eMobility

Mobile and Wireless Communications
Technology Platform

Strategic Research Agenda

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Staying ahead!

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List of Acronyms

AAA	Authentication Authorisation Accounting
API	Application Programming Interface
BAN	Body Area Network
BWA	Broadband Wireless Access
CMOS	Complementary Metal Oxide Semiconductor
DoS	Denial of Service
DRM	Digital Rights Management
DMB	Digital Multimedia Broadcasting
DVB-H	Digital Video Broadcasting-Handheld
EC	European Commission
GHz	Giga Hertz
ICT	Information and Communications Technologies
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
MEMS	Micro-Electro-Mechanical Systems
MIMO	Multiple Input Multiple Output
NEMS	Nano-Electo-Mechanical Systems
NoC	Network on Chip
OS	Operating System
PAN	Personal Area Network
PC	Personal Computer
PDA	Personal Digital Assistant
PN	Personal Network
QoS	Quality of Service
RAN	Radio Access Network
R&D	Research and Development
RF	Radio Frequency
RFSIM	Radio Frequency Subscriber Identity Module
RTOS	Real-Time Operating System
SDR	Software-Defined Radio
SIM	Subscriber Identity Module
SLA	Service Level Agreement
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
WSDL	Web Services Description Language
WSN	Wireless Sensor Network
XML	Extensible Markup Language

1 Vision of Future Mobile & Wireless Communication

By the year 2020, mobile and wireless communications will play a central 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 on any device, right content in the appropriate context, in a secure 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 communication environment, e.g., effecting personal preferences independently of the system, device, location, operator, service, and so on. This also means that networks and service provision should be based on users' needs and interests, namely the establishment of group communications. User communities, e.g., families, 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. 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 in hiding 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 benefits through a system made available. The user will pay for usage, devices and services, but the cost needs to be justifiable. A trend towards taking things for granted exists, but will bring more emphasis on security and trust. Furthermore, systems and networks should be waiting for users, and not the other way around, i.e., efficiency is high at all times. This leads to considering dynamism and resource-borrowing. Seamless connection between private and public services, local and long-range communications, will be a major enabler of 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 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 communications, 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, being 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 vision depends very much on simplicity of access and use of services and of 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, viruses, etc.) 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 any unnecessary, irrelevant and redundant components.

Multi-sensory is related to all the users' devices, and also to the fact that the environment will be capable of sensing the user's presence. Also, virtual presence may be considered, implying more sensory information being communicated, and an ideal of a rich communication close to the quality achieved in interpersonal communications or direct communications with another environment; this could also include non-invasive and context-aware communication characterising polite human interactions. Therefore, this stretches 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 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 surrounding us is quickly increasing. This will increase the amount of data traffic needed to be transported.

Information and content signifies that voice traffic will lose its place as the main contributor to the data traffic. The myriad of hyped services and applications and those that have not yet been invented are now growing the transport need. E.g., e-government will have a big role. 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 look at users as our children and grand children, who will be the active population in 15-20 years' time.

Many steps are required to put this vision into reality, and clearly 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 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 projects dealing with these specific areas.

2 Seamless User Experience

2.1 Vision

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, desktop or laptop-centric computing. Furthermore, foldable displays and printable electronics offer opportunities for new innovations, as current physical restrictions are gradually disappearing.

Ultimately, it is the user experience that drives the adoption of new services. 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 also 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 users' requirements to be derived in a systematic way.

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

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

2.2 User Experience and Acceptance

2.2.1 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, competencies and levels of acceptance chances over time. Then the research and testing activities should be done following a dynamic process – not in need basis.

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 infrastructure. One should understand the user's preferences and

requirements regarding future multimedia communication services in different contexts, and to 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.

2.2.2 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 (children, disabled, elderly) through multi-modal user interfaces. New mobile technologies can overcome the digital divide and increase in possible cultural, social and political participation and understandings. 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 experience, where user becomes a part of a community. Online games, media on demand, rich communications, education, 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.

Coming back to the fundamental user research questions, advanced technical solutions do not guarantee success if they are not justified by users' needs and requirements.
The fundamental questions that need to be investigated are:

- How to ensure and improve the acceptability of services? 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 to 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 user's 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.

2.3 Smart User Interfaces and Interactions

2.3.1 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-explaining, 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 intuitivity 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 different 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.

However, the multi-dimensional heterogeneous usage environment poses several important challenges with respect to zero-configuration and hiding complexity from a user. Machine-to-machine communication and sensor networking technologies 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.

2.3.2 Research Priorities

Key challenges in user interfaces and interaction area is 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.

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 people's data do not end up in wrong hands and is not used against them.

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

In summary, multi-modality and context-awareness in user interfaces create fundamental research challenges that target enabling better user experience:

- Explore how context-awareness can provide rich and consistent user experiences for future mobile applications and systems.
- 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 input/output devices, and bring new opportunities for user interfaces and more comprehensive interaction.
- Enable automatic zero-configuration and complexity management (including the management of privacy and trust) in order to make it easy and simple for users to reach services with a minimum of effort.

2.4 Future Mobile Device Form Factors

2.4.1 Rationale and Objectives

So far, mobile devices design has been bounded by different practical factors 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 foldable 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 (inside) her clothes or other wearable materials without additional weight.

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?

2.4.2 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)
- Usability and simplicity of the new devices

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.

3 Business Infrastructures

3.1 Vision

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 actors leading to a new supporting architecture.

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 are now appearing, mainly providing value-added services for enabling efficiency and system interoperability, network monitoring and management, customer-care support and device management.

Among the new stakeholders, we can identify virtual network operators, sensor network 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 unlicensed spectrum harmonisation and even the IPR-related industry and community.

Consequently, additional research priorities appear in business infrastructure context: it is imperative to be able to quantify the viability and sustainability of a business model, especially in relation to disruptive technologies that will be developed under the European Community umbrella. Indeed, the SRA's user-centric vision should propagate onto business strategies that maximise the value for the end-user, whilst minimising the cost for this value creation.

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.

3.2 Rationale and Objectives

The main question regarding business issues of current and future wireless systems concerns how to maximise the potential of the technical change in terms of business objectives. However, a knowledge gap exists as to the degree to which economic, financial and organisational aspects are integrated with technological models 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 financial approaches for building the business architectures and models.

