Towards Ubiquitous and Unlimited-capacity Communication Networks – European Research in Framework Programme 7

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Abstract. The European Union is presently funding collaborative research and development activities in the *6th Framework Programme* (FP 6) that has covered the period of 2002-2006. Activities in the communications field have made significant progress towards advanced communication technologies, systems and services enabling low cost broadband end-to-end connectivity and seamless mobile and wireless access solutions across a range of heterogeneous network infrastructures. Currently the European Commission is starting to implement the *7th Framework Programme* (FP 7) that will cover the period of 2007-2013. The area of communication technologies is characterised by the main technical objective of "ubiquitous and unlimited capacity communication networks". Activities are expected to aim at ubiquitous access over heterogeneous networks - fixed, mobile, wireless and broadcasting networks - spanning from the personal area to the regional and global area allowing the seamless delivery of ever higher volumes of data and services.

INTRODUCTION

FP6 research activities under the headings "Broadband for All" and "Mobile and Wireless Systems Beyond *Third Generation* (3G)" have allowed consolidating a common approach towards advanced mobile, wireless and broadband systems.

Activities in broadband communications have achieved progress towards network technologies and architectures allowing a generalised and affordable availability of broadband access, fixed and wireless, to all users, including those in less developed regions, peripheral and rural areas.

In mobile and wireless communications, the research community has perceived the limitations of 3G cellular communication systems in terms of user throughput and cost of operation and usage and consequently has focussed on research towards systems *Beyond Third Generation* (B3G) that outside Europe have been called *Forth Generation* (4G) systems. The recommendation M.1645 of *International Telecommunications Union - Radio* (ITU-R) [1] has been approved to be the basis of future activities for systems beyond 3G. The ITU vision aims at integration and cooperation of existing and evolving access networks on the one hand and advanced air interfaces with significantly improved performance compared to 3G systems on the other hand. Driven by the EU research framework programme, European industry has federated in the *Wireless World Initiative* (WWI) [2] towards a common technological, industrial, regulatory and service approach to realise this vision.

Similar ambitious initiatives on mobile broadband communication systems have been started in other regions of the world where the issue has been recognised as strategic.

In Asia, both Japan (Super 3G, ubiquitous Japan), China (863 FuTURE Project) and Korea (Wireless Broadband, 4G) are investing massively in research on 4G systems. In these frameworks mobile radio technologies with data rates of up to 1 Gbit/s indoor and 100 Mbit/s outdoor with handover support have been demonstrated. Japan, China and Korea have agreed on the CJK initiative that is aiming at a common approach towards next-generation IP networks and 4G mobile communications.

In North America, research and standardisation activities are dominated by the global wireless IT sector. *Wireless Local Area Network* (WLAN) and *Wireless Metropolitan Area Network* (WMAN) system concepts are further developed by IEEE 802 standardisation. So called IEEE 802 wireless systems are designed for low cost nomadic Internet access, at least in offices, at home and in public hot spots. In the next decade, 802 wireless systems

are expected to become an integral part of 4G cellular communication systems, where the convergence of wireless and mobile networks is expected to materialize through support of inter-working and seamless roaming across wireless and cellular radio access technologies.

In Europe, the *European Technology Platform* (ETP) eMobility has been established as an action forum where all stakeholders, led by industry, have come together to define a *Strategic Research Agenda* (SRA) on mobile and wireless communications for the next seven years.

As stated by eMobility, future research activities should aim at "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" [3].

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

The future system is seen to be complex, consisting of a multitude of service and network types ranging across *Wireless Sensor Networks* (WSN), Personal Area, Local Area, Home Networks, Moving Networks to Wide Area Networks. The increasing dependency of society on such communication infrastructure requires new approaches and an emphasis in European research captured in a new concept called the “SET Concept” that underscores the need for a 3-dimensional vision of research activities that will deliver *Simplicity, Efficiency and Trust*.

Complementary research agendas have been set up by the technology platforms *Networked and Electronic Media* (NEM) and *Integral Satcom Initiative* (ISI). These vision documents have been taken into account as important input for the definition of the first Challenge of the FP7 *Information and Communication Technologies* (ICT) *Work Programme* (WP) with the title "Pervasive and Trusted Network and Service Infrastructures". The challenge is to deliver the next generation of ubiquitous and converged network and service infrastructures for communication, computing and media. This entails overcoming the scalability, flexibility, dependability and security bottlenecks, as today’s network and service architectures are primarily static and able to support a limited number of devices, service features and limited confidence. Such new infrastructures are expected to permit the emergence of a large variety of business models capable of dynamic and seamless end-to-end composition of resources across a multiplicity of devices, networks, providers and service domains.

This paper first describes the current state of the art of mobile broadband communication and the main achievements of FP6 research projects in the area. On this basis the rationale and content of the FP7 WP in this area and the expected activities are presented. This includes the research challenges, the identified research topics and the expected impact of these activities.

CURRENT STATUS OF MOBILE AND WIRELESS BROADBAND COMMUNICATIONS

In the last decade and recent years, mobile communications and broadband Internet access have been the main contributors to growth in the telecom sector.

