Building the Wireless Universe

EU Research on the Move

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Mobile and personal communications and systems, including satellite systems and services
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Resumo **- Este artigo apresenta uma visão geral das actividades em curso do programa da União Europeia para a Sociedade da Informação (IST) na área das comunicações moveis, acesso sem fios e sistemas via satélite. As linhas de orientação da investigação especificas desta área são apresentadas em detalhe, com referencia aos projectos já em curso, definindo um possível percurso para evolução das comunicações moveis para além do UMTS.**

Abstract **- This paper provides an overview of the activities currently carried out under the IST research programme of the European Commission, in the area of mobile and wireless communications and satellite systems. The research orientations specific to wireless communications are described in detail, with reference to the projects already approved in each area, defining a possible roadmap for the evolution of Mobile Communication systems beyond UMTS.**

I. INTRODUÇÃO

A. The 2G Success Story

Mobile telecommunications is playing a crucial role in today's economy and lifestyles, as witnessed by the impressive statistics on its diffusion. Amongst the four largest cellular markets, including China, USA and Japan, Europe is now at the first place, with a very steep increase which is expected to be sustained over the next few years. In May 2001 the number of GSM subscriptions exceeded 70% of the EU population, Figure 1. The yearly subscription growth in some EU countries, such as Spain or Germany, is in excess of 100% and the annual penetration increments, since 1995, are quite extraordinary, Figure 2. This may be attributed in large part to the multiple benefits generated by the single second generation (2G) digital standard agreed for Europe as opposed to the situations in other world regions where multiple technological standards were advocated. Among them is the possibility of seamless service provision over networks managed by different operators, the economies of scale both for users and network operators, the international roaming that enables the use of the same handset over all European countries and in many regions abroad, and on top of all the effective competition between operators which has led to increasing benefits for the customer in terms of tariffs and quality of service. The GSM standard, now in use by over half a billion subscribers world-wide deployed in more than 168 countries, is indeed a perfect illustration of the rewards possible through an articulated European policy in telecommunications such as that carried out in the past 10 years.

As the penetration of GSM is approaching 100% and reaching the network saturation in certain areas, operators and manufacturers are preparing the ground for the commercial start of the third generation (3G) of mobile communications, which brings the promise to allow convenient mobile access to the Internet with all foreseeable and non-foreseeable implications (m-commerce, m-networking, etc.).

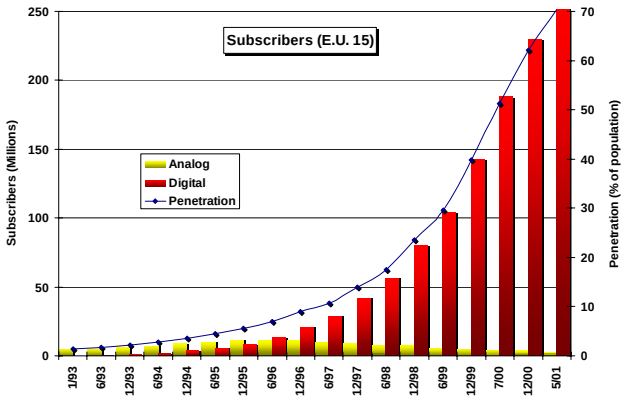

Figure 1 – Number of subscribers in EU, in absolute terms and as a percentage of the population

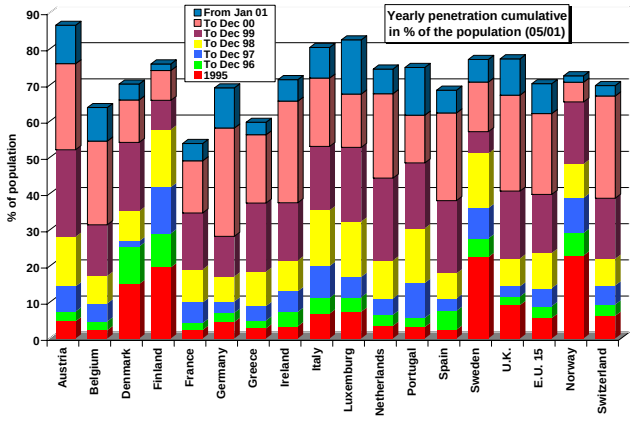

Figure 2 – Cumulative trend of yearly penetration in European countries, in percentage of each country's population

B. The 3G Ambition

European efforts in 3G, referred to as UMTS, followed a

[1] *The views expressed herein are those of the authors, and do not necessarily reflect the views of the European Commission.*

process very similar to the one that led to GSM, in a time-frame shifted by nearly 10 years. Indeed, the first UMTS R&D project was launched in 1989, with spectrum being first identified for this purpose by WRC'92. Many EU-funded R&D projects under the RACE and ACTS programs have contributed to lay the foundations of the UMTS standard (as for network aspects and tools, services, radio aspects), and have in particular made significant contributions towards solving the most controversial issue –the choice of the air interface– which was made by ETSI in January 1998. The UMTS vision, initially developed in the context of research and development activities, is nowadays being further developed and refined by the 3GPP. The European proposal together with other air-interface proposals are members of the IMT 2000 family endorsed by WRC 2000. In parallel to the standards and R&D work, the European Commission very early on launched a process aiming at setting the licensing and regulatory framework to be used for UMTS. This process culminated in the UMTS Decision which inter-alia requires Member States to allow for the deployment of commercial UMTS networks by 2002. As demonstrated by the amounts that operators have been willing to pay for UMTS licenses, the expectations placed on mobile internet are of unprecedented proportions and will no doubt place Europe at the heart of the coming wireless revoluton.