Hence the need arises for the adoption of new modelling methodologies for business model estimations. 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.

The modelling practices should relay on the domain class, which is instantiated for any traditional or new stakeholder. The figure below represents a simple domain class in pictorial form. The domain is intended in a business sense; its attributes are:

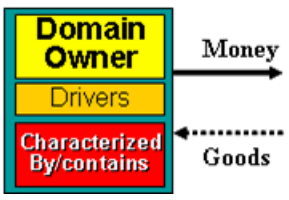

Figure 1. Domain as a basic building block

- The ownership: e.g., a wireless network operator
- The drivers: e.g., the wireless network operator's business drivers relate to managing users, their profiles and the SLA to which they are entitled
- The domain characterisation (from the business viewpoint): e.g., for a wireless network operator, billing, subscription management, AAA rules

Note also that a domain interfaces with other domains. The interactions are in terms of paid money versus received goods (e.g., equipment, services)
The figure below represents an example business application, in which only three domains are identified: the wireless network operator, the wired network operator, and the application or service provider.

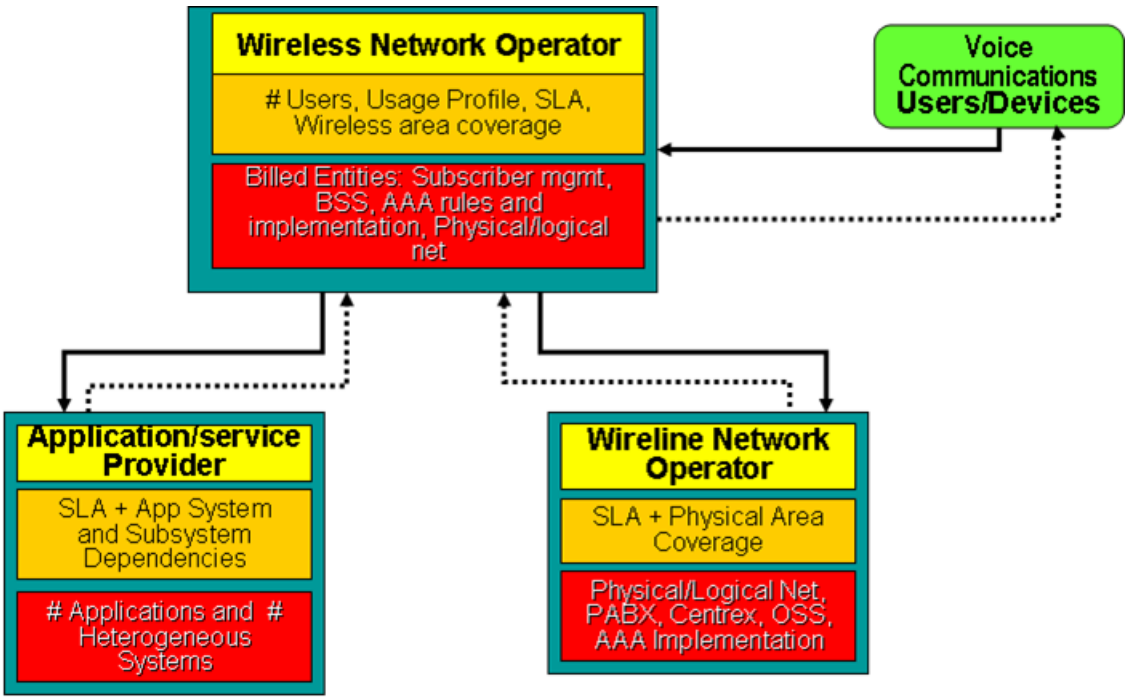

Figure 2. Example of a business application with three domains

The domain concept is a means for a simple representation of financial transactions between different stakeholders in today's well-established business situations.

This approach is somewhat limiting for treating future mobile business, where the seamless end-user experience is at the centre of the overall picture and where multiple simultaneous business agreements may take place between classical and new stakeholders. The domain building block (e.g., class) should undertake significant modifications in order to fulfil the vision paradigm and consequently reflect the business expansion for accommodating the role of new stakeholders. Examples of the domain class extension are:

- Capability to have concurrent and or complementary business relationships with other 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)

Final objective: consolidating and disseminating business architectures and modelling practices that allow a quick pre-estimation of the business viability and sustainability that can result from a novel enabling technology. Such practices could prove extremely useful if implemented in IST across a wide range of projects.

3.3 Research Priorities

The priorities that need to be considered are:

- Consolidating the modelling approach and practises after wide consultation with worldwide stakeholders (both traditional and new)
- 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 peer-to-peer mobile e-commerce
- Case studies on highly successful real mobile e-commerce. Posterior verification of the capability of forecasting the success of these case studies
- Comparative techno-economic analysis of new competing radio technologies and their specific environments (e.g., local, wide-area, residential, sensor-based)

In order to consider the above priorities and quantify market and value impacts, suitable software tools need to be identified or constructed.

4 Security and Privacy, Trust Architectures

4.1 Vision

Mobile and wireless communications will deliver an always connected environment for the general public. This environment offers a new world of secure mobile services that are trusted by end users as well as by the service or content providers, operators and business partners. It protects users from attacks by viruses, Trojan horses, privacy violations, spam, phishing attacks, etc. and it provides convenient and secure solutions for mobile business, privacy, payments, messaging, and user authentication and authorisation. To this end, all components in the system and the tools for their development encompass support of strict security and privacy requirements. A common, trustworthy and interoperable security and privacy infrastructure, in connection with well-defined security management service as a part of mobile service life cycle management implement these requirements.

4.2 Rationale and Objectives

Technology convergence will be a key driver of the evolution of wireless communications towards eMobility. The converging sectors of the industry (e.g., internet and IT, infotainment, mobile communications, consumer electronics) carry a different history on security perspective and technical solutions. Therefore, security should integrate and evolve the existing security technologies through open standards in order to meet the requirements of the future advanced service products.

In addition to security technologies, attention should be paid on security management as a part of life cycle management of mobile infrastructures or mobile services, and what kind of functionalities should be established to take care of this, especially in the case heterogeneous networks. There will be no security if there is no security management. Security technologies enable the actual management. Management should be as automated as possible. In particular, end users cannot be required to carry out complex security procedures. Attention should be paid to supporting crime and fraud detection in networks and services.