Broadband is becoming the dominant access mode to the Internet. High capacity broadband connections enhance the users' experience, freeing them from the inconvenient dial-up service. With user data rates of typically between 1-20 MBit/s downstream, broadband access enables the user to get more out of existing services and, more importantly, opens up opportunities for new services. Already the expansion of broadband networks has brought with it a host of new services, such as voice over IP and video streaming. The number of broadband subscriptions world-wide continued to increase during 2005 to 158 million. Broadband penetration growth held steady at 15% reaching 13.6 subscribers per 100 inhabitants [4]. By 2010-2012 it is expected that advanced countries will reach an 80-90% household penetration. This market success in broadband access has been made possible by cost-efficient technologies and by the adoption of flat-rate tariffs. Dominating technologies are *Digital Subscriber Line* (DSL), which is based on copper infrastructure made for fixed telephone services, and transmission over coaxial *cable* using the infrastructure made for the provision of television and radio programming. Depending on specific deployment conditions in certain regions other broadband access technologies can be suitable, such as *Fixed Wireless Access* (FWA), Satellite or *Power Line Communications* (PLC). To enable higher user data rates of 50 MBits/s and above, operators in Europe, USA and Asia are currently investing in optical fibre infrastructure driven by the need to overcome the limitations of existing DSL and cable infrastructures.

The mobile communications industry continues to enjoy strong growth and the total number of subscribers for mobile telephone services worldwide at the end of 2005 grew to 2.129 billion. This figure is expected to increase to approximately 3.964 billion by the end of 2011. Worldwide mobile phone penetration is expected to pass the 50%

mark around the end of 2009. Basis for the creation of this mass market was the European standard *Global System for Mobile Communication* (GSM), a standard for digital cellular mobile radio networks specified in the late 1980s in Europe and introduced worldwide in the 1990s. While its principal use is for mobile telephony, mobile data services are becoming more and more popular. The success of text messaging in Europe and the growth in both subscriber numbers and usage of mobile Internet and mobile TV services in Asia, has led to very high market estimations for packet-oriented mobile data services. As a first step towards mobile multimedia services GSM systems were upgraded by packet data services, such as *General Packet Radio Service* (GPRS) and *Enhanced Data Rates for GSM Evolution* (EDGE) [5]. For a comparison in terms of mobility versus user data rate of existing and future mobile communication systems see Figure 1.

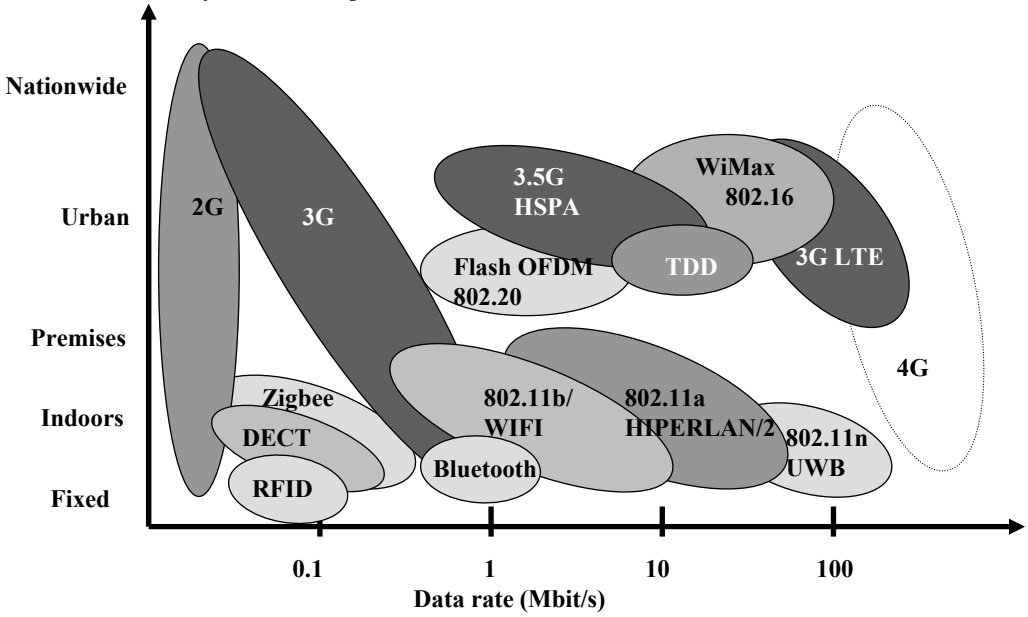

Figure 1: Mobility versus user data rate of mobile and wireless communication systems

Third Generation Mobile Communication Systems

With penetration of mobile phone services reaching saturation in developed countries, the next big growth opportunity is seen in 3G mobile data services. The first of these 3G networks, are now starting commercial services in Europe. In 2004 there were 75 licensed 3G operators, of which 31 were offering commercial services and another 21 were in the pre-commercial phase. By the beginning of 2005, it is estimated that there were around 5.4 million *Universal Mobile Telecommunication System* (UMTS) subscribers in the EU out of 16 million worldwide. This figure is growing rapidly as new operators roll out their 3G networks and worldwide subscriptions to 3G networks. After the UMTS Forum, worldwide subscriptions to 3G networks have exceeded 100 million in June 2006.

Despite the promises of more feature-rich, highly interactive and high bit-rate multimedia services for the end-users and increased revenues for the operators, the research community has perceived the limitations of these systems in terms of user throughput, which is typically not exceeding 64-384 kbit/s, and cost of operation and usage. Consequently, evolved 3G standards have been developed. Possibly the most important improvement is the new series of technologies referred to as *High Speed Packet Access* (HSPA). These technologies are available as a relatively straightforward upgrade to existing UMTS networks and are offering improved user data rates, typically 1-2 MBit/s, improved network capacity, and improved interactivity for data applications [6]. As the next step, 3G *Long Term Evolution* (LTE) is currently standardised. Based on the different radio interface transmission technology *Orthogonal Frequency-Division Multiplexing* (OFDM), 3G LTE is aiming to achieve a downlink data rate of three to five times higher compared to HSPA in the same bandwidth and significantly lower latency. For most situations, the cost to evolve a UMTS network to a next generation radio interface will be low compared to the cost of deploying a new network. The reason is that most of the existing infrastructure will remain the same, requiring only major upgrades at a base station and on terminals and inter-working with existing systems is easily achievable as the same core network can be used.