C. Beyond 3G

While the mobile telecommunications industry is currently considering how best to reap the benefits of the UMTS "always-on" technology, that will ultimately provide the users with 2 Mbit/s, researchers world-wide have started considering solutions beyond third generation, trying to fulfil the expectations of the latest self-realising prophecy of this turn of millennium, after the Moore's law: a new generation of mobile systems every 10 years. Today's society is indeed at the threshold of a communications revolution, of extremely large proportions, where wireless will become the dominant "life-style", characterised by a proliferation of terminals and devices permitting new forms of untethered communications and the development of a truly personal communications space. While there is a general agreement that wireless communications will play a central role in the future, questions are being asked as to what to expect from fourth generation systems (also better named "future generation"): is it just a matter of higher bit rates and interconnection capabilities, a network of self organised wireless devices (sensors, actuators), or a whole new concept of "mobility", and a new service paradigm?

A short term technological perspective of the likely evolution of a number of different wireless technologies is provided in Figure 3. In order to exploit with a better

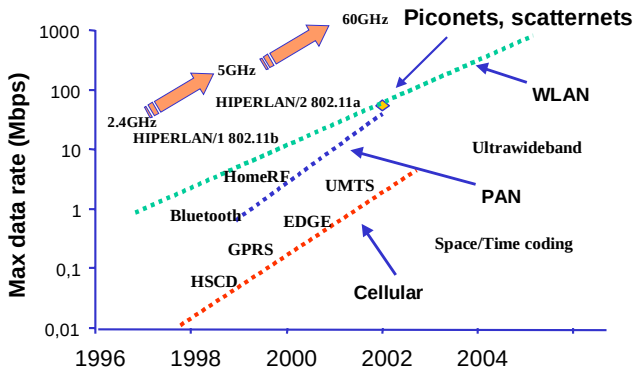

Figure 3 – Short term Technological perspectives

cost/efficiency higher and higher spectrum regions, two particular disruptive technologies, namely space-time coding and ultra wideband modulation, may bring about major changes in the economic viability of many systems and networks.

But what will the user terminal look like? In the most likely view several different levels of functionality will be possible, corresponding to different sizes –and prices– of the user terminals. What is even more innovative is the concept of "personal mobility": there should be no need to bring around any bulky piece of equipment, as far as the surrounding environment has some kind of "*embedded intelligence*" which can recognise our presence and our preferences, and seamlessly adapt to our needs. The "handset" will only contain the "minimal" set of functionality according to individual requirements, while the additional capabilities will be simply downloaded from the network to reconfigure the terminal itself, or they will be made possible by external "co-operative" devices (e.g. a Bluetooth networked printer, a bigger screen, etc.). An area of particular interest, depicted in Figure 4, is that of the networking of a variety of wireless devices, sensors or actuators, which once embedded in our environment can spontaneously interact with each other and therefore extend our personal communications space.

On the other hand, providers of services will use a variety of radio interfaces to reach the user, depending on what is available or most convenient at a given time and place. An individual channel may be required for a personal video call, but the newspaper or the local map may be simply downloaded in fractions of a second when passing

Figure 4 – Self-configured ad-hoc networking of devices

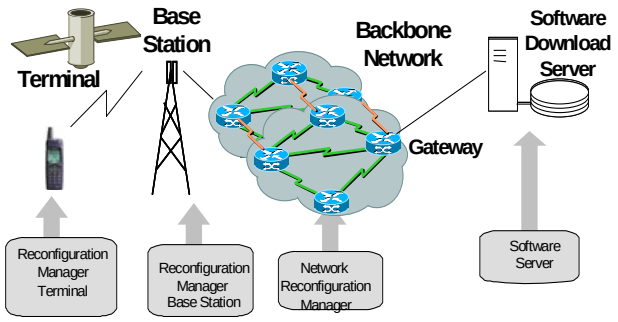

Figure 5– Re-configuration at all network levels

by the cheapest and nearest "e-news kiosk" through a hot spot wireless LAN providing a short-range broadband channel, etc. The terminal needed to do all this could range from a sophisticated re-configurable radio (with a large screen –flat or in the eyeglasses– and adequate input devices) down to the minimal secure "identification tag" (artificial as an RFID tag or natural as a retina) allowing the ubiquitous "network" to recognise our preferences (and billing account) and therefore re-configure itself accordingly. This scenario is depicted in Figure 5, which illustrates the need to reconfigure all network elements, and also to provide a software downloading capability, to cope with specific user requirements.

Thus, any information appliance (resembling a TV, a phone, a web browser, a block notes or whatever else) is just a part of the furniture or of the normal clothing, connected to any other such appliance in order to share information and increase power and functionality. Realisation of this vision presents many societal and technical challenges, including issues of privacy, "digital divide" (i.e. the risk of increased segregation between people who can afford the benefits of the Information Society and those who cannot), security, spectrum allocation, standardisation and interoperability. It requires also a strong linkage and proper articulation between technology, applications, policy developments and implementation. Indeed this concept of "ambient intelligence" is the vision at the basis of the Information Society Technologies (IST) programme.

D. The IST Programme

This IST programme (which is part of the 5th Framework Programme of EU RTD, see www.cordis.lu/ist), is the European Union framework under which the above referred R&D activities take place. It is implemented through a series of annual workprogrammes, each of which is developed in close co-operation with industry, academia and user organisations.

