3G network consumption data[1]

Furthermore, it is a fundamental goal to extend the equipment's lifetime. This will lead to a lower impact of the production phase in the overall footprint.

Although the network itself needs energy efficiency optimization, it never got too much attention from the energy efficiency viewpoint, as it was easy and relatively cheap to get power fed to the equipments. This view is changing quite fast, and the inclusion of environmental approaches,

namely energy efficiency, into the design of networks, is becoming a factor for increasing competitiveness. Many ideas can already be found, some of them implementable with current technologies, like switching off a base station during the night when traffic is low or non-existent. More generally, flexible networks that adapt their capacity to the requested requirements can lead to significant energy savings. Also new network paradigms that assure all components are used at their fullest capacity will need to be introduced.

Way forward:

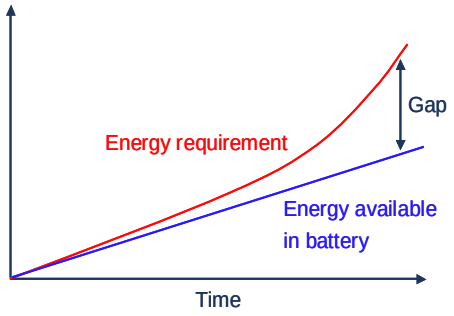
- To significantly increase the energy efficiency of wireless communications systems, a global optimization approach is required considering equipments and networks.

7.2 Green radio

The combination of mobility and connectivity has become a commodity in today's society. We have seen a continuous accelerated deployment of broadband personal communications and increasing demand for higher data rates over the last decades. In parallel, silicon technology has become ever smaller and faster. These two evolutions have reinforced each other so far, offering 'more (bandwidth) for less (area/cost, power)'.

7.2.1 Conflicts on essential resources

The gigantic success of wireless communications is however forming a threat to itself. The spectrum gets crowded, and increased service requirements are draining mobile devices batteries (Figure 7-1).



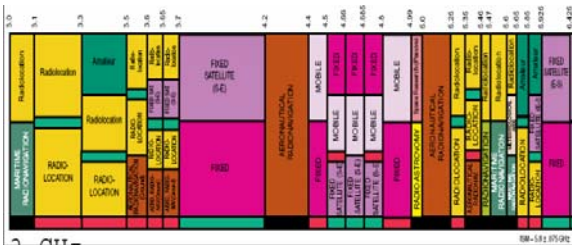


Figure 7-1. Growing energy gap (top) and over-allocation of the spectrum (bottom) hamper progress in mobile communications

The proliferation of radios and the intensification of their usage, is leading to a massive increase of 'wireless activity in the ether', increasing the risk of bad communication quality.

In addition to the emerging communication problems mentioned above, technology scaling also is reaching its limits. Indeed, CMOS scaling has arrived at the point where parasitic problems are becoming dominant: variability, reliability, and last but not least leakage, can not be resolved anymore at the technology (transistor) or circuit level only, and will have their impact on the system level performance. Even more important, the leakage may become the dominant component in power consumption, and this challenge has to be tackled thoroughly in order to provide energy efficient solutions for future designs. Leakage cannot be totally handled anymore at transistor level. Appropriate measures at design and even at system level (e.g. through intelligent control) are needed.

Way forward:
In order to cope with the challenges explained above, we need disruptive solutions. The following essential paradigm shifts show the potential to enable green radios:

- We will need to design next generation radios aware of power dilemmas, to deliver services under constrained resources (energy, spectrum). 'Green challenges' will need to be integrated in the optimization criteria, while traditionally the design and operation goal of wireless systems has been to guarantee Quality of Service (QoS).
- More flexible use of the spectrum should be exploited to reduce overall energy consumption. Cognitive radio is investigated already, yet the goal so far has been to guarantee QoS, while the concepts could bring much greater value when addressing 'Green challenges'.
- The traditional link between a service and a network should be disconnected, as it leads to huge energy and spectrum wastes. For example, more than 30% of mobile phone calls are made from user's homes, thus generating unnecessary energy consumption.