Fixed Broadband Wireless Access Systems

In recent years, wireless technologies and solutions, often stemming from the IT sector, have become popular, especially for laptop users. So called *IEEE 802 WLAN* systems are designed for usage in offices, homes and "hot spots". Additionally, FWA technologies such as *IEEE 802.16 WMAN* show promising signs of fulfilling existent and growing user needs [7].

Wireless Local Area Networks

WLAN, in the form of IEEE 802.11 (also known as Wi-Fi) has been on the market for several years and is used by a wide range of user groups. WLAN systems enable several computers in an office or household to be connected to the Internet via a wireless access point and a fixed broadband service such as DSL or Cable. WLAN hot spots have become increasingly available in public areas such as hotels, cafes and airports. An emerging phenomenon that can be witnessed in a number of European countries is the establishment of wireless clouds or zones. Another concept called FON that was first introduced in Spain is based on an open community of users, so-called "Foneros" that share their wireless Internet access at home and, in return, enjoy free WLAN access wherever they find another Fonero's access point.

This freedom provided by WLAN has stimulated the demand for wider coverage and extended service provision of wireless broadband services, features unable to be adequately satisfied by these low-cost limited-range WLAN systems.

Wireless Metropolitan Area Networks

Alternative operators are interested in using WMAN systems based on IEEE 802.16 (also known as WIMAX) to bypass the local loop barrier when delivering broadband services and to gain additional attractive revenue through the delivery of voice services. As mobility support for IEEE 802.16 has only very recently been standardised (December 2005) and is currently not permitted in most European countries, so-called *pre-WiMAX* deployments that are using early versions of the technology to deliver *Fixed Wireless Access* (FWA) are currently available in some regions of Europe, US and Asia-Pacific.

In the US and also in Europe, *IEEE 802.20* (also known as *Flash Orthogonal Frequency-Division Multiplexing* (Flash-OFDM)) has been identified as another promising wireless broadband technology, because of its combination of high throughput, high mobility, and low latency as its major advantage.

The more attractive spectrum bands for mobile wireless broadband are those used and foreseen for UMTS, making actual available licences scarce. The licences awarded for use with wireless broadband technologies restrict the service to portable but non-mobile applications, because IEEE 802 wireless systems are not part of the IMT-2000 family of standards accepted by the ITU [2].

Wireless Short-range Communication Systems

Several proprietary and standardised solutions exist for wireless point-to-point connectivity in home entertainment and office environments as well as other professional more specific scenarios such as vehicular, hospital and industrial applications. Applications range from high-data-rate connectivity, e.g. the replacements of cables by wireless connections (AV device connectivity, wireless USB), to low-power and low-data rate connectivity with very low activity factors, typically used in sensor networks.

These short-range transmission technologies are also seen as the enablers for wireless *Personal Area Networks* (PANs), which interconnect personal devices in the close physical vicinity of a user, and *Body Area Networks* (BANs), which support the wireless communication of sensors on a body or other objects.

The field of sensor networking research has been attracting tremendous interest particularly since it has been demonstrated that concepts for multi-hop self-organizing networks with energy-efficiency as a primary constraint are feasible, and that high levels of the miniaturization of network nodes, under the guiding vision of *smart dust*, are just a matter of time. Besides well-known applications ranging from healthcare to environment monitoring, this development generates the potential for innovative user-centric applications based on sensor networking. A recent ITU report depicts a futuristic scenario of *An Internet of Things* [8], a world in which billions of objects sense their environment and report on their location, identity, environmental parameters and history over wireless connections. In this scenario, boundaries between the physical and digital world are partly disappearing.

4th Generation Mobile Communication Systems

4G is a concept that is currently subject to intensive research efforts throughout the world. These envisioned advanced mobile communication systems are expected to offer broadband mobile applications with access to high-quality multimedia content and offering communication with and among objects, machines and devices.

4G Research and Standardisation

The technological approach driving 4G efforts is however somewhat different from the one that has driven other mobile and wireless technologies such as GSM/2G, UMTS/3G, or even wireless access technologies such as WLAN and WMAN (see previous section). These technologies have been developed with a vertical approach, with a target subset of services and environments supported by one particular radio access scheme complemented with a supporting network infrastructure in the case of 2/3G. 4G is on the other hand researched with a comprehensive system approach that includes a continuum of different access technologies, federated through a core network that ensures the following requirements.

- **True broadband**, i.e. no user-perceived difference from fixed and mobile broadband access
- **Enhanced resource efficiency** (in particular spectrum-efficiency) and versatile/reconfigurable technologies, minimising *Capital Expenditure* (CAPEX) and *Operational Expenditure* (OPEX).
- **Increased service capabilities**, in principle enabling design and implementation of *context-aware* applications
- **Full fixed-mobile convergence**, i.e. equivalent service capability across a fixed or mobile access
- **Service portability** and operations across multiple networks/service provider domains

For new radio access schemes that are aimed to be integrated with other existing radio access networks, ITU has set the target of 100 Mbit/s for truly mobile applications, and 1 GBit/s for fixed/portable radio access [1]. These objectives are framing the research and the characteristics of the test beds that are currently being developed in various regions of the world. Although a number of concepts and demonstrators towards this target have been developed in several research projects world-wide, 4G standardisation has not started, yet. This is mainly due to the uncertainty of the identification of frequency bands for such new radio schemes, which will be addressed in the framework of the upcoming *World Radio Conference* (WRC) 2007.