The role of security is essential in all parts of the future network architecture. Security should be taken into account in the operation of the terminal, the radio access network, the core network and the service platform part and in all layers including hardware, operating systems, protocol stacks and applications addressing the relevant constraints and security threats (e.g., virus, DoS, spam, spim, spit). The great challenge for the future security framework is to maintain simplicity and efficiency without leading to heavy implementation solutions.

The security solutions should be analysed from the overall system point of view. Furthermore, it is extremely important to understand cross relationships between different security risk factors that can be generated by the heterogeneous environment and interconnection of equipment and services designed originally standalone.

The level of offered security should be adapted to the service needs in terms of user authentication, authorisation, confidentiality, integrity, privacy, anonymity, identity management, and content delivery. Security-dependent applications like m-payments, m-health, content distribution and user profile management, are expected to drive the evolution towards an eMobility security framework. The required level of security depends also on the context. It should be noted that security threats in future services might also have implications to the relevant regulatory and legislation framework. Research efforts and results should be taken into account when reviewing the regulatory framework for electronic communication starting in 2006.

The *e*Mobility vision will also evolve the business model by including a wide range of business players (e.g., terminal manufacturers, operators, service providers, content providers, hot spot operators), which will constantly interact even in real time in order to achieve the delivery of attractive user services. The stability of such a complex and demanding value constellation

requires a trustful transaction framework which will ensure appropriate interfacing between a large number of business players.

Trustworthiness depends on adequate provisions of security throughout in the chain of communications and its environment.

Security has to be one of the design criteria pervasive in system and service engineering. The way security is included has strong implications for functionality, efficiency and costs. The objective is to identify and develop options providing for appropriately tailored trustworthiness taking into account both private and public concerns.

Privacy is inherently important part of user trust on mobile services. From the point of view of service providers and service developers, correct and careful implementation of privacy requirements is important too. If their privacy solutions are not adequate, the situation can lead to heavy financial implications.

4.3 Research Priorities

The research priorities for security, trust and business infrastructure aim at the development of the security infrastructure for the eMobility vision and include the following areas of research:

Security in the Future Network Architecture:

- Device: 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 security concerns into the picture and new measures are needed to protect the devices and data stored in them or accessed through them. As the device acts as a gateway to the user's environment, authentication and authorisation need to be bullet-proof. Also, there is a need to move up from the current paradigm of authenticating the device to the system into actually authenticating the user
- Radio Access Network: The evolution towards a heterogeneous wireless access environment with cooperating access systems introduces challenging issues for security, which mainly ensure seamless secure roaming
- Core Network: Future composed networks will introduce new security requirements to be addressed
- Service Infrastructure: Future service platforms will introduce new security requirements to be taken into account

Security and trust in future business models: Issues related to secure transactions between business infrastructures need support of advanced services including the exchange of sensitive information like charging, accounting, user profile data, user location, context, etc. In addition technologies to allow for secure and trusted transactions among multiple business players are required. The role of brokers responsible, e.g., of security and privacy management (trusted certificate authorities) in certain networks and services needs to be understood.

Regulatory issues and legislation implications: The research activities can provide early detection of regulatory and legislation issues which may include for example recognition of modern security crime, adoption of security technologies as a trustful basis for treating sensitive information (e.g., user private data). Reaction from legislation could be needed for example.

User perspective: Commercial success of *e*Mobility vision heavily depends on user confidence. In this context, the user needs should be taken into account in any relevant research activity while user trials should be exploited in order to capture the user perspective on security aspects. Adequate security and privacy solutions can be seen as an enabler for new mobile services.

The security framework and associated technologies: The future security framework needs to contain evolved security mechanisms in the areas of:

- Authentication and authorisation
- Encryption and cryptology
- Identity management
- Privacy
- Content protection
- Trusted transaction environment

The overall challenge is to maintain seamless and transparent end-to-end security 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 as desired, while ensuring accurate charging for the services that have a cost.

5 Ubiquitous Services

5.1 Vision

The potential separation between business related to access provisioning, and business related to services (as it has been discussed earlier in the document) brings out new challenges as far as the profitability of emerging business models is concerned. The agenda of future services includes creation of, adaptation, hosting, provisioning, configuring, and using new services that improve the quality of life of the individual who is part of a dynamic and interacting environment. In order to realise this, a total of 4 orthogonal research agenda points are identified which are explained in more detail throughout the remainder of this chapter:

- The innovative services: user services that change the quality of life of the individual in a sensor-filled, dynamically changing and interacting environment
- Service creation process environment that realises and eases the creation of services and decreases the time-to-market
- Content and media creation and adaptation that improve information and content and make available services instantly on various terminals
- Service execution environment, that 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 need to be taken into account in the solutions of tomorrow, working towards convergence of the various network domains, depicted in **Figure 3**.