The IST Programme is structured around four interrelated Key Actions (KAs) all geared towards the achievement of the Programme vision. These are: KA I *systems and services for the citizen*; KA II *new methods of work and electronic commerce*; KA III *multimedia content and tools*, and KA IV *essential technologies and infrastructures*. For the purposes of the workprogramme, the KAs are sub-divided into Action Lines (ALs). "*Mobile and personal communications and systems, including satellite-related systems and services*" are considered as part of Key Action 4. In this area the following specific action lines have been defined:

1. Re-configurable radio systems & networks
2. Terrestrial wireless systems and networks
3. Satellite systems and services
4. Fourth Generation system and network concepts for wireless communications
5. Mobile and personal communications and systems – take-up measures

As the definition of such Action Lines is subject to change and refinement each year, based on the results of the calls for proposals and on the shift in strategic focus in the research arena, the text of the Action Lines for the Calls for Proposals open in calendar year is published in the yearly workprogramme (available through the IST web site http://www.cordis.lu/ist/).

In the remaining of this paper a basic description of such Action Lines will be provided, more in terms of concrete projects which have been already accepted for funding than in abstract words. The definition of the project acronyms (referred to in capital letters) is reported in Table 4, and further details on every single project can be found at www.cordis.lu/ist/ka4/mobile/projects.html. It has to be noted that, since many of the research projects mentioned actually address a wide variety of objectives, their collocation under a certain action line is purely indicative of their main area of activity.

II. SPECIFIC R&D ACTION LINES

A. Re-configurable radio systems & networks

The objective of this Action Line is to create open architectures and service/application development environments that allow heterogeneous wireless networks and platforms to inter-work and adjust adaptively to traffic load and characteristics, services and user requirements. This addresses both terminals and base stations, and includes in particular multi-streaming, dynamic bandwidth allocation, and dynamic spectrum sharing. A key goal for future research is the development of novel techniques and technologies in the area of combined DSP/RF design for efficient and cost-effective adaptive transceivers. Particular interest lies with the combinations of dedicated ASIC implementations and re-configurable logic as well as optimised algorithmic partitioning.

Many different projects are running in this area (Table 1), launched at the beginning of 2000 following the first IST call. CAST, PASTORAL, SODERA and TRUST are focusing on the intelligent and adaptable configuration and management of the radio resources at the physical layer. The feasibility of the selected techniques and radio architecture will also be validated, possibly with the more advanced technologies presently under development (BICMOS-SiGe, SOI & Micro-Machining). PASTORAL is studying reconfigurability already for the GSM (Phase II), W-CDMA (FDD) and TD-CDMA standards, while TRUST addresses the development of re-configurable

terminal platforms from the "user friendly prospective", also including the underlying enabling technologies.

Adaptable reconfiguration of radio resources	*CAST, PASTORAL, SODERA, TRUST*
Open architectures for converging network services (in dynamic usage conditions)	*MOBIVAS, MONASIDRE*
Jointly optimised DSP/RF design for high bit rate modem architectures	*WIND-FLEX*

Table 1 – Projects in AL 4.5.1 Reconfigurable Radio

Upper in the OSI stack, the development of architectural approaches and prototypical implementations of integrated software platforms and systems, adaptable to converging network services and technologies (following TINA/CORBA principles to support a required QoS) is the objective of MOBIVAS, in order to open new opportunities for advanced Value Added Service Providers. The open and adaptive services which are expected should be able to operate in dynamic usage conditions while maintaining the highest available level of quality. Also MONASIDRE is addressing radio resource control (network planning) and QoS management in all IP-based heterogeneous networks, taking into account the flexibility provided by software radio.

More on a system level, WIND-FLEX is studying a high bit-rate flexible and configurable modem architecture, which works in single-hop, ad hoc networks and can provide a wireless access to the Internet in an indoor environment where slow mobility is required. The trade-off between performance and complexity is attained by using a jointly optimized adaptive system (configurable in the run time) which includes the multiple access method, diversity, modulation, coding, equalization and decoding. Bit rates from 64 Kbit/s up to 100 Mbit/s (variable depending on the user needs and channel conditions) are considered in the band of 17 GHz - 19 GHz (5 GHz will be also analysed). Flexibility is attained by using a multicarrier modulation method.

B. Terrestrial wireless systems and networks

The objective of this AL is the study, development and validation of novel terrestrial wireless systems and networks, including fixed wireless access systems and advanced public/private wireless local area networks. It extends to the interworking of mobile/broadcasting systems supporting the provision of broadband multimedia services for interactive and distributive services. Key aspects concern:

- Innovative issues of Quality of Service evaluation and management for multiple radio environments, support of mobility, radio resource control mechanisms (e.g. load sensing) and protocols, including intra-/inter-network handover and seamless roaming between public and private networks supporting full service mobility.
- Optimisation of network elements and terminal performance in heterogeneous (e.g. mobile/broadcasting, public/private) contexts with a variety of symmetric, asymmetric and broadcast services.
- Roaming of location-based services.
- Further enhancement of mobile-related IPv6 capabilities for improved addressing and security.
- The study of novel concepts and architectures for systems and networks offering significant advances in terms of performance, cost, dynamic spectrum sharing, service capabilities and network management features, including high altitude platforms.
- Technological and algorithmic development and demonstration with the objective of enhancing network performance.