Next Generation Mobile Networks

Recently, a group of operators published a white paper on *Next Generation Mobile Networks* (NGMN) [9]. Most of the concepts and requirements outlined in this paper are similar to the requirements taken into account by current 4G research activities including the need to develop a new radio access scheme, called the *NGMN Access,* and to satisfy a large range of interoperability requirements. Key concerns are relating to the need to simplify the architecture, which is already considered as too complex and whose complexity will increase as interoperability requirements increase. New standards should be defined with well-defined transparency of *Intellectual Property Rights* (IPR) from the outset. Emphasis is also put on the need for upwards compatibility, i.e. for standards enabling an evolutionary migration of 2G/3G towards the target NGMN system whilst ensuring transition towards end-to-end support of *Internet Protocol* (IP) -based applications.

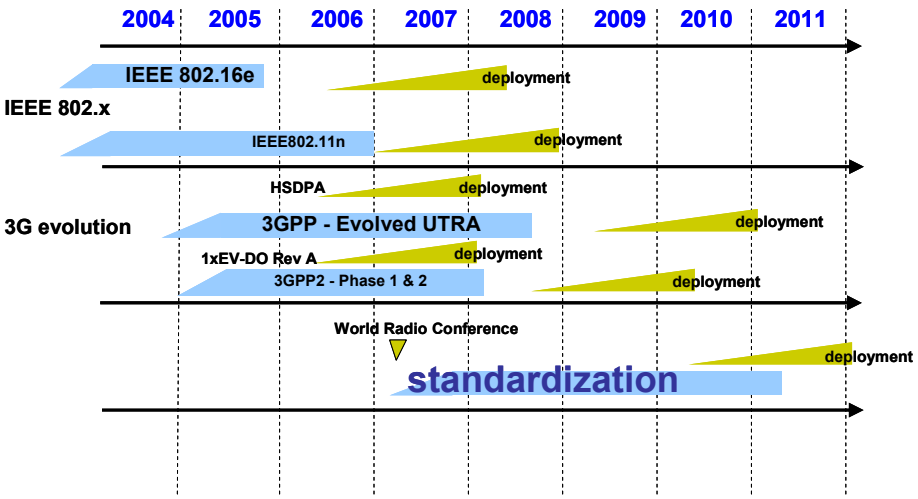

Figure 2: Time schedule of 4G research and standardisation activities

Multimedia Convergence

Multimedia convergence encompasses convergence of products and solutions in telecom, broadcasting, digital media and consumer electronics. It is a profound revolution in the ICT sector that has started several years ago and finds its origins in technological evolutions allowing for the ability of different network platforms to carry essentially similar kinds of digital services, including the integration of consumer devices such as telephony, television and personal computing.

Rapidly convergence has affected businesses by changing the business roles and the competitive environments of the sector actors. Convergence is at the source of major reshaping of the telecom, broadcasting and digital media worlds. Multimedia convergence has further triggered radical changes in the ways digital multimedia services are consumed by the end-user, who evolved from a passive multimedia services consumer towards a major player controlling and creating his own communications and media. In turn these changes in consumer's behaviour have opened a series of new technological and scientific fields in the areas of multimedia networking, services, applications and devices.

Broadband Triple-play and Next-generation Networks

A first step of convergence has already been implemented and offered in so-called triple-play packages, where broadband Internet access is complemented by a number of applications, such as television and VoIP. A triple-play access supporting mobility in addition is also called quadruple-play access. Whereas the term *Fixed-Mobile Convergence* (FMC) has originated with the aim of fixed-mobile telephony convergence, the vision today is larger aiming at making accessible any service seamlessly fixed or mobile.

From a network point of view, convergence is realised by the evolution of networks that support all kinds of different services or even "converged services", which are no longer designed to be deployed or delivered over a specific network. The basis for the future of a plethora of converged services is the emerging *Next Generation Network* (NGN). This will consist of

- Various next generation access networks, reducing any bandwidth bottlenecks that may exist today at the access level. This evolution is not related to any single access technology but to characteristics of an access infrastructure capable in providing higher and scalable bandwidth, better symmetry and lower contention
- Global next generation core networks with nearly unlimited bandwidth in the backbone
- Next generation service control, which will provide the framework for intelligent and convergent service creation

Mobile Broadcasting

The combination of wireless broadcasting and interactive communications technologies opens significant new opportunities to offer cost-effective interactive rich multimedia content to a large number of mobile users. Mobile TV platforms are today reaching the maturity stage. These platforms, allowing TV content to be broadcast to mobile terminals, additionally offer the potential for specific local channels, e.g. providing hotel and restaurant guides, information on cultural events or alerts for emergency situations, as well as easy-to-navigate portals of interest to local communities.

However, there are a number of uncertainties still to be resolved. These are mainly related to the availability of spectrum for digital broadcasting services, the deployment of *Digital TV* (DTV) in the context of the switchover from analogue to DTV services, or the varying licensing plans of mobile broadcasting networks in different states. Finally, several technological solutions are competing in offering mobile interactive broadcasting services, and are very likely to coexist in the near future, such as the UMTS *Multimedia Broadcast Multicast Service* (MBMS), *Digital Video Broadcasting to Handhelds* (DVB-H), *Terrestrial Digital Multimedia Broadcasting* (T-DMB) and *MediaFLO*.