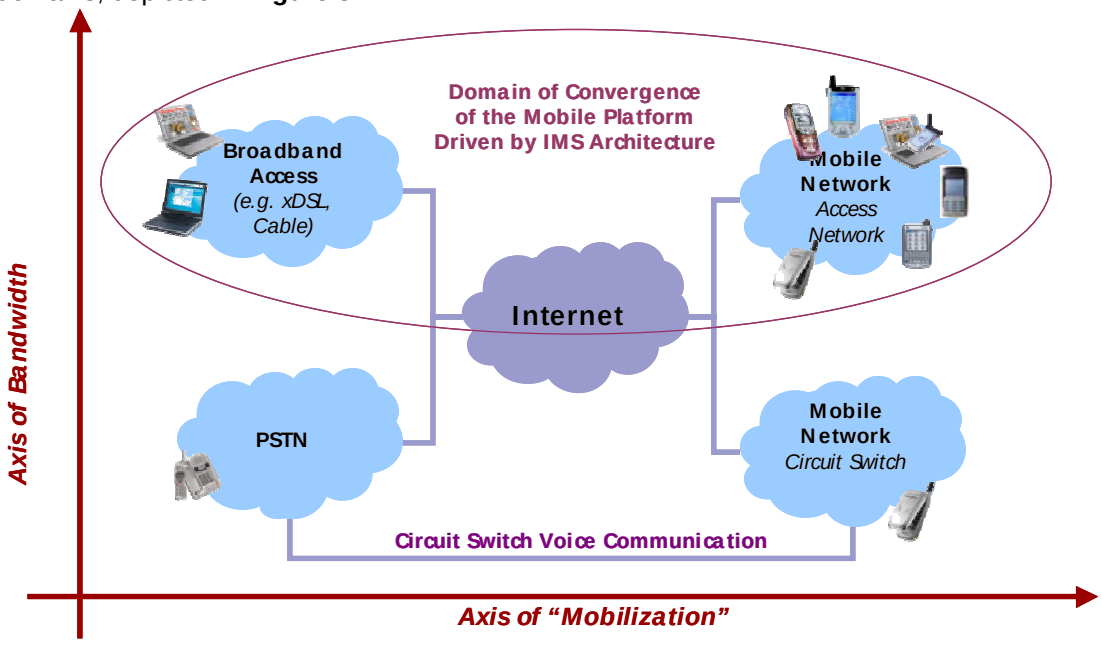

Figure 3. Trends in Service Architecture: The Telecom Evolution

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
- optimally exploit the communication capabilities available at the user side
- be easy to 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, e.g.,

- 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 able to anticipate
- 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

- Managing in an efficient way the huge amount of information either gathered (or pushed) by (to) the user allowing an efficient and accurate a posteriori 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 kinds of 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., 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

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. If wireless applications and services become pervasive, it would mean that the users would use a truly substantial number of wireless terminals and devices. People and all their "things" communicate: there will be a transformation from one transmitter per thousands of persons in the broadcast age, via one transmitter per person in the mobile phone age, to hundreds of tiny wireless devices per person in the ubiquitous networking age. 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. A truly pervasive technology is (almost) taken for granted to work and be extremely reliable. Electric power is a good example of such a technology. An invisible technology needs to be

- Auto-everything (almost no conscious user interaction to configure, install network elements and terminals)
- Reliable and simple to use
- Easy to add new services
- Extremely low cost (the future user will spend proportionately a similar amount of money than today on ten to a hundred times as many wireless devices and their communications)

The networking world will become a world divided between a wide-area networking and a local networking world. The

- Wide-Area domain

  is the one of today’s public systems providing fixed broadband networks and wide-area mobile coverage. “Natural monopoly” economics rule this domain and public operation, with few competing market actors is the natural evolution. In the mobile domain “any-time-any-where” communication is what the user expects, hence the demands on reliability have to be very high. Interworking with other network infrastructure will provide full connectivity between legacy and new types of networks, e.g., home networks, office networks, body networks, campus networks, vehicle networks, moving networks, and production networks. A common service support over all these networks makes the services available anywhere over any access.

- Local domain

  is the networking close to the user and includes local wireless access in homes, offices, shopping malls, so called hot spots, where people live and dwell. In this world there will be a large number of competing technologies that will cater for reliable access and larger capacity at low cost. Wide-area technologies will be part of the connectivity offering. Here new wireless terminals and infrastructure components (similar to electric appliances) are no-maintenance or disposable and self-configuring, local access networks that 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 which creates new business opportunities and competition. Facility, shop and restaurant owners and even private persons will provide both wireless access to global services, as well as, 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 dominated by the following trends:

- *More intelligence in the end-points - not in the transport infrastructure*

Moore's law works for electronic devices - not for infrastructure since infrastructure costs are dominated by wiring, installation, maintenance etc. New user equipment and servers appear on the market in a matter of months, large-scale infrastructure deployment takes years. The consequence: more flexible and intelligent end-points (terminals, access points, PANs, devices, and network elements such as servers and gateways) that autoconfigure, adapt to services, user needs and network capabilities. IP-based (or similar) transport network, independent of access (fixed or mobile) – the end-to-end principle applies to all services beyond basic connectivity, and are provided at the edges of the network, not by the transport network itself.

- *From "Single system for all needs" to navigating in the "Wireless mayhem"*

No single wireless access solution or radio technology is capable of providing affordable 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 local area networks (WLANs). Instead, future wireless access will be provided by a system of heterogeneous access networks. New access technologies will appear (e.g., Super-3G, high data rate WLAN, gigabit-per-second short range systems) and many will be successful in niche scenarios, thus complementing existing technologies rather than replacing them. More advanced radio access networks (RANs) (e.g., for high speed mobility and quality of service (QoS)) will need to coexist with simple local access solutions (e.g., best-effort nomadic connectivity), and modern infrastructure will coexist with the old. 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 & competition*

Multimode terminals can adapt to both new services and new wireless access technologies in a much faster and flexible way, than the infrastructure itself. Significant cost gains are derived from multimode terminals and efficient use and reuse of access resources. The fact that full coverage is no longer necessary for all access options is probably a key factor. Infrastructure can be incrementally and cost-efficiently deployed, where needed. Effective access competition may provide additional benefits for the users.

- *Networks that automatically "compose" and manage themselves*

The heterogeneity between the network administrators will increase, ranging from the typical non-technician who expects the systems to work flawlessly and will spend only minimal, if any, 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 want to spend less money on management. This implies that the management systems must be more self-managing, 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.

6.2 Ubiquitous Networks

6.2.1 Rationale

Flexible growth from small-scale, up to Europe-wide systems and services needs to be supported, enabling a wide variety of man-to-man, machine-to-man and machine-to-machine solutions for all the various application areas offering both unicast and multicast solutions. This implies full data and multimedia connectivity between and amongst users and devices and sensors in their main locations (e.g., in the home, office and car).

The heterogeneity between the network administrators will increase, ranging from the typical non-technician that expect its systems to work flawlessly and will spend only minimal, if any, 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 want to spend less money on management. This implies that the management systems must be more self-managing, 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. This will include policy-based networking within a given business framework to enable maximum and stable use of the networking resources.

The support of the applications will have to be extended; increasing the semantic understanding of media flows in the network and creating service-specific overlays. This will require considerable research efforts.

Wireless sensor networks will capture the ambient intelligence surrounding mobile users. Capturing, classifying, filtering and sensing situation and context through phenomena and signals from the physical environment will support and significantly enhance and enrich personal, family and community-focused mobile applications and services, as well as, enhance wireless communication systems.