- Optimal usage of scarce resources should be considered across (OSI) layers, cross the link, cross the implementation levels (functionality/algorithms, platforms, architectures, circuits). Mainly local optimizations have been carried out for energy savings so far, where gain at one point often is counteracted by the loss at another.
- Alternative energy sources should be considered and where possible designed for. E.g. for very low power radios energy scavenging can be considered, and for small energy efficient base stations or even terminals solar energy may be used.

The above listed challenges have to be addressed at the terminal as well as at the infrastructure side, as will be explained in the following section.

7.2.2 Terminals & Infrastructure

Multi-mode terminals integrating reconfigurable green radios, i.e. radios that are aware of energy, can enable radical energy savings in heterogeneous network environments.

Power consumption in infrastructure for wireless systems is already becoming an important design target, and is expected to become even more crucial in the future. Smaller and/or distant base stations will not be connected to the power supply net in the future. The overall need to save on scarce energy make it a bottleneck and will also impact the infrastructure which is connected to the power supply. Moreover, recent communication systems offering much higher capacity, unfortunately often do so at the expense of more power consumption at the base station, especially the power amplifier, as explained below.

In Figure 7-2, the power consumption of a typical medium power GSM base station is shown for a link with GMSK modulation serving three sectors with four carriers per sector. It can be seen that the power amplifier consumes the largest amount of power and converts more than 50 % of the total input power into heat. Compared to this example, new modulation schemes (e.g., OFDM used in LTE) aiming at optimum data throughput, suffer from even worse power efficiency. The reason is that the signal of such modulation schemes feature much higher peak-to-average ratios, thus requiring higher power amplifier back-off which in turn leads to lower power efficiency.

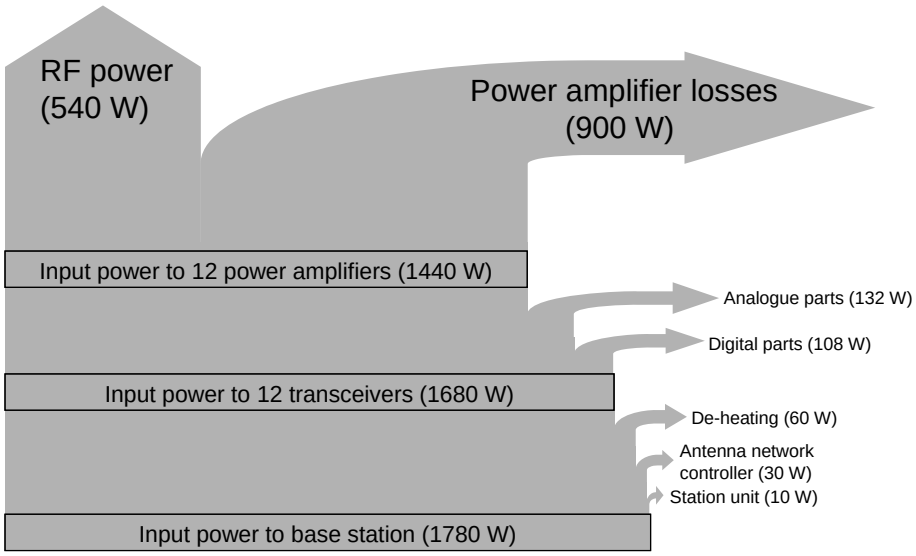


Figure 7-2. Power consumption of a base station (example: GSM medium power base station with GMSK modulation, serving 3 sectors with 4 carriers per sector).