The Future of the Internet

The Internet is now a critical part of our economy's infrastructure and is expected to be an integral part of future industry, and society as a whole, similar to any other utility, e.g., electricity and water. In addition, it is expected that the future Internet will help to shape modern society, especially in the areas of health, education, and government.

However, its limitations due to the design made in the nineteen-seventies start hampering its potential. Evolutionary improvements to the current network will help sustaining the growth of the Internet up to a certain point, but are not seen as being enough to face the deep rooted weaknesses of Internet as regards support of *Quality-of-Service* (QoS) including security, efficient mobility support, scalability and wireless generalisation.

The Future Internet should be able to sustain by one or many orders of magnitude higher the number of people, devices and objects connected, billions—perhaps even hundreds of billions of users, sensors, tags, processes, micro controllers, etc. It should ensure efficiency, security and trust in transaction for new services, incorporate mobility and universal connectivity in its conception, include the technical features for easy operations and management including guarantees for privacy, multiparty governance and delivery of new services.

Concepts should be developed that lead the way how to evolve from today's telecommunication networks and the Internet of today. There should be room for new concepts and paradigms, such as autonomic network management, protocols beyond TCP/IP, new architectures and new routing, identification and addressing schemes that are free from the constraints the Internet has imposed.

RESEARCH ON MOBILE AND BROADBAND COMMUNICATIONS IN FP6

Activities in the communications field have made significant progress towards advanced communication technologies, systems and services enabling low cost broadband end-to-end connectivity and seamless mobile and wireless access solutions across a range of heterogeneous network infrastructures.

Mobile and Wireless Systems beyond 3G

The area of mobile and wireless systems has been funded by the EU with in total approximately 263 M€ in 52 FP6 projects. The general vision from a user's point of view has been to be "Optimally Connected Anywhere, Anytime" supported by all system levels from access methods and networks to service platforms and services. Preparatory work has characterized systems beyond 3G as a horizontal communication model, where different terrestrial access levels and technologies are combined to complement each other in an optimum way for different service requirements and radio environments. Main outcome from this work is:

- A consolidated European approach to serving mobile users with appropriate enablers for applications and services. These include the personal level the local/home level, the cellular level, the wider area level and also broadcasting to mobile handheld devices, possibly complemented by a satellite overlay network

- A consolidated European approach to technology, systems and services, including location-based services, notably in the field of future standards for systems beyond 3G
- A consolidated European approach regarding the spectrum requirements, for terrestrial and satellites technologies, in the evolution beyond 3G and a clear European understanding of the novel ways of optimising spectrum usage when moving beyond 3G

Research has been placed in a system context, and has helped provide full seamless and nomadic user access to new classes of feature-rich applications, as well as person-to-person, device-to-device and device-to-person applications.

Project Portfolio

The objectives of horizontal integration of industry-driven Wireless World Initiative [2] activities on the one hand and the possibilities for long-term disruptive technologies on the other hand can be seen by the following clustering approach in Figure 3.

The four objectives to develop competitive European technologies for systems beyond 3G are represented by the clusters driven by large industry-led projects.

- **Broadband Air Interface**: concepts for a new air interface towards a future European standard beyond 3G towards higher data rates and better spectrum-efficiency.
- **B3G System Architecture and Control**: new network and signalling concepts for heterogeneous mobile and wireless networks. The general aim is the integration of existing and future mobile and fixed access technologies based on a common IP infrastructure.
- **Mobile Service Platforms**: technologies for interoperable service platforms enabling a variety of data services to become successfully deployable over existing and future heterogeneous mobile networks.
- **Spectrum and Resource Management**: advanced resource management is needed both for current and future systems to make efficient use of existing spectrum resources and existing and future infrastructures in an adaptive, cooperative and integrated way. This topic is covered by this cluster focusing on Spectrum issues, *Radio Resource Management* (RRM) and *Software Defined Radio* (SDR).