Wireless broadband IP(v6)-based network architectures for mobile/fixed IP convergence	*BRAIN/MIND, DRIVE, MCP, MOBY DICK, ARROWS, WINE*
Mobile/broadcasting interworking (FWA to asymmetric services):	*ADAMAS, EMBRACE, MAMBO*
Location and QoS-aware services	*WINE GLASS, CELLO, EMILY*
Network aspects	*ANTIUM, CAUTION, OBANET*
Security aspects	*SHAMAN*
Industrial environments	*R-FIELDBUS*
New transceiver concepts (space-time processing, beamforming)	*ASILUM*
Smart antennas (MIMO channel modelling)	*METRA, SATURN*

Table 2 – Projects in AL 4.5.2 Terrestrial Systems

A growing number of projects in this area (Table 2) is dealing with wireless broadband IP based networks, in order to evolve third generation mobile and wireless infrastructures further towards the Internet. BRAIN and MIND proposes an open architecture allowing for the convergence of fixed Internet, emerging wireless/mobile Internet specifications and UMTS/ GSM/ GPRS, to provide end-to-end IP integrated services. The access network will provide hot spot coverage in urban, suburban, in-building and home cells. Its radio interface, based on HIPERLAN 2, provides the high speed coverage with data rates up to 20 Mbit/s for the user.

The vehicular environment is the target for DRIVE and MCP which, in different ways, integrate also broadcast networks, such as DAB and DVB-T, to enable spectrum-efficient high-quality wireless IP for universal access to information and support for education, communication, navigation and entertainment. They address the convergence and interworking of cellular and broadcast networks in a common frequency range with dynamic spectrum allocation, and the co-operation between network elements and applications in an adaptive manner. Their objective is to implement IPv6-based mobile infrastructures, handling the available network access taking into account the asymmetry of the communication, the position of the user, the terminal decoding capacity and the user preferences in terms of delay and quality.

MOBY DICK is considering an IPv6-based mobility-enabled end-to-end QoS architecture starting from the current IETF's QoS models and Mobile-IPv6. This will be demonstrated in a testbed of interactive and distributed multimedia applications comprising UMTS, Wireless LANs and Ethernet. ARROWS addresses radio resource control and QoS management for UTRA, to support multimedia IP services up to 2 Mbit/s. Finally WINE approaches the issue from the network side, realising a Wireless-IP adaptation layer configured to optimise different wireless media, and testing it in Bluetooth, IEEE 802.11 and HIPERLAN environments.

Three projects are specifically dealing with the integration/interworking of mobile and broadcasting systems, for fixed wireless access to asymmetric services. While ADAMAS is studying a novel adaptive (at physical and DLC layers) OFDM point-to-multipoint system with bit rates ranging from 64 kbit/s up to 25 Mbit/s (depending on channel conditions or traffic requirements), EMBRACE aims at low cost radio access using MPEG-2 in the downlink and MF-TDMA in the uplink, providing also solutions for nomadic users. Efficient utilization of radio frequency bands is a concern for both projects; in particular the first one will investigate a wide range of service symmetry (from broadcasting to symmetric services). Finally, MAMBO will study the optimisation of the bandwidth allocation for interactive DVB/IP services, based on the perceived QoS. The return channel used for such a feedback can be implemented through LMDS, GSM or UMTS.

Enabling location- and QoS- aware services for wireless mobile users is the goal of WINE GLASS, which will exploit enhanced and/or new IP-based techniques in a wireless Internet architecture incorporating UMTS and WLANs. The Project will develop a testbed incorporating an IP backbone, UTRAN access to IP-based core network, and WLAN access to intranets. Also CELLO and EMILY are exploiting the location capability of mobile terminals, respectively to enhance 2G/3G mobile networks (e.g. with location-aided handover algorithms, or mobility functions supporting multiple wireless systems, including WLANs) and to implement location services integrating terrestrial (E-OTD) and satellite (GNSS) location data in the context of UMTS handset based solutions.

Three projects are dealing with network aspects. CAUTION addresses the development of algorithms and new techniques to provide enhanced capacity management in present (GSM, WAP) and future (HSCSD, GPRS, EDGE) cellular networks. It will provide facilities to monitor the network from a central site so to have an overall view of the network and its components. ANTIUM deals with radio monitoring techniques (mobile network planning) for EDGE/UMTS/DVB-T systems. OBANET addresses specific coverage area management strategies for the optimisation of QoS and spectrum resources in fixed and mobile Wireless Access Networks at 42 / 60 GHz, to be realized through adaptive antennas using photonic beamformers.

Security architectures have been addressed by SHAMAN, in relation to the global roaming in UMTS networks (for instance, through WLAN and Bluetooth) and the dynamic configuration of the components of mobile (e.g. wearable) terminals. Enabling technologies considered are public key infrastructures and smart card security modules.

Devoted to the needs of industrial application services, R-FIELDBUS is developing an innovative high-performance radio fieldbus. Such a radio fieldbus architecture will avoid the need for re-cabling or allow to install new, and probably moving, sensors and control units in manufacturing plants. It will also provide full transparent access to a wide range of information needed on-site, such as data concerning real-time control and status information, or other industrial-type multi-media information with a user-defined QoS. The architecture will be based on the integration of emerging wireless technologies for broadband systems and networks with existent industrial communication protocols (such as those specified in the European Standard EN50170).

Dealing with enabling technologies for mobile communications, the objective of the ASILUM project is to validate new transceiver concepts, for both base station and mobile terminal, to increase the capacity of the future generation of UMTS through new and efficient interference mitigation schemes, based on space-time processing, downlink beamforming, advanced coding and hybrid analog/digital signal processing. A software-based simulation platform running a number of competitive techniques will be designed, implemented and validated to evaluate the performance of the schemes in terms of capacity.