Way forward: Green radios should be targeted both in design of functionality and implementation, as well as in operation:

- Radio implementation: There is a need for innovative radio solutions (analog front-ends and digital platforms, antennas and antenna interface), which exploit the possibilities enabled by new technologies, while taking into account the problems they bring. With this regard, in future terminals the integration of RF MEMS (Micro-Electro Mechanical Systems) in RF front-ends and the co-design of some RF components (e.g, antennas and amplifiers) is promising. Reconfigurability and scalability are key to realizing a cognitive radio so that it can reconfigure itself according to spectral opportunities. These reconfigurable capabilities should be available from the transceiver level up to the resource management strategies. Important impact on energy saving wireless devices is also expected from new antenna design techniques such as:
    - RF MEMS base reconfigurable directive antenna.
    - Combining with indoor localization Positioning ID devices/tags or DOA estimators).
    - Using cooperative beam-forming.
    - Better understanding of indoor propagation.
    - Antenna LNA co-design approach .
- Radio functionality: Energy efficient modulation and coding schemes, including network coding and cooperative networks, can bring significant savings. Indeed, wasting energy due to high interference levels, need for packet retransmissions, or very long contention

periods, can be avoided if the communication system and the air interface are designed with the goal of reducing energy consumption. Furthermore, new. sampling or sensing techniques such as "Compressed Sensing" that allows the faithful recovery of signals from what appear to be highly incomplete sets of data, typically using fewer data bits than traditional methods used to request, appear to be very promising. Indeed, following this approach would bypass the current wasteful acquisition process in which massive amounts of data are collected only to be in large part discarded at the compression stage and hence results in a significant saving of the transceiver processing power.

- Radio operation: Progress on the radio design alone will not be sufficient to cope with the green challenges. A need for holistic strategies exists, to enable energy aware and spectral efficient operation. Green intelligence can be brought in the radios through the cognitive cycle in which the analysis step considers the reconfiguration opportunities also in terms of global energy consumption (terminal & network) through an interaction between the terminal and network infrastructures (Figure 7-3). As such, future terminals should be context aware and their ultra low power communication aspect will be enabled by an appropriate joint combination of sensing, localization and identification.

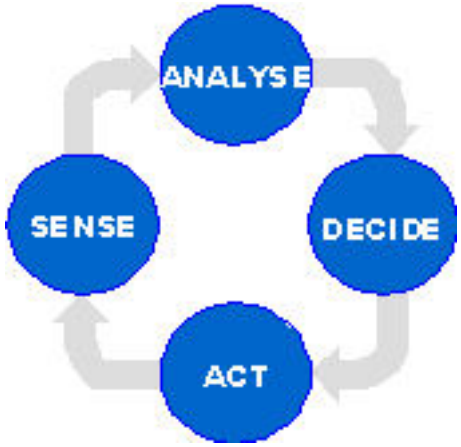


Figure 7-3. Cognitive cycle should target green operation

7.3 Green networking

It is expected that in the coming decade there will be an explosion of the number of wireless devices and, consequently, of the amount of wireless communication that takes place, e.g., WWRF foresees roughly 1000 wireless devices per capita by 2017 . Providing services and running applications on these devices, we will face the double challenge of (1) significantly reducing the energy consumed by these systems, and, (2) sharing the spectrum (licensed and unlicensed) in an efficient way among a huge number of indoor and/or outdoor devices. Energy consumption needs to be reduced for two reasons: to curb the growing share of energy

consumption of ICT systems and to significantly extend battery autonomy of wireless devices, a necessary condition for providing dependable services on wireless devices, e.g., in telemedicine or ambient assisted living for the elderly.

Up to now these concerns played only a marginal role in the design of wireless networks and even less so in wireline networks. Present network architectures, protocols and implementations are to a large extent unable to face the new challenges. Therefore, we need a new approach, the green networking.

Green networking refers to techniques, mainly related to data link, network and transport layers, aiming at provisioning services to the communicating entities under the premise of minimizing the impact in terms of energy consumption, spectrum use and radiation while guaranteeing the QoS user profile. It requires a rethinking of architectures, protocols and implementation techniques in the light of these concerns. Moreover, it should be part of an overall holistic cross-layer approach to address energy and spectrum concerns jointly at networking and radio levels.