Home is to be modernised by a collection of specialised intelligent networked devices, which ideally will be seamlessly integrated with the home environment.

6.2.2 Objectives

The scope and major objectives of the research are therefore to:

- Enable development and integration or interworking of ubiquitous network technology with innovations in the applications field to provide full connectivity between legacy and new types of networks, e.g., home networks, office networks, body networks, campus networks, vehicle networks, moving networks, and production networks
- Enable the future infrastructure supporting multi-service capability and mobility over multi-access networks (fixed and the mobile networks) that enable true broadband for all and everywhere. It will be increasingly important to simplify the usage of services, including, e.g., activation, robustness, understandable charging and quick response. Privacy, security and safety are prerequisite 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
- Define a network architecture that supports high-bandwidth real-time services over multiple access technologies
- Develop new network solutions with full acknowledgement of optical transmission, and integration and support of existing and future mobile and fixed access technologies supporting all types of traffic
- Support network-sharing between (mobile) operators within the boundaries of the respective licensing conditions

- Understand the evolution towards context-awareness and support of cognitive networks and media-aware networking
- Enable always-on systems: Information can be accessed anytime, anywhere as if it were stored locally (e.g., music database on mobile players). All services that are used in one location shall be made available everywhere with support of user and device context
- Create support for network and system management that are highly self-managing to lower the level of required skill 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)
- Support extended interoperability of heterogeneous devices critical for ubiquitous home networking. Starting from today's strictly separated domains all having their own industrial players, and carrying on to domains interoperable and able to communicate with each other in an ad hoc manner
- Support automatic context-aware discovery, selection and composition: Automatic discovery of devices, networks and services as well as personalised service selection and composition will need to be supported by in-home networks
- Provide constant and ubiquitous access to data, services, devices, and networks

6.2.3 Research Priorities

Today's trend is that large, feature-rich systems tend to become more complex to specify, build and operate. We also see that more elementary location-sensing is becoming universally available for mobile users. In the future, devices will scan the surroundings of mobile users, or sense the physical situation of the users themselves, extending their capabilities. Hence further research is needed on the:

- Design of network architectures and definition of functional requirements for auto-configuration, auto-connectivity, self-organisation and self-management of heterogeneous devices in heterogeneous and dynamic (access) networks in view of seamless support of various professional and private, fixed and mobile services, ranging from low data rate, non real-time to broadband, interactive services
- Scalability of network and service control technology which can deal with all sizes of network 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 (including 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 radio technology as well as application middleware to support applications of all kinds
- Network-driven transmit diversity to find suitable (access) networks that can be used simultaneously to transmit and receive data
- Multi-layered mobility support, which enables ad hoc cluster mobility, as well as, user-mobility across networks
- Integration of sensor networks, which efficiently use the resources of larger networks (from PANs to WANs) for communication
- Delivery of information and media flows to users, adapted to their current access situation, location-dependent interests and preferences

- Unified solutions for personal networking (PN), interaction with body-area networks (BAN), new types of home networks, vehicle networks, wireless sensor networks (WSN), 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)
- 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 transmission fully into account
- Low-cost solutions for access networks with fibre, fast DSL or BWA drop technologies enabling very high bandwidths
- New protocols optimised for IP-only in a public access environment. Especially capacity and latency-effective alternatives to IP and TCP
- Network security, information and trusted content security
- Wireless sensor ultra-low-power and bandwidth-efficient air interfaces and data transport and networking protocols for wireless sensors, clusters and gateways
- Self-growing, robust, and scalable wireless sensor networks
- Self-organising sensor networks in mobile and dynamic heterogeneous wireless sensor systems
- Home design for ambient intelligence: The usage of smart objects will change the way we live in our home

6.3 Radio Access

6.3.1 Rationale

Future Radio Access Networks (RANs) will comprise a uniform entity where user does not need to care how the access to predefined service portfolio is organised. The complexity and multi-modality of the networks is hidden from the users by utilising intelligent user profiling, context-awareness and new means for service delivery operations. Different RANs will co-operate, but their capabilities will be developed somewhat independently from each other. From the user point of view, the network will be able to deliver a large number of different context and application-related information related to, e.g., multi-sensory data or universal position information. The terminals will act according to a predefined user profile changing the preferred ways of operation according to time and place. Any device will be able to access the Internet to retrieve information, receive commands, actively learn about its environment, and make its information about the local environment available to others, through various sharing environments.

Such an extensive ubiquitous network cannot be managed with the currently established infrastructure or with emerging ad hoc radio network technologies since traditional radio access schemes will not scale to large collections of nodes and is destined to be plagued with interference, electromagnetic pollution, and network congestion. To develop such a scalable and dynamically pervasive network, we need fundamentally new methods to address spectrum sharing, radio frequency (RF) agents, cooperative and adaptive link management, opportunistic access, information routing, and quality of service. Solutions to these challenges will enable vast new application areas beyond traditional communications including medical monitoring and diagnosis, mobile e-commerce, sensing and security, automotive industry applications and much more.

6.3.2 Objectives

The radio interfaces of future systems for different application areas and deployment scenarios will be developed and optimised in terms of flexibility, peak data rates and granularity of data rate allocation, latency, power consumption and frequency range. As far as possible, the different access systems should be based on a common platform, in order to, ease the implementation of multimode devices. New spectrum-efficient access technologies, deployment concepts and advanced signal processing methods are needed considering operation in various bands, and allowing the parallel operation of high-performance radio interfaces in handheld devices.

Radio access network research is one part of the overall system design. It needs to be emphasised that radio interfaces for the future are 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.

A huge challenge for the future RANs is to realise the co-operation of different networks in practice. Also the flexibility between ad hoc and structured network approaches must be fully supported. New spectrum-efficient access technologies, deployment concepts and advanced signal processing methods are needed considering operation in various bands, and allowing the parallel operation of high performance radio interfaces in handheld devices. In longer run, this will lead to the larger-scale deployment of cognitive radio technologies.

International standardisation of new radio interface concepts is expected to start after WRC 2007. These activities have to be supported by detailed link and system level simulations and larger scale trials. New methods of flexible and adaptable frequency usage and sharing methods as well as the impact on the system design and implementation need to be considered.