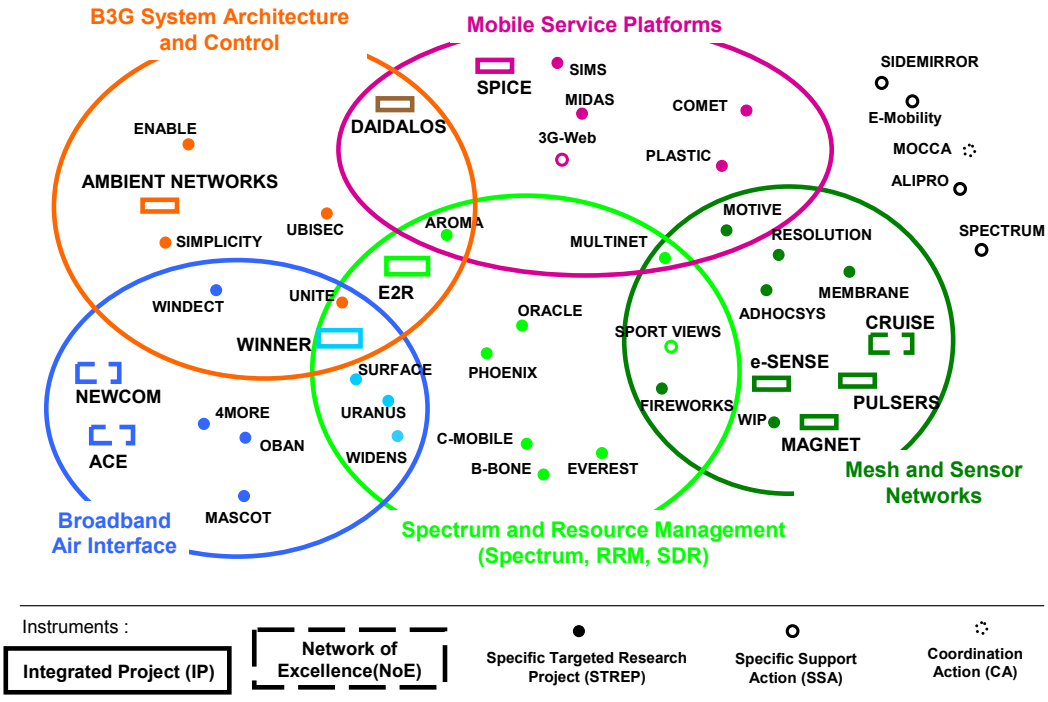

Figure 3: Project Clustering – Mobile and Wireless Systems

Besides these research activities driven by industry and leading network operators a cluster has been established that gives room for new, possibly disruptive technologies in the area of mobile radio networks. These activities are integrated by the cluster **Mesh and Sensor Networks** and have started to further develop concepts like ad-hoc, relay, sensor and mesh networks.

Broadband for All

Main objective of this area, which has been funded by the EU with approximately 159M€ in 38 FP6 projects, has been to develop the network technologies and architectures allowing a generalised and affordable availability of broadband access to European users, including those in less developed regions, peripheral and rural areas. Outcome from this work is:

- Optimised access technologies, as a function of the operating environment, at affordable price allowing for a generalized introduction of broadband services also in less developed regions
- A European consolidated approach regarding regulatory aspects, and for standardized solutions allowing the identification of best practice, and the introduction of low-cost end user and access network equipment.

Research objectives are framed in a system context and are required to address the technological breakthroughs in support of the socio-economic evolution towards availability of low-cost and generalized broadband access.

Project Portfolio

The rapid evolution in view of the emergence of an e-society and the risk of the digital divide is putting stringent demands on the need to offer all citizens equal opportunities to access broadband services in an affordable and democratic way. From a technology-viewpoint, the main bottleneck to realise "Broadband for All" today is the "last mile" covering the area between the customer and the first node in the network. As digitisation became a reality, supported by the increase in available network bandwidth due to the penetration of optical technologies in the backbone, a mix of last mile technologies appeared, both based on legacy networking techniques and based on new technologies. Future broadband offerings will consist of a mix of technological solutions, which will have to interact in an optimum way, in order to offer the services that the consumer needs. However, in order to guarantee the successful introduction of broadband services to all, an overall view of the end-to-end broadband services must be kept in mind, involving many parts and layers of the overall network. Projects in the Broadband area have been structured in the following clusters (see Figure 4).

- **Low-cost broadband access technologies**: access and edge network equipment, for a range of technologies optimised as a function of the operating environment, including optical fibre, fixed wireless access, interactive broadcasting, satellite access, xDSL and power line networks.
- **Network Engineering, Management and Control**: new concepts for network management, control and protocols, inter-domain routing and traffic engineering for delivery of new added-value services, with Quality of Service, security and end-to-end network connectivity, including IPv6.
- **Broadcast and Multicast**: use of broadcast and multicast techniques in broadband networks in order to save bandwidth and make new services economically viable.
- **Optical Network Technologies**: increased bandwidth capacity, in the access network as well as in the underlying optical core/metro network, including in particular optical burst and packet switching, commensurate with the expected evolution in user requirements and Internet-related services.