Green networking is not just a new approach to classical networking issues: it has to deal with the drastically different nature of future networks. These networks will be largely hybrid networks, formed by the combination of wireless and wired infrastructure networks, and ad-hoc networks. We can distinguish two (related) domains with different focus regarding green networking:
green deployment and green operation of wireless networks.

7.3.1 Green deployment

Green deployment, relates to the establishment of a network infrastructure, dealing with, e.g., radio access, cellular, pico- and femto- cellular networks, WLAN infrastructures, etc.

7.3.1.1 Integration of multi-hop solutions into cellular networks

Wireless Mesh Networks (WMNs) are an emerging two-tier architecture based on multi-hop transmission, forming a self-organised wireless backbone. WMNs have the capability of enhancing network coverage and reducing deployment costs. The fact that a wired infrastructure is not needed for interconnection of mesh routers makes WMNs a solution that provides connectivity to end users in a very efficient way. They can be deployed easily to optimise routes and minimise energy consumption. Furthermore, the usage of multi-hop solutions for the backhaul of heterogeneous networks leads to an efficient usage of radio resources in base stations and access point. It also minimises interference and hence requires lower transmission power. Furthermore, the use of a wireless backhaul in WMNs reduces the use of wireline transport networks, hence, reducing the natural resources needed for deploying these networks and the impact on the environment of the installation.

Way forward

- We need to develop multi-hop mesh solutions for backhauling of heterogeneous networks to get a significantly more efficient usage of radio resources in base stations and access points.
- We need to develop multi-hop mesh solutions for reducing energy consumption from the terminals to the base stations and access points.

Tight-integration of network deployment (from macro down to femto)

With the upcoming roll-out of femto-cell architectures, future mobile communication will be even more characterized by a nested architecture where macro-, micro-, pico-, and femto-cells deliver wireless connectivity. In addition, in all these network topologies, different radio access systems are used (e.g., UMTS, HSDPA, LTE and WIMAX), which increase the problem of efficient resource management, the key anchor point to facilitate green wireless communication.

Delivering indoor coverage with femto-cells strongly reduces power consumption compared to the use of macro-cells. However, parallel operation of these networks may cause mutual interference. This clearly distinguishes the problem of managing different deployments from handling heterogeneous access networks since different access technologies usually operate in different frequency bands.

Way forward:

- We need unified resource management to significantly reduce overall power consumption of wireless systems with nested topologies. The mutual interference demands full integration of network deployment. It requires the design and development of new technologies and concepts ensuring such a full integration of several deployments.
- We need novel advanced techniques for interference coordination and interference management between femto-cell and macro-cell base stations at levels from physical up to higher layers.
- We need protocols and architectures for heterogeneous access and core networks aiming for a fixed mobile convergence of networks with a tight integration of several network deployments applying identical wireless access technologies.
- To deal with the increased complexity of the solutions, we need better solutions for self-configuration and self-optimization technologies in the context of the variety of network deployments.

Resource sharing and resource management techniques for energy saving

In order to make optimal use of the limited resources when deploying a wireless network, an optimal combination of topologies, radio-interfaces, and protocols has to be selected, taking into account energy saving in the nodes and subsystems, spectrum use, radiated power, etc. The shape of the cost function will depend, e.g., on the desired model accuracy, the computational overhead allowed (very relevant when running over limited computational capability devices). Network load balancing and smart information storage in distributed networks could lead to substantial energy savings. Networks need environment sensing capabilities, where users are communicating, establishing a map of signal, interference, and other parameters. This will lead to the possibility of networks to predict the channel behaviour of users, hence, optimise the use of resources.

Way forward

- Optimization techniques and tools are needed for optimizing resource sharing and resources management during the deployment of wireless networks.

7.3.2 Green operation

A number of different techniques can contribute to green networking in the highly-dynamic emerging networks. Besides some classical approaches like routing, cross-layer optimization, etc., new networking paradigms offer opportunities to save energy.