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 type of networks by somewhat independent system optimisation. The identified major research areas are: radio network and deployment concepts, radio interface technologies, reconfigurability, spectrum and coexistence, trials and prototypes, as well as, regulation and standards. The research topics in these areas include, e.g.:

- Investigation of alternative deployment concepts beyond the classical cellular approach in order to increase range and to provide coverage in an economic manner
- Preparation of evolutionary radio access concepts and further evolution of existing radio access systems and their integration in the evolving network infrastructure in order to leverage deployed investment combining efficiently flexible data rates, power aspects, mobility and multi-user support
- Integration of different access technologies to result in true heterogeneous networks
- Development of decentralised and self-organising network topologies and operatorless radio access network concepts for special application areas (e.g., disaster relief and campus networks) in order to avoid the planning effort to improve network robustness and adaptability
- Opportunistic communication systems utilising different spatiotemporal approaches in a multi-user environment, cross-layer optimisation and inter-cell interference reduction
- Development of the novel multiple input multiple output (MIMO) transmission schemes including channel coding schemes, transceiver baseband algorithms and implementation of the concepts. The MIMO techniques must be studied taking into account relevant cross-layer issues and new network topologies
- Detailed design of the different new radio interface systems with maximum commonality in order to develop a flexible platform, which can be implemented at lowest possible cost and to achieve economy of scale and international roaming
- Investigation of the impact of new frequency bands for future systems on the radio propagation including a scientific and biomedical study of the impact of newly identified frequency bands on the human body
- Flexibility and reconfigurability of software-defined multi-antenna, multi-standard radio systems and related platforms
- Cognitive and spectrum-agile radios
- New methods of frequency usage and sharing for available and newly identified frequency spectrum
- Methods for coexistence and cooperation of different radio access technologies
- Implementation issues for reconfigurability and cognitive radio systems and for new frequency usage techniques and sharing methods in a heterogeneous environment
- Investigation of techniques to minimize the size, weight, power consumption and cost of telecom equipment
- Simulations, trials and demonstrations for: novel air-interface schemes operating at new frequencies and variable bandwidths, as well as, novel radio access network technologies and heterogeneous networks. These results will be contributed to the international standardisation activities in order to achieve global impact

6.4 Platforms and Implementation

6.4.1 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, 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 between different technology domains. 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 and baseband signal processing, as well as for computing architectures, middleware and application software. 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.

6.4.2 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) facilitating reuse over 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 multiple access environment in heterogeneous networks 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 and the cost of mobile devices require investigations of the impact of sub-micron integration on the circuit and system level. 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 based on the maximum amount of commonalities would allow retargeting to different products and give possibilities to achieve low costs through economies of scale.

6.4.3 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

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:

- New architectures of RF front-ends matching with the microelectronics roadmaps and including advanced technologies and components such as RF MEMS and NEMS (Nano Electro Mechanical Systems)
- 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 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
- Optimisation 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)

6.5 Opportunistic Communications

6.5.1 Rationale

The demand for wireless communications will continue to increase at an accelerated pace, which with the current paradigm of 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 if both the dimensions of space and time were considered, and hence the problem is more a problem of inefficient spectrum access to under-used parts of the spectrum rather than 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 likely facilitate the emergence of new business models. For instance, they might 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.

6.5.2 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 environment scenarios and then provide deterministic schemes for 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. Socio-economical advantages of opportunistic spectrum usage in both time and space need also to be demonstrated.

6.5.3 Research Priorities

The main areas of opportunistic communications requiring research advances include:

- Sensing techniques to acquire relevant information from the radio environment and define the feasible operating region
- Decision making processes to allow intelligent choice of spectrum access, based on spectrum access policies and available or unused spectrum
- Optimisation procedures to define the best waveform when applicable given the environment
- Identification and dissemination of space dimension opportunities in opportunistic radio networks and collaboration strategies to efficiently make use of them on a network level
- 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)
- Prototyping and field trials

7 Frontier and Multidisciplinary Research

7.1 The perspective

R&D history is full of success stories concerning ideas that were considered “wild” by the time they were proposed and that later on have constituted a huge success. Optical fibres (i.e., the notion of guiding waves without metal) and operating systems based on windows and a mouse (i.e., interacting with a computer without the need of using text line commands) are just two of the examples. Hence, creating disruption is part of the essence of research and development, and only by such a perspective can society develop further – by creating new products and markets, and by reaching users with new services and technologies. Obviously, there are also many failure stories, many of which are not known.

Unfortunately, there is no measure of success that can be used. At the start, it is virtually impossible to know if an idea will be successful and it will make the difference, or on the other hand, it will be just a waste of resources. But this is what R&D is all about, namely dealing with basic and fundamental areas. Furthermore, by neglecting basic and fundamental R&D activities, one will be jeopardising the future, since more applied R&D is always based on results coming from the basic and fundamental one.

In the next decade, mobile and wireless applications and services are likely to become pervasive, with a widely spread use of devices everywhere. Computation and communication capabilities will be radically integrated in a great variety of different everyday objects, from simple sensors and interactive appliances (e.g., cards, rings, eyeglasses) via pocket and lap-sized devices to wall or table screen working areas. Technology will undergo a transformation, from an expensive, highly visible, hi-tech approach as in early cellular phones, over the current state, where practically everyone owns a mobile phone, to a disappearing technology that is present everywhere and taken for granted.

In the area of mobile and wireless communications, one should aim at farfetched objectives for basic and fundamental research that do not constitute an approach similar to the Olympic Games motto ("Citius, Altius, Fortius", standing for “Faster, Higher, Stronger”) applied to current systems and techniques (i.e., more of the same, but just better). Such a perspective challenges many of the current paradigms in mobile and wireless communications. But it is felt that Europe does need to explore ideas beyond the usual topics being currently presented and discussed in technical meetings; only by doing this, will the European industry continue to play a leading role in the area of mobile and wireless communications, moving from a decreasing manufacturing role to an increasing conceptual one.

In what follows, topics are split into major groups:

- frontier research, addressing basic and fundamental topics in the specific area of mobile and wireless communications, and in telecommunications in general
- multidisciplinary research, bridging mobile and wireless communications with others unrelated to telecommunications, namely those identified in the EC proposal for FP7.