Also in this area is worth mentioning two projects which will analyse the feasibility and evaluate the performance of introducing multi-element adaptive (smart) antennas into mobile terminals in combination with adaptive base station antenna arrays, including transmit diversity, for 3rd generation mobile communication systems (UMTS) and wireless LAN/WANs. They will perform multiple-input and multiple-output (MIMO) matrix radio channel measurement in various mobile communication scenarios. The expected impact of METRA is on standardisation of future phases of EDGE/UMTS, while SATURN will also investigate the potential of array processing to provide enhanced location information for UMTS outdoor broadband networks, particularly in areas where triangulation between several base stations is problematic.

C. Satellite systems and services

The objective of this AL is to study, develop and validate technologies and architectures for the support of multimedia services in the context of advanced mobile systems and of next generation interactive broadcasting systems. The focus is on the:

- technologies and architectures demonstrating a viable implementation of 3G MSS systems, integrating satellite with terrestrial UMTS networks. Fostering convergence between satellite mobile and broadcasting (e.g. S-DAB or S-DVB), it aims at an efficient implementation of

IPv6 multicasting and seamless roaming/service provision across mixed satellite-terrestrial networks.

- Development of advanced technologies and architectures allowing for introduction of novel BSS subsystems (evolved from legacy broadcasting systems, in integration with terrestrial networks) with scalable support for multimedia services. The work relates for instance to optimised multicasting, caching architectures, dynamic optimisation of spectrum and network resources.

The work is also conceived with the objective of complementing support actions sponsored by Space Agencies (e.g the ESA), without overlapping with it.

Several projects (see Table 3) are dealing with high speed multimedia via satellite. The objective of BRAHMS is to define a universal user access interface for broadband multimedia (IP) satellite services which is open to different system implementations, including GEO and LEO constellations. It addresses a range of user groups with data rate requirements up to 150Mbit/s. The goal is to open up the market for satellite systems in general, by harmonising the majority of common satellite access network functions whilst allowing flexibility for optimised or proprietary air interfaces to satellite systems. This commonality and flexibility (e.g. for frequency, access type, orbit) is obtained by separating physically-related functions from common service and access functions.

High speed multimedia (IP) via satellite	*BRAHMS, VIRTUOUS, SUITED, SATIN-0, FUTURE*
Convergence of satellite, mobile and broadcasting using IPv6 multicasting	*IBIS, MOBILITY, SATIN-7*
Fixed Satellite Services (multicasting):	*GEOCAST*
Multibeam Ka antennas	*MULTIKARA*
Navigation/communications system integrating S-UMTS and Galileo	*GAUSS*

Table 3 – Projects in AL 4.5.3 Satellite Systems

Also VIRTUOUS aims to design, develop and implement (in test beds) an URAN (UMTS Radio Access Network) Radio Technology Independent part and two URAN Radio Technology Dependent parts able to handle a terrestrial and a satellite link, respectively. It will also design and implement appropriate terminal and network InterWorking Units (IWUs) integrating the GPRS and UMTS segments. The demonstrator will then include three segments: GPRS, terrestrial UMTS and satellite UMTS, and will be further complemented to perform trials of meaningful UMTS service (such as voice over IP).

SUITED aims to design and develop IP based mobile networks consisting of both satellite and terrestrial (UMTS, GPRS, W-LAN) components. Theoretical analysis and experimental work will be performed concerning issues of network architecture (splitting of functions between edge and core network), quality of service and mobility management. The project will carry out extensive series of trials, using an integrated test-bed comprising a multi-segment infrastructure and a multi-mode mobile terminal, capable of operating seamlessly with both satellite and terrestrial networks.

SATIN-0 and FUTURE study new S-UMTS architectures for integration in the UMTS core network, to provide IP based, point-to-multipoint services with end-to-end QoS functions.

Some of the projects selected in the third IST call are addressing the convergence of satellite, mobile and broadcasting using IPv6 multicasting. In this context IBIS will design, develop and test a satellite interactive system (combining the DVB-RCS and DVB-S), to support Interactive TV, Internet and Multimedia services, interworking with the terrestrial network. With a more focused scope, MOBILITY is addressing the provision of mobile satellite TV through DVB-S for mobile (maritime, car, etc.) users, while SATIN-7 deals with the set-up of high-speed interactive IP and multicast services for info-kiosks using DVB and VSAT as a return channel.

In the field of pure FSS systems, GEOCAST (launched in the more general framework of KA4) is investigating the use of geostationary satellites used for TV broadcasts as a platform for two-way IP-based data services (multicasting). GEOCAST intends to help the definition and standardisation of next generation multicast systems, which are evolving towards higher frequencies (Ka and EHF) and more complex missions (multi beams, inter satellites links, regenerative payloads with on-board processing).

Not directly targeting system aspects, MULTIKARA will design and test innovative multibeam receiving antenna around 30 GHz with its associated microwave circuits and evaluate its feasibility for future in-flight use. The ultimate goal is to provide an integrated Tx/Rx Ka band antenna for high rate communications via satellites, complying with constraints of user equipment, such as small sized antennae and low power transmitters, in the Ka band (18-31 GHz), the only non-saturated one available.

Belonging to the area “Intelligent transport infrastructure and mobility management”, GAUSS aims at defining an integrated navigation/communi-cations system using S-UMTS as the communications component of Galileo. Such a project will also develop applications in the field of health care and waterways navigation.