7.3.2.1 New networking paradigms

Cooperative networking is a strategy where network elements belonging to the same owner or across domains cooperate and assist each other, instead of competing in using resources in order to globally optimize spectrum usage and reduce power consumption. Cooperation is a logical way forward when network elements belong to the same owner, as for instance in home networks and personal networks. Considerable gains can be obtained through cooperation.

Cognitive networking refers to the use of artificial intelligence-like techniques to make better choices in operating a network or a set of networks. An example could be that a mobile network could predict time and access points to dock with another network or with the Internet. It could be possible to save energy by predicting when to transfer non-time critical data at the best possible moment via the best choice of access point.

Opportunistic networking is a technique applicable to networks where the connectivity is intermittent and, by extension, where the characteristics of the connectivity vary considerably in time. This is in particular applicable to moving networks, that intermittently dock with an infrastructure or other moving networks (e.g., vehicular networks). Opportunistic networking, in particular in combination with cognitive networking can be used to choose the best opportunity to transfer data.

Delay-aware and delay tolerant networking is applicable to the support of services where delay is not a key requirement. Instead of activating resources that consume energy but cannot be necessary because of the delay-tolerant nature of the service, the goal of this approach is to optimize consumption using minimum resources.

Virtualization implies flexible mapping of virtual communication resources, e.g., virtual gateway or router, onto real resources. It has the potential of sharing resources and consequently decreasing energy consumption. Moreover, decreasing the equipment deployed not only reduces direct energy consumption but also the energy and pollution that its recycling implies once equipment is replaced.

Way forward:

- Besides global optimization techniques, principles and techniques are needed to base cooperation on, e.g., incentive schemes.
- Apply cognitive techniques, in particular prediction, to choose network elements and access times for reducing energy consumption.
- Develop opportunistic networking techniques for minimising energy consumption.
- Develop decision-making techniques based on the conditions of the network and the type of services, e.g., when to transmit and to which node.
- Develop virtualization techniques to achieve energy-saving resource-sharing.

7.3.2.2 Classical networking issues

Typically routing algorithms use a single cost function, the number of hops, when selecting a route between two nodes. Green networking requires multi-criteria routing involving “green variables” weighted according to criteria agreed by the stakeholders.

Pattern-based optimization of network resources can be an energy-saving alternative to network over-provisioning. Aspects such as the use of the network by end-users, the location, the time, etc. are actions that exhibit patterns. A fully configurable network with the ability to envisage to some extent the requirements in terms of network use will optimize the necessary resources and consequently minimize the required energy.

Opportunistic interface selection by users can be used to improve the connectivity of users in flexible spectrum environments and, thus, help alleviate the problem of excessive energy consumption. This approach is applicable in scenarios where a user can connect to several

networks using a multiple interface terminal or in a personal network where the user can select one of the many interfaces of different personal devices.

Energy efficient security and trust is crucial since most security protocols are energy hungry and resource consuming, and require many interactions between wireless devices as well as between wireless devices and fixed network elements. Solutions need to be investigated for providing the necessary security with less resources and energy.

Way forward:

- Multi-criteria routing techniques for optimizing energy usage need to be developed.
- Techniques are needed to recognize and predict patterns in network usage to optimize energy usage in conjunction with fully configurable networks.
- Develop techniques to allow opportunistic selection of air interfaces to achieve a best-connected situation from an energy point of view.

Develop new ways to achieve the required levels of trust and security in wireless environments with significantly less resource and energy consumption.

8 Business Environment

8.1 Changes in the environment

Future systems have to support a changing and flexible mobile ecosystem. Therefore it is predictable that multiple viable business models will coexist with the emerging new players in the arena.

Indeed, the traditional stakeholder model (e.g., content provider, service provider, network operator, equipment or device manufacturer, end-user) and the stakeholders' relationships can have significant evolutions. New stakeholders in the value chain are now appearing, mainly providing value-added services for enabling efficiency and system interoperability, network monitoring and management, customer-care support and device management.