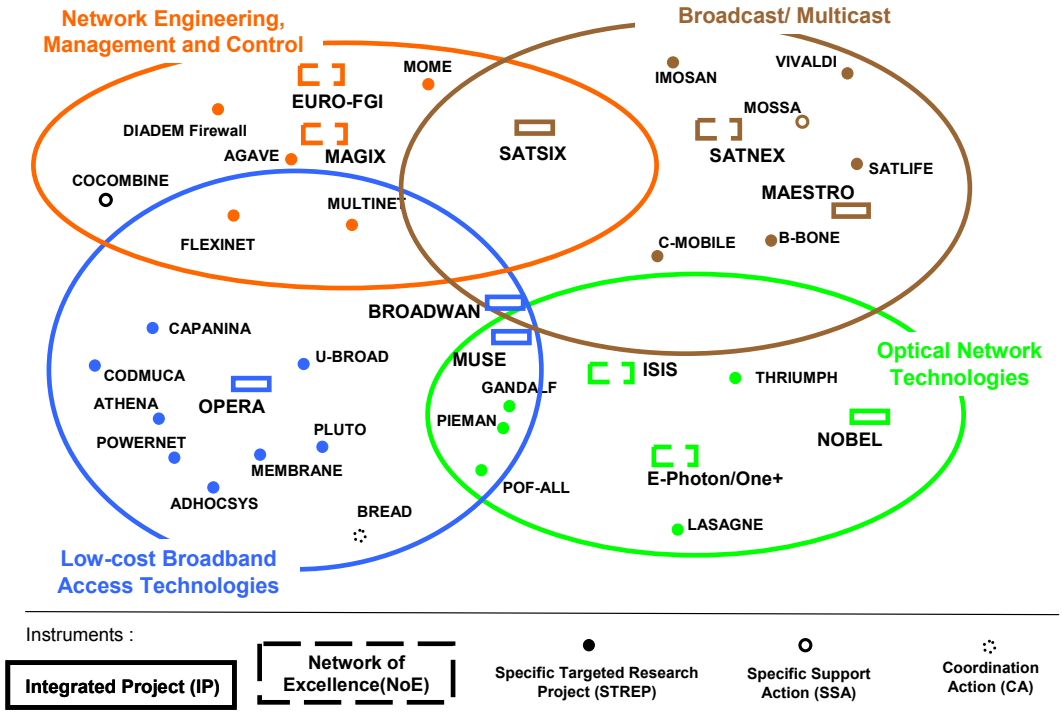

Figure 4: Project Clustering – Broadband for All

THE SEVENTH FRAMEWORK PROGRAMME

The Work Programme for the ICT theme of the FP7 Specific Programme "Cooperation" defines the priorities for the calls for proposals and the criteria that will be used for evaluating the proposals responding to these calls. The priorities reflect the input received from the Programme Committee, the *IST Advisory Group* (ISTAG), the European Technology Platforms in ICT and other preparatory activities including workshops involving the main stakeholders. The first FP7 Work Programme has been defined for the period 2007-2008 and will be updated for the following period on a regular basis. This Work Programme is structured around seven *Challenges* that are driven either by industry and technology objectives or by socio-economic goals.

Towards Pervasive and Trusted Network and Service Infrastructures

The first Challenge of the ICT WP [10] is to deliver the next generation of ubiquitous and converged network and service infrastructures for communication, computing and media. This entails overcoming the scalability, flexibility, dependability and security bottlenecks, as today's network and service architectures are primarily static and able to support a limited number of devices, service features and limited confidence. Such new infrastructures will permit the emergence of a large variety of business models capable of dynamic and seamless end-to-end composition of resources across a multiplicity of devices, networks, providers and service domains. The future infrastructures envisaged will need to:

- Be pervasive, ubiquitous and highly dynamic. They have to offer almost unlimited capacities to users, by supporting a wide variety of nomadic interoperable devices and services, a variety of content formats and a multiplicity of delivery modes. They also have to support context awareness and the dynamic behaviour needed for applications with requirements that vary with time and context.
- Guarantee robustness, resilience, trust and security compatible with networks and software service platforms reaching a complexity and scale that are an order of magnitude greater than those of today's infrastructures.

- Support networked and managed business and service convergence across a multiplicity of environments such as the home, businesses, or nomadic situations.

This entails addressing the evolution from today's large legacy infrastructures towards new infrastructures by striking a balance between backward compatibility requirements and the need to explore disruptive architectures to build future Internet, mobile, broadband, and associated service infrastructures.

The evolution drivers of this Challenge relate primarily to the technological evolution of ubiquitous mobile and broadband networks, the availability of dynamic service platforms, trust and security, in the context of converged and interoperable networked environments.

The Network of the Future

Challenge 1 of the ICT WP is composed of seven integrating objectives, namely *The Network of the Future; Service and Software Architectures, Infrastructures and Engineering; ICT in Support of the Networked Enterprise; Secure, Dependable and Trusted Infrastructures; Networked Media; New Paradigms and Experimental Facilities; Critical Infrastructure Protection.* Research on Communication and Network technologies is at the heart of this challenge.

While media and network convergence is already emerging today, users are still obliged to handle separate networks, a multiplicity of devices, and to rely on disparate services. The vision of FP7 is the availability of all communication services as a commodity anywhere, anytime, with any device, in a seamless way. Moving from connecting people to connecting objects, a transition has to be achieved from supporting billions to trillions of devices connected, i.e. overcoming the problem of scalability. Whereas today security and trust are "added on", the vision of FP7 is to have "built-in" security and trust. That does not mean that the design goal is a network that is 100% secure, which is not realistic, but scalable security solutions available when needed.

Target Outcome

In the Work Programme a precise target outcome is identified in a 10 year time frame. The way to achieve this target outcome is not specified in terms of potential technological solutions, but in terms of key characteristics of future systems. While the choice of the technological solution is left to the researchers proposing a project, proposals will be evaluated based on the potential ability to achieve the target outcome identified in the Work Programme. Target outcome of the Objective *IST-2007.1.1 The Network of the Future* are:

- **Ubiquitous network infrastructures and architectures:** Next generation infrastructures need to support convergence and interoperability of heterogeneous mobile and broadband network technologies. The main enablers are expected to be flexible and spectrum-efficient mobile broadband access technologies and optimised protocols and routing concepts. Moreover, increased scalability, context-awareness and efficient traffic management is needed to support an order of magnitude increase in the number of connected devices and enabling the emergence of applications that are machine-to-machine or sensor-based and are capable of functioning within a multiplicity of public or private operating environments.

- **Optimised control, management and flexibility of the future network infrastructure:** New control and management schemes are identified as key research topics towards flexible and cognitive networks. They are expected to enable seamless end-to-end network and service composition and operation across multiple operators and business domains. Programmability and dynamic features, re-configurability of resource allocation, of protocols and routing, self-organisation and -management should support a wide diversity of service attributes and requirements, which are expected to be an order of magnitude more complex than those of today's infrastructures. New forms of ad-hoc communications with intermittent connectivity requirements and time-varying network topology need to be manageable in real-time. Finally, they should enable the intelligent distribution of services across multiple access technologies with centralised or distributed control.

- **Technologies and systems architectures for the future Internet:** Activities in this area are aimed at overcoming the expected long term limitations of current Internet capabilities, architecture and protocols. They are driven by the need for generalised mobility, scalability from the perspective of devices, service

attributes and application environments and security and trusted domains. New forms of routing and content delivery with dynamic peering of end-to-end delivery and control, of ad-hoc connectivity in a generalised wireless environment are expected building blocks towards these long-term goals. The work of exploratory nature is expected to address how various classes of new requirements constrain the foreseeable evolution of the Internet and identify corresponding long term solutions.