D. Fourth Generation system and network concepts for wireless communications

With a long-term perspective, the objective of this AL, which has been open only in June 2000, is to prepare the ground for the likely technological and service evolution from current cellular and wireless systems and networks. Key goals are:

- to investigate advanced and innovative concepts such as self-aware, self-organising ad-hoc wireless networks;
- to develop innovative air interfaces for scalable pervasive connectivity;
- to assess potential spectrum requirements and co-

existence issues, including the study of strategies and the development of appropriate tools allowing a distributed flexible management of the spectrum resources;
- smart interfaces and innovative applications including service personalisation and global portability.

The scope of any future work in the area of "4th generation" was refined in the workprogramme 2002 on the basis of the successful proposals selected so far. Some projects will start soon their activities. However, some projects in other IST sectors (such as the *Future and Emerging Technologies* longer-term research area) have already been selected which are addressing related issues. Several projects in such an area are differently interpreting the vision of "ambient intelligence", with the common purpose of networking the more disparate artefacts found in everyday life: from wearable devices (e.g. hidden in glasses, buttons, pens, wallets etc.) to smart everyday objects (in some cases, made adaptive by using neural networks), up to the proposal of a "gadgetware" architecture style.

E. Mobile and personal communications and satellite systems – take-up measures

The objective of the "take-up" measures is to facilitate the broader application and rapid take up of mobile and personal communications and systems. The work comprises trials that use and evaluate innovative and advanced, yet not fully established, technologies and solutions such as:
- Multimedia interactive, distributive and asymmetric information services over a range of terrestrial networks (terrestrial cellular, cordless and "indoor" radio systems and networks);
- Implementation and validation of new business scenarios where the benefits of satellite communication systems and services can be clearly established;
- Wireless technologies for evolving and scalable systems and networks (including cellular networks, private wireless networks, fixed wireless broadband access systems, wireless local loop systems, cellular interactive systems, and mobile broadband systems).

Three of the projects active in this area (HOME ON AIR, POS.IT and WIRELESSINFO) are exploiting WAP technology, respectively for home control services, fleet management and electronic payment, and agriculture and forest information. The others are addressing different issues:
- TRIADIS will validate the "Distributed Speech Recognition" technique in a real Mobile Network (GSM, DCS-1800), also for possible adaptation to GPRS and UMTS.
- RADIATE will conduct trials to validate their proposal for digital broadcasting in the AM bands around 30MHz (DRM). They expect to show that the expected improvement in audio/data quality and reception reliability are consistently achieved. Also issues of compliance with broadcast legislation and co-existence with analogue broadcasts will be addressed.
- WIN will develop and demonstrate a cellular wireless IP-based communication platform (2-10 Mbit/s, based on Spread Spectrum technology and operating in the 3.6 GHz band), which will cover the networking needs of a medium size area cell (e.g. apartment buildings, businesses, university and school campuses, etc.). The project will design and deploy the wireless network, survey the market and select subscribers' groups, develop user specified and E-commerce applications, as required, and measure post-deployment network performance and subscriber acceptability and satisfaction.
- WITNESS aims to upgrade, test, and validate equipment and planning algorithms to aid the standardisation of a digital terrestrial television (DTT) return channel that can be implemented across Europe, and in other territories adopting the DVB standards. It will upgrade the technology already developed in the earlier project iTTi.

F. Accompanying measures and other related Action Lines

In addition to the previously mentioned research projects, the IST programme allows for funding of "accompanying measures" dealing with activities supporting the implementation of the EU research policy, such as:
- LOCUS, which will help defining the future Emergency Call Service (ECS) in Europe taking into account all aspects of a possible implementation such as: user needs, institutional issues, technical and technological issues, foreseen markets and convergence with other applications. This will provide orientation for the EC policy regarding the most relevant European regulatory framework for enhanced 112 emergency services.
- WSI, whose objective is to focus research capacities on strategic objectives and essential issues through active information and the formation of Innovation Cells, also offering a platform that enables synergy among projects in the wireless area of the IST Programme and disseminating information. The goal is to significantly reduce the time-to-market for future wireless products and services through timely experimentation with research prototypes and collaboration with leading-edge users in trials, also to accelerate the emergence of standards and to support interoperability in and between wireless technologies.

In addition to the focused action lines specific to the mobile communications domain which have been mentioned in the previous paragraphs, the workprogramme 2001 includes some new "cross key action" ALs which strengthen the focus on the development of a pervasive computing environment for seamless access to services. These include actions which:
- Focus on networked embedded information systems and "intelligent" resource-constrained devices in decentralised networks, including in particular the areas of consumer applications and wireless networking in limited mobility environments (action line IV.1.1).
- Focus on the development of middleware (adaptation layer) for seamless access to scalable, personalised and

interactive services, over a range of heterogeneous transport networks (terrestrial and satellite, mobile and fixed, wireless and wire based, symmetric and asymmetric, public and private). The work addresses issues of personal mobility (to facilitate location and terminal-independent working) and service customisation and portability (through various user interface profiles and subscriber profiles). It also covers the application of multi -bearer -streaming techniques, splitting multimedia traffic between bearers of different latency, bandwidth, etc (action line IV.1.2).

Moreover, in order to further stimulate integration between IST Key Actions, there are wider and multidisciplinary "Cross-Programme Actions" (CPA). Some of these have direct links to wireless communications, namely:

- CPA3 "use of geographic information", which also spans the development and demonstration of location based mobile services integrating global positioning and fixed/wireless network technologies, to allow context-based information management and retrieval;
- CPA6 "next generation networks", which promotes large scale experiments of novel IP infrastructures resulting from the convergence of fixed, mobile and wireless technologies and architectures from a service perspective;
- CPA13 "advanced signal processing systems and applications", one of whose foci concerns specifically the application areas of communications (fixed, mobile, wireless, navigation).