However, the convergence of telecom, ICT and media industry is challenging the traditional linear value chain model. In the telecommunication sector, the work in standardization organizations had a crucial role and the collaboration between the network operators, infrastructure and handset manufacturers was quite straightforward. At the converged situation, new stakeholders are arising, and the same stakeholder can be simultaneously in a position of competitor, vendor, and complementor. This makes the interrelations between the stakeholders more complex, replacing the linear value chains with value nets. Totally new stakeholder categories, as content aggregators and brokers, are also arising due to new business models.

Also the stakeholders in the current business model are changing. As new players one can identify virtual network operators, sensor network and RFID manufacturers, sensor network connectivity operators, mobile and ad hoc network operators, customer care support centres, security (e.g., certification, key distribution) authorities and guarantors, regulatory bodies for spectrum harmonisation and even the IPR-related industry and community.

Consequently, additional research priorities appear: it is imperative to be able to quantify the viability and sustainability of a business model, and how the business innovation is combined with the technological innovations, especially in relation to disruptive technologies. Indeed, the SRA's user-centric vision should propagate onto business strategies that are in line with the SET Concept that stresses the need for integrated solutions and not for a specific technology research.

In particular, mobility and mobile e-commerce will require radically faster processes for setting up new business relationships. Time-to-market for a new type or instance of a value network must be cut down to a fraction of what it is today. This requires a streamlined approach for taking into account, e.g., automated service provider discovery, negotiation processes and contracting, as well as adoption of micro-payments and streamlined pricing and billing. Different automated auctioning procedures are also emerging that tackle simultaneously several of the above mentioned issues.

8.2 Evaluation of Business Models

The main question regarding business issues of current and future wireless systems concerns how to create an ecosystem utilizing fully the changing roles of different stakeholders and the technological changes affecting the area. However, a knowledge gap exists as to the degree to which political, economic, social, technological, legal and environmental aspects are integrated with each other in innovation trajectories. One example of this gap can be found in the different level of maturity between the technical approaches for building the functional architecture and the approaches for building the business architectures and models which fit the demands of the society and create sustainable added value to the customers.

One solution to the problem would be the adoption of new modeling methodologies for business model estimations and for defining the sizes of the profit pools in the value network. These new practices should address the specific requirements set forth in the vision paradigm, and should allow efficient value vs. cost estimations for different stakeholder financial relationship scenarios. However, the customer reactions are difficult to model, and therefore end-user studies and pilots will always be needed, additionally to models.

When generating new business models, they are typically considered domain-specifically, but new opportunities can be reached by the

- Capability to have concurrent and or complementary business relationships with different domains
    - Example: a peer-to-peer service provider may experience business relationships with its subscribers, with an infrastructure operator, with a wireless network provider, with value added service providers, with advertisers, etc.
- Capability to manage more complicated business relationships with a peer domain
    - Example: a manufacturing domain owner may undertake third party relationships for subcontracting whilst granting manufacturing licenses or IPR royalties

- Construction of a dedicated user domain class, in conformity with the user-centric vision.

Specific aspects should include:

- Support of seamless and simultaneous connectivity to different domains (e.g., wireless operators, wired operators, local residential connectivity, etc.)
- Simultaneous accessibility to services from different service providers (e.g., having a phone conversation during a NetMeeting connection, the two services being provided by different domain owners)
- Complex connectivity conditions (e.g., simultaneous roaming with different network operators, sensor network connectivity)
- Different simultaneous connectivity and service consumption situations (e.g., audio and video streaming with different media transport supports)

The objective of the work would be to create business model evaluation practices that allow a quick pre-estimation of the business viability and sustainability that can result from a new ecosystem of different stakeholders, and takes into account the disruptive technologies changing the roles of the stakeholders.