These activities are linked to the Objective *IST-2007.1.6 New Paradigms and Experimental Facilities,* which aims at advanced architectures and protocols designed to cope with increased scale, complexity, mobility and requirements for security, resilience and transparency of the future Internet. These research activities are expected to be coupled with their validation in large scale testing environments based on a combination of physical and "virtual" infrastructures. Interconnected test beds can be funded exploring new paradigms for distributed protocol and service architectures, for advanced embedded or overlay security, trust and identity management, and for systems that provide trusted access to e-services with users requiring no administration and security skills.

Expected Impact

Whereas the target outcome can be seen as a scientific or technical result, it should have an impact in terms of industrial competitiveness, societal goals and technology progress. The impact expected from activities in each specific area is identified in the Work Programme and proposals will be evaluated based on the degree how far the target outcome of a potential project can have this expected impact. Impact of activities in the area of *The Network of the Future* is expected towards the following goals.

- Global standards for a new generation of ubiquitous and extremely high capacity network and service infrastructures. These should support convergence, full interoperability, and a significantly larger and diverse number of devices, new services and complex user requirements.
- Reinforced industrial leadership in wired and wireless networks; developing stronger synergies between various sector actors and contributing to new business models that take advantage of convergence and full interoperability.
- New industrial/service opportunities, especially in the field of Internet technologies.

Building Blocks and System Approach

Research is expected to be placed in a system context. Focused activities are expected to aim at technology building blocks that are generating essential IPR for the participating partners and by enhancing or defining new parts of future networks, from edge networks to access up to the core network and the public Internet, see Figure 5. Fundamental new approaches of future networks, e.g. in the context of the future Internet, are also expected. Based on these technology building blocks, system concepts should be developed in larger scale activities in order to make the building blocks efficiently cooperate and to increase the success probability for future standards. An example for this needed system approach is the development of new air interface technologies for 4G that should be co-researched with evolved radio network architecture and radio interface protocol stack, especially *Medium Access Control* (MAC) and *Radio Resource Management* (RRM). Since it is unlikely to achieve a full harmonisation in particular in the area of access networks, the accommodation of a significant number of heterogeneous networks should be achieved. As a means to overcome the problem of heterogeneity of network standards the concept of re-configurability and programmability is seen as a promising approach towards "plug-and-play" network equipment.

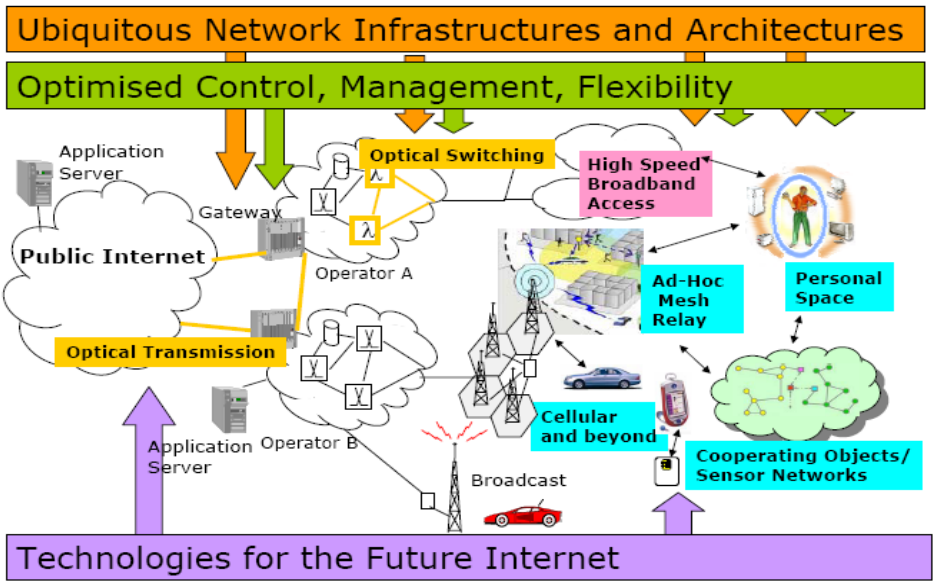

Figure 5: End-to-end perspective

CONCLUSIONS

In recent years, mobile communications and broadband Internet access have been the main contributors to growth in the telecom sector and have been identified as one of the most positive overall market developments. Already today, network and service infrastructures underpin economic progress and the development of our societies. This can be illustrated by two billion mobile terminals in commercial operation, one billion Internet users and 400 million internet enabled devices.

Besides this important role of communication technologies for society and general industrial competitiveness, FP7 research and development activities should lead to both future standards and essential IPR.

Goal is the development of the converged communication and service infrastructure that will gradually replace the current Internet, mobile, fixed and audiovisual networks. This infrastructure should be interoperable in order to support seamless converged services accessible everywhere supporting mobile usage. There is need for shared infrastructure solutions exploiting legacy, evolved and new infrastructure components.

With unlimited capacity of optical transmission being a reality today, the important goal for core networks is the further development of optical switching and the related network technologies and the facilitation of full deployment.

There is especially a need for more capacity and user data rates for mobile users towards GBit/s mobile access. In this context the development of technologies for the efficient and dynamic usage of radio spectrum and the demonstration of their benefit is expected to play a key role.

Communication technologies for sub-networks at the edge such as personal and sensor networks and the network technologies for their integration towards the Internet of things for the benefit of humans need to be researched.

Finally, in order to support high-quality media services and support critical infrastructure, e.g. for energy and transport, the existing Internet needs to be significantly enhanced or even gradually replaced.

FP7 as one of the world-wide largest research programmes in this area is facilitating and stimulating joint research actions towards this next generation of ubiquitous and converged network and service infrastructures.

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