In this context it is worth mentioning the project TONIC, resulting from the CPA7 "socio-economic analysis for the Information Society". It aims to evaluate the new business models associated with offering IP based mobile services in a competitive context, also in terms of cost and benefits of providing fixed broadband access to both competitive and non-competitive areas, so to suggest the most appropriate network infrastructure from an economic viewpoint.

Another kind of integration activity are the "cross-programme clusters", launched through accompanying measures (action line VIII.8.1), whose objective is to build links between existing projects to reinforce their complementarity and synergies. On the other side, Networks of Excellence and working groups (action line VIII.8.2) have as objective to bring together a critical mass of industrial and academic research groups to coordinate their research or other activities in order to advance towards common strategic goals.

III. THE ARCHITECTURE IN PLACE

In summary, Figure 6 reports a "map" of the IST projects currently running in the mobile communications area. The horizontal axis provides a distinction based on the simplified OSI layer primarily targeted by the research (Air Interface, Network, Application), while the vertical axis defines different groups based on the coverage characteristics of the system considered:

- **Satellite**: global coverage and global mobility through satellite (low bit rate per user, complementing terrestrial segments to provide economically viable global coverage);
- **Terrestrial broadcast**: wide coverage and mobility for broadcast or distribution services (such as DAB-T or DVB-T: long range and big cell size, any other access systems can be used as a return channel);
- **Cellular**: full mobility and roaming for individual links maximising the system capacity. It encompasses evolutions of GSM (2G+: GPRS, EDGE) and 3rd generation systems (3G: IMT-2000/UMTS);
- **WLAN or PAN**: local hot spot coverage for very high data rate asymmetric individual links (e.g. IEEE 802.11, HIPERLAN) or for "universal" wireless networking (e.g. Bluetooth and DECT);
- **Fixed wireless**: providing wireless local loops, e.g. for new operators.

This map shows for example that a large part of the research activity is focused on network aspects of 3G cellular systems, and many projects deal with applications of 2G+

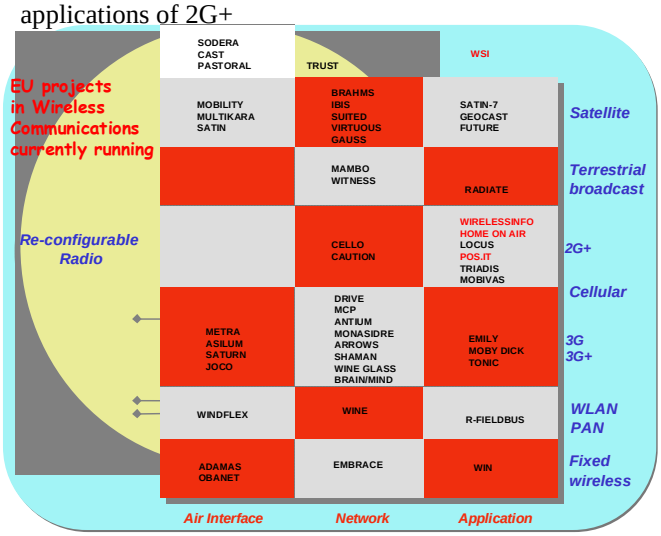

Figure 6 – Map of the projects currently running in the Mobile and Satellite Communications area of IST. The horizontal axis is divided in three portions corresponding to a simplified OSI structure, while the vertical axis distinguishes between different radio coverage characteristics of the systems (as explained in the text). The position of the project name indicates the main area of activity, and the links point to any other areas of interest of the project.

(taking advantage of GPRS and EDGE). One can also easily see that several projects realise a high degree of integration between fixed, mobile, on-line and broadcasting technologies (e.g. DRIVE, MCP, MOBIVAS, MAMBO, SUITED, IBIS, BRAIN, MOBY DICK, just to name a few). This kind of integration is also one of the main objectives specified in the workprogramme for 2001. Other foci of research activities lie in the development and interconnection of embedded technologies, and in the development of middleware, distributed systems and multi-layered architectures to enable inter-operability, inter-working, openness and integration of applications and services across platforms. The use of open source software for the application levels is also strongly encour-

aged.

IV. CONCLUSIONS

This paper aimed at providing an overview of the recent achievements and current developments of European Union funded IST-R&D programme. Clearly many if not all the issues referred to are of a global nature and require close collaboration and consensus building amongst telecommunications operators, equipment, content and service providers as well as academia and research institutes. Since these issues are very often related to standards and specification work or relate to the future planning of the frequency spectrum, the IST Programme has been opened to participation beyond Europe. Indeed the basic condition for participating in EU-funded R&D actions is that the consortium submitting a research proposal include at least 2 partners from EU countries or one from an EU country and one from an Associated State (i.e. from the EEA, the EU Candidate Member States, Israel and Switzerland). While all the partners from EU or Associated States can be funded, partners from other countries can participate to the activities under self-financing, excepted special cases in which their participation is considered essential to achieve the objectives of the project and therefore Community funding can be envisaged.

Acknowledgements

Special thanks to our colleagues in unit E4 of DG Information Society for their continued support and to the members of the many R&D projects who have been making major contributions to the establishment of a European wireless information society.