Other topics that need to be considered are:

- Prototyping and piloting vertical market-specific light-weight value-oriented networks.
    - In the SET framework new network topologies would be considered. In this respect new ecosystem topologies may appear as well, leading to the need of modeling the value proposition in different contexts.
- Research into value networks based on non-monetary compensations (e.g., social agenda for end-users, brand lift for manufacturers and operators, etc.)
- Specific research into peer-to-peer mobile e-commerce
    - Peer-to-peer is not just a communication support: it implies new tenets in regulation of economic transactions. Its impact on the value chain and on traditional stakeholder business opportunities must be assessed and quantified.
- Case studies on highly successful real mobile e-commerce. Posterior verification of the capability of forecasting the success of these case studies
    - Business viability modeling practices need ‘calibration’: Specific parameters, variables, information models must be consistent in a wide variety of representative cases.
- Comparative techno-economic analysis of new competing radio technologies and their specific environments (e.g., local, wide-area, residential, sensor-based)
    - Two basic SET tenets are simplicity and efficiency: These reflect onto viability and sustainability of the underlying business relationships. Only a quantitative techno-economic analysis can allow such assessments.

8.2.1 Business Models Applied to 'Trust and Dependability'

Trust implies the following main issues (non-exhaustive list):

- Terminal ID authentication and verification
- User ID authentication and verification
- ID federation across terminals and networks
- Access right management and consequent secure communication

Typical stakeholders in this domain are, e.g., ID guarantors, biometric chip manufacturers, secure communication service providers, etc. The typical metrics for evaluating the viability of Trust are, e.g., solution scalability, solution cost and clearness in establishing the liabilities of the different stakeholders. The profit pools in the business relationships among the stakeholders should be estimated and defined.

8.2.2 Business Models Applied to 'Ubiquitous Services'

From the ubiquitous services perspective, tenets and research priorities, it stems that service management and related network support functions can be pushed more and more towards the network edges (e.g., gateways and even end-user devices). Irrespectively of the service provisioning architecture and topology, service providers and application developers need to maintain their control points, in order to grant content usage policies, customer support and billing procedures to their customers. New stakeholders could appear in this respect: for instance, the emergence of intermediaries like portal providers, portal personalisation service providers and others. In such context it becomes important to evaluate and quantify whether new business opportunities exist, in order to ensure the most cost effective service consumption procedures to the end-user via the most appropriate terminal.

Typical metrics for evaluating the viability of ubiquitous services are, e.g.,

- Solution scalability
- Speed and easiness of service deployment
- Cost of media servers
- Cost of Service Level Agreements

The above metrics should be formalized and quantified to estimate the impact on the business relationships among the stakeholders, including the newcomers.

8.2.3 Business Models Applied to 'Ubiquitous Connectivity'

Ubiquitous connectivity implies the inter-working of, e.g., wide area networks (WAN), metropolitan area networks (MAN), local area networks (LAN). These are different environments, from the technical, management and business viewpoint. Lines inside WAN, MAN, LAN can be owned or

leased, thus implying different impacts on the system cost and billing models. Additionally connectivity implies roaming, and consequent complicated roaming relationships based on different business and technical metrics. In the connectivity domains many diversified stakeholders play prominent roles whose relations have to be estimated:

- Network providers owning different domains in the WAN, MAN, LAN spaces
- Inter-domain gateway providers
- SLA and O&M tool providers

8.2.4 Business Models Applied to 'Radio Access'

Specific issues in the Radio Access framework go well beyond classical radio design. Topics like 'self-organising network topologies and operatorless radio access networks', 'cognitive and spectrum-agile' radios and 'frequency sharing' imply new control points, in order to guarantee ubiquitous coverage and capacity and ultimately, guarantee the QoS to the end-user. New stakeholders would probably appear: for instance, the opportunistic spectrum use implies a strict control on the spurious emissions, at both terminal and infrastructure side. Again, liability issues appear affecting possibly the legislation and regulatory aspects: if an operator is liable for providing radio access in its assigned frequency spectrum; is such operator equally or even more liable when it uses additional frequency bands on secondary basis?

The role of a radio access network provider can have a significant evolution, according to new revenue opportunities and to new responsibilities to the end user. Again, quantifying the business aspects of the future radio systems and their complexity is of paramount importance, for helping the relevant stakeholders quantify the expected return of investment, and thereby deciding on the most appropriate business strategies.

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