7.2 Frontier Research

7.2.1 Vision

Frontier research will continue to open up new options to meet present and future requirements. For mobile and wireless communications, further improvements in user-experience, transparency and autonomy are in need of better solutions.

Frontier research drawing on several disciplines is, e.g., expected to overcome the current dependence on traditional input devices such as keyboards, offer more efficient power-management and answers to social computing application issues. In addition, in order to understand mobile users’ behaviour, multi-disciplinary work for learning and behaviour-modelling is required.

7.2.2 Rationale and Objectives

The focus of the eMobility Platform is not frontier research. However, in this domain some basic and fundamental research can have a very profound impact, and inversely problems do arise which may need additional research. The objectives of frontier research are to explore new fields in the area, as well as to extend the borders of mobile and wireless services and applications.

7.2.3 Research Priorities

The priorities are to be seen as a complementary activity of frontier research carried out in other frameworks and objectives. These activities are needed to fill gaps and to transfer research results.

While much progress has been made in facilitating the interaction with equipment and the services, the present solutions remain a major bottleneck for new applications and services. Terminals without keyboards and innovative display techniques will change the user experience and enable new applications. The fundamental developments in sensor technology and sensor networks in general will drive the new interfaces towards more contextual computing. In the future input functions could, in fact, be thought controlled. However, frontier research is needed not only for hardware innovations, in many cases new modes of interactions in the software are even more important. The emerging social computing on mobile device platforms requires fundamental multi-disciplinary research combined with network theory, game theory and computer science.

The limited battery-power remains a major constraint to the use of mobile technology. While improvements have been made, the power-management problem has to be addressed at the system level and requires fundamental innovations not only at the hardware level, but also in energy-efficient software where frontier research has a great promise, but is also very challenging.

The work on identifying risks due to radio emission has so far been inconclusive. While it may prove to be of no concern, a better understanding of the biological effects would help to avoid problems and provide peace of mind.

Other areas can be identified as well. The list of ideas presented below does not carry any concern about how they can actually be implemented, or what is the path to follow. It is a list of ideas that it is considered to be worthwhile to explore. Moreover, some of these ideas are more farfetched than others, which does not constitute a devaluation of some over the others. The following topics are identified:

- Wireless protocol (WP): a new protocol approach, replacing IP, designed for all the coming features of mobile and wireless communications
- User identification: the capability of users being identified only by some kind of RFSIM (Radio Frequency Subscriber Identity Module)
- Millimetre and submillimetre waves: exploration of propagation and channels at frequencies in these ranges
- Inter- and intra-device communications: replacement of wired communications by wireless ones for these types of applications
- Information and content deposits: users having access to all their relevant information and content via a wireless terminal, without actually carrying any of it
- Network information theoretical limits: re-evaluation of these limits for new approaches of communication systems
- Theoretical limits of cooperative communication paradigms: study of the link and network capacity gains of cooperative transmissions, involving several terminals
- Theoretical limits of self-organising networks: study of ad hoc network capacity limits for asymmetric networks, in the number of origin and destination nodes
- New codes: development of codes for networks, broadcast, and quantum applications, among others

7.3 Multidisciplinary Research

The EC has identified the priority disciplines for R&D in FP7, which are, besides the one including mobile and wireless communications (Information and Communication Technologies):

- Health
- Food, Agriculture and Biotechnologies
- Nanosciences, Nanotechnologies, Materials, and New Production Technologies
- Energy
- Environment
- Transport
- Socio-economical Sciences and the Humanities
- Security and Space

Multidisciplinary research, bridging the gap between mobile and wireless communications and other sciences, should focus on the above listed ones. Examples are:

- Measurement of the health state and transmission of an alarm in case of a problem
- Use of wireless communications to establish communication in the nervous system
- Use of biometrics for user identification
- Usage of multi-sensory information, making use of all human five basic senses
- Molecular computing
- Incorporation of circuitry or terminals in common use objects, like eyeglasses
- Cooperation with the clothing industry for the use of jackets for virtual reality
- Expansion of the lifetime of batteries
- Wireless power
- Decrease on the electromagnetic pollution
- Environment-related applications
- Installation of terminals in cars as a basic feature in the automotive industry
- Automotive and related ITS (Intelligent Transportation System) applications
- Sensing the mood and state of mind of the user
- Interaction with other users based on matching needs, wants or drives
- Virtual presence
- Telepathy based on wireless communications
- Use of birds for relay communications

8 Accompanying Measures

8.1 Non-Technical Barriers

Future communications will be truly ubiquitous – capabilities, applications and services delivered over interworked heterogeneous wired and wireless networks by multiple diverse service providers who will not own, nor necessarily even exercise management control, over these networks. Such communications will have major societal implications, impacting all spheres of life and social interactions.

Potential impacts will include *inter alia* the areas of:

- e-Governance
  - Communications between state and citizen, with impacts upon the democratic process itself, as well as, on delivery of services by the state
- Environmental & Personal Security
  - Provision of always-on sensing and monitoring to contain a wide variety of natural and man-made threats to the human environment and personal health and safety
- Societal Interactions
  - Interpersonal and person-business relationships and behaviours will change as new technologies permit new methods of interaction and socialising
- Industry Efficiencies
  - Always-everywhere communications will allow the introduction of new business models, not simply bringing efficiencies, but revolutionising value chains and industry operations

8.2 Rationale and Objectives

As such, many factors will affect technology requirements and inversely affect social requirements. The interaction of technology possibilities, requirements and society is a two-way process:

- Desired societal outcomes can give rise to requirements on technology
- Unfettered technology evolution, without consideration of implications, can give rise to highly undesirable societal outcomes

To create awareness of these evolutionary processes taking place in very different frameworks (e.g., education, social policies, regulations, business, laboratories) a continuous effort is required.

Further, an effective combination of industry and regulatory policies, research and commercial pull-through of R&D is required if the fruit of the research requirements described within the Strategic Research Agenda is to be realised in terms of economic prosperity and growth for Europe. Without an effective ecosystem the SRA will fail to achieve this goal.

Supporting measures that address these complementary issues are essential. Success in these areas is critical to the existence of a healthy society and a vibrant ICT industry in Europe in the 2015-2020 timeframe.