ADAMAS	*Broadband fixed wireless access for asymmetric services*
ANTIUM	*Advanced NeTwork radio Identification equipment for Universal Mobile communications*
ARROWS	*Advanced Radio Resource Management for Wireless Services*
ASILUM	*Advanced Signal processing for Link capacity increase in UMTS*
BRAHMS	*Broadband Access for High Speed Multimedia via Satellite*
BRAIN	*Broadband Radio Access for IP based Networks*
CAST	*Configurable radio with Advanced Software Technology*
CAUTION	*CApacity Utilization in cellular networks of present and future generaTION*
CELLO	*Cellular network optimisation based on mobile location*
DRIVE	*Dynamic Radio for IP-Services in Vehicular Environments*
EMBRACE	*Efficient Millimetre Broadband Radio Access for Convergence and Evolution*
EMILY	*European Mobile Integrated Location sYstem*
FUTURE	*Functional UMTS Real Emulator*
GAUSS	*Galileo and UMTS Sinergetic System*
GEOCAST	*Multicast Over Geostationary EHF Satellites*
HOME ON AIR	*WAP Access for a Home Automation Server*
IBIS	*Integrated Broadcast Interaction System*
JOCO	*Joint source-channel Coding-driven digital baseband design for 4G multimedia streaming*
LOCUS	*Location of Cellular Users for Emergency Services*
MAMBO	*Multi-Services Management Wireless Network With Bandwith Optimisation*
MCP	*Multimedia Car Platform*
METRA	*Multi-Element Transmit and Receive Antennas*
MIND	*Mobile IP based Network Developments*
MOBILITY	*Mobile Real Time Tv Via Satellite Systems*
MOBIVAS	*Downloadable MOBIle Value Added Services through Software Radio & Switching Integrated Platforms*
MOBY DICK	*Mobility and Differentiated Services in a Future IP Network*
MONASIDRE	*Management Of Network And Services In A Diversified Radio Environment*
MULTIKARA	*Multibeam Ka-band Receiving antenna for future "multimedia via satellite, direct to home" systems*
OBANET	*Optically Beam-formed Antennas for adaptive broadband fixed and mobile wireless access NETworks*
PASTORAL	*Platform And Software for Terminals: Operationally Re-configurAbLe*
POS.IT	*Terrestrial Wireless Services for Courier Management*
RADIATE	*Radio DIgital Am TEsts*

R-FIELDBUS	*High Performance Wireless Fieldbus In Industrial Related Multi-Media Environment*
SATIN-0	*Satellite-UMTS IP-based Network*
SATIN-7	*An innovative SATellite-based public Internet terminals Network*
SATURN	*Smart Antenna Technology in Universal bRoadband wireless Networks*
SHAMAN	*Security for Heterogeneous Access in Mobile Applications and Networks*
SODERA	*Re-configurable RADIO for Software Defined Radio for 3rd Generation mobile terminals*
SUITED	*Multi-Segment System For Broadband Ubiquitous Access To Internet Services And Demonstrator*
TONIC	*TechnO-ecoNomICs of IP optimised networks and services*
TRIADIS	*Trials on Distributed speech recognition for mobile network embedded voice-controlled services*
TRUST	*Transparent Reconfigurable UbiquitouS Terminal*
VIRTUOUS	*Virtual Home UMTS on Satellite*
WIN	*Wireless Internet Network Objectives*
WIND-FLEX	*Wireless Indoor Flexible High Bitrate Modem Architecture*
WINE	*Wireless Internet Networks*
WINE GLASS	*Wireless IP Network as a Generic Platform for Location Aware Service Support*
WIRELESSINFO	*Wireless supporting of agricultural and forestry information systems*
WITNESS	*Wireless Interactive Terrestrial Network Systems*
WSI	*Wireless Strategic Initiative*

Table 4 Acronyms and full titles of the IST projects mentioned in this paper

Biographies

José Fernandes received his degree and Ph.D. from University of Aveiro, Portugal, both in Electrical Engineering, in 1990 and 1997, respectively. Just after his graduation he joined the Department of Electrical Engineering of the same University as a researcher, where he became an assistant professor in 1997. In 1994 he joined the Institute of Telecommunications where he performed most of his research work. Since September 2000 he is with European Commission, DG Information Society, where he works in the field of Mobile, Satellite and Personal Communications. He has been participating in several national and European research projects, as well as in COST actions. He has published more than 50 technical papers and is a member of IEEE.

Fabrizio Sestini joined in 1997 the Directorate General Information Society (ex DGXIII) of the European Commission, where he now acts as a scientific project officer, in charge of several research projects and of proposals selections in the area of mobile and satellite communications. He received a PhD in information and communication engineering from the University of Roma “La Sapienza” in 1993. He started carrying out research activities related to multicast ATM switches and radio interfaces for third generation mobile systems in 1989, and later collaborated with the research centre CSELT (Turin), also for the adaptation of dynamic channel allocation techniques to the existing GSM network. Up to 1996 he has also been involved in the technical and commercial development of the first terrestrial and satellite databroadcasting systems and services at RAI, the Italian public broadcasting company, in collaboration with IBM and Olivetti. Fabrizio Sestini is a member of the IEEE Communications Society since 1991.

Joao Schwarz da Silva joined the European Commission in 1991 and now manages the mobile and personal communications area for the European Community Research and Development Programmes. He was instrumental in the development of Universal Mobile Telecommunications Systems, UMTS, is a recipient of the UMTS Forum Chairman's award, granted for the best individual contribution towards UMTS and is now involved in the development of re-configurable radio and 4th Generation system concepts. Prior to the European Commission he served in various capacities the International Telecommunications Union and the Ministry of Communications, Canada. Joao Schwarz da Silva received a PhD on the Performance Analysis of Mobile Packet Radio Systems from Carleton University, Ottawa.