8.3 Objectives of the SRA: Non-Technical Barriers

8.3.1 Objectives

The key rationale for the e-Mobility Technology Platform and its Strategic Research Agenda is fundamentally to create technology that will enable economic growth and societal prosperity for Europe. Good technology resulting from such research, if pulled through with appropriate business applications, will result in economic growth, and prosperity for a wide range of European industries, not simply the communications or ICT industry.

The Economic Potential - Economic and industry growth will occur if there is significant technology adoption by business to create efficiency and productivity gains. Such gains may take two forms:

- Incremental gains
  - through technology offering improved efficiencies in existing processes
- Step-change gains
  - through technology enabling completely new business processes, and thereby revolutionising the value chain

Both are important. The latter has potential for greater and deeper impact and economic benefit, but equally is much harder to secure due to cultural aversion to such changes amongst incumbents. Such potential gains will however be recognised as early adopters are seen to benefit. Such potential offers not only benefits for other industries, but also for telecommunications operators, through the introduction of new services and applications, and for manufacturers, to support these new applications and application and industry specific opportunities.

8.3.2 The Economic Challenge of Today's European Environment

Existing Markets - Recently, in Europe and globally, many new wireless and mobility technologies have been rapidly emerging. As they compete for a place in the existing markets many of these lack economy of scale, as they attempt to compete with standardised solutions. Traditionally the telecommunications industry has secured economies of scale through international standardisation – indeed, this was the key in the 1990s, through the formation of ETSI, to the transformation from national to truly European telecommunications companies. GSM is in this respect the classic exemplar.

New Markets – The significant future economic potential however resides not in existing, but in new markets. In Europe today, after the downturn of recent years, new technologies are failing to find opportunity for the significant scale field trials needed to prove technology in real applications and create these new markets. In Europe companies are hesitant to invest in unproven business cases, in some cases potentially leaving markets open to overseas competitors, who are often actively supported by their Governments who have prioritised these new ICT markets. A current example would be the way in which Korea has developed and commercialised DMB, a potential competitor to DVB-H, for which pan-European spectrum has yet to be allocated, and which it is now actively seeking to export to Europe.

A Changing Environment – Compared to the past, the combination of evolution of a European policy environment which mitigates against economies of scale – nationally fragmented, and increasingly technology neutral – together with the consequences of the telecom industry downturn, are reducing opportunities for the pull-through of EU R&D compared to, say, the early 1990s. This applies particularly in the area of wireless, where lack of harmonised spectrum directly restricts market size – pan-European spectrum was a key enabler of the success of GSM.

Exhibit: The Change in Europe's Wireless R&D Context 1980-2010

- 1980s: GSM-focussed R&D
  - mandated spectrum, mandated regional technology & standard
- 1990s: 3G and short range wireless
  - consensus spectrum & global standard(s)
  - unlicensed global usage
- 2000s: Beyond Generations?
  - B3G, 4G – the Asian thrust, high bitrate initial push has now embraced EU perspectives of interworking
  - Multiple new air interfaces, aimed at low cost (Intelair)
  - Sensor networks – wireless embedded everywhere
- 2010: Spectrum liberalisation & trading
  - Buy spectrum & use whatever technology wished
  - Implications
    - Economies of scale through SDR, but only if the overhead costs of SDR are almost zero
    - Changes in business models are inevitable

Industry Policy– ICT is today a globalised industry, with minimal geographical barriers. Market liberalisation has removed the concept of industry promotion in many member states, whilst in others it still exists in camouflage. Even in such countries however the focus of much government policy is on reducing consumer costs and supporting consumer demands, resulting in increasing regulatory burdens on industry. Overall across Europe industry policy is poorly linked with R&D and such linkage is different in different member states. This situation must be acknowledged, studied, understood and new approaches identified if the benefits of strategic research are to be realised as economic gains.

From Today to Tomorrow – In today's environment as just described, R&D pull-through is harder & less effective than ten years ago, at a time when the industry has globalised and European industry is facing seriously increasing competition from Asia. In Europe commercial funding for R&D application pilots and similar mechanisms for research pull-through is available for proven business cases, but for little else, potentially threatening Europe's global competitiveness in the longer term.

This is not to *say* that Europe should move backward, or should re-adopt its own historical policies, which are now being pursued in Asia; this would be both inappropriate and ineffective in the 21st Century. Rather, Europe should move forward, with new policies that can achieve the goal through new approaches. However, significant work is needed, alongside the proposed SRA research activity, to identify effective mechanisms that will achieve the desired goal of leveraging the fruits of the research to create major new markets, invigorate other industries and thereby stimulate significant economic growth.

8.3.3 The Social Challenge

Changing Behaviour – The diversity of Europe is its strength. Politicians and Eurocrats have ignored this cultural diversity at their peril. Polite and appropriate behaviour in one country may be unacceptable in another, even across Europe; personal space has differing definitions, normal topics of discussion vary. Despite this, the ability to communicate anywhere and anytime, via phone or texting, has changed everyday behaviour – for example, no need to take a map, if you can call from the car and ask for directions. Less need to plan ahead if you can always reach friends by phone.

Future Changes - Future technology will potentially allow the user to identify someone with similar interests as he passes in the street, to locate them across a city. But what interests are acceptable to society or are deviant? How may this vary between countries? What about privacy and anonymity? What new forms of productive, or aberrant social behaviours could such capabilities encourage?

The Role for Social Research – Traditionally scientists and engineers have left the application of their technology to others and neglected consideration of its potential consequences. The classic example is the reference "I am become death" from Robert Oppenheimer, describing the perspective of the creators of the atomic bomb as they contemplated the prospect of what the technology would result in. Arguably the importance or necessity of such considerations is related to the scale of its potential impact upon human society.

Social Research in Communications - Little research has traditionally been undertaken on the future impact of communications. The unforecast success of texting and the still uncertain future of today's hoped-for-killer-application mobile-TV are examples reflecting this; the growth of the adult content industry facilitated by the Internet is another. Yet communication is a fundamental human need and activity and as we move into an era of personalised devices and services, of context awareness, and ubiquity, technology has the potential over a generation to profoundly change an inherent aspect of the historical personal psyche. Surely this issue is potentially as profound as GM crops – the latter impacts our environment, the former impacts humanity directly.

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