The Book of Visions 2000

Visions of the Wireless World

An invitation to participate in the making of the future of wireless communications

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PREFACE

The work on "Visions of the Wireless World" is supported by the European Commission under the IST programme, contract number 1999-12300, the Wireless Strategic Initiative (WSI).

The Document "The Book of Visions - Visions of the Wireless World" will be continuously refined over a period of three years, spanning 2000 to 2002. The present version is intended to be the starting point of a process, taking a very first stab at the collection of issues that will in all probability have to be addressed by the R&D community in the years to come. Potential approaches to address the issues are also sketched out.

It is assumed that in later versions of the document better precision of the required actions can be proposed.

The issues represented in this document are the result of contributions collected in a Think Tank, with leading experts from industry and academia, and from a public "Call for Contributions". The contributions received from the public call are reprinted in section 3 "Annex" of this document.

The Think Tank has met three times and has the following members:

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Please note that the views expressed are the view of the individuals that contributed to the document.

Table of Contents

The Book of Visions - Visions of the Wireless World

1 INTRODUCTION AND SUMMARY

1.1 Mobile Technologies conquer the World

Third Generation Systems are currently being rolled out in large scale to world markets. Given the amount of money at stake or already invested, these systems are doomed to succeed on an even larger scale than current second generation mobile telecommunication systems like GSM, D-AMPS and PDC. The recipe for success in the market is the detection and satisfaction of fundamental user needs.

Second generation systems have succeeded due to their ability to answer demands for mobility of voice, global availability and roaming as well as simple messaging. In essence, third generation mobile technologies address the essential need of being in permanent contact with the Internet and its information, and e-commerce transaction services. It is expected that mobile access will outnumber fixed access to the Internet as early as 2003.

1.2 How does the revolution continue?

As history has shown, mobile systems pass through a paradigm shift roughly in a 10 year cycle. This implies that now is the time to consider the Wireless World of 2010.

A few of the essential questions to be answered are:

- What will be the fundamental changes that have to take place to make the Wireless World?
- How can advances in technologies be combined in a consistent manner?
- What essential demand will a Wireless World address?
- How can wireless communications become universally available for both people and things?
- What business models will drive the Wireless Worlds (what are their fundamental laws)?

1.3 A Vision of the Wireless World

At this early stage of reflection one can only express a feeling that a driving and shared vision is needed, rather than to spell out the vision in detail. The success of mobile communications so far has been made possible only by shared and stable visions and principles, at the system level and among a wide set of players.

It has become clear in the discussions that the development of a purely “technical” vision, debating, say, new network concepts or radio interfaces, will not be sufficient to come to grips with the future. Rather, such a technical view must be complemented by:

- an user centred approach, looking at the new ways users will interact with the wireless systems
- new services and applications that become possible with the new technologies, and
- new business models that may prevail in the future, overcoming the by now traditional user, server, provider hierarchy.

It is expected that the major innovative thrust will come from new ways of interaction with the system or among systems.

An example for a vision of the Wireless World is the emerging need to bridge the real and the personal virtual world and to continuously stay in contact with both. Such a Wireless World therefore has to address issues of things that communicate as well as communications between humans and cymans (our synthetic counterparts in the virtual cyber-world – a sort of autonomous avatars). Such, a Wireless World of the future will become your natural enhanced living environment.

1.3.1 The Think Tank's Approach

The Think Tank of independent experts called by the project WSI (Wireless Strategic Initiative) has met to bring together experts of a wide variety of domains, to explain their individual area's of expertise vision of evolution and to address the question of a common Wireless World vision at the same time. This approach has been accompanied by an open call for contributions. The result is a number of ideas, evolution roadmaps and research issues put together in this report. It is far from being complete but an attempt to summarize key issues of the Wireless World from a number of complementary perspectives. The exercise has revealed a number of common themes (like ad-hoc configuration, multiple radio environments integration and multihop capabilities) but also shown the need for a consistent system (or world) level approach driving the definition of the Wireless World to come.

1.3.2 Now is Time for You to Join

You can find the result of the exercise in this first Book of Visions. It is not claimed to be complete or consistent at this stage. Rather the Think Tank considers this initial step as starting point for focusing and opening for larger participation at the same time. While the Think Tank members have learned a lot from their first experience with the Wireless World it seems now important to constantly update the visions, assess the state of research and reformulate the opportunities. Therefore, the Think Tank now calls for participation and involvement in this process based on an *open forum* approach. The added value of such a platform is the possibility to detect opportunities and synergies of current trends and technologies. Furthermore it should allow us to foresee potential discontinuities and alternatives. Otherwise we might be too much bound to the viewpoint of individual technologies and their potential in isolation.

1.3.3 The Foundation of the Wireless World

The Wireless World that will eventually come out of this process is commonly believed to be rather based on policies, rules and principles than on standards as we know them today. This new system approach needs a firm and well-constructed foundation. The process started with this exercise aims to start laying those foundations. We will continuously monitor and extract from contributions, workshops and projects what can be the essential building blocks of the wireless world. Such, the wireless world of the future and its required research can be shaped in a common and open approach.

1.4 The first book of visions

This first book of visions is structured into various viewpoints, spotting a few critical developments and detailing them in terms of issue descriptions and potential approach. As such, it addresses to identify a first set of key issues for the wireless world. This report needs to and will be updated and completed.

The book in its current form features trends in user interaction, applications, generic and enabling services, system issues, technology issues and spectrum issues. All of those elements are regarded as critical and the book should also serve to highlight its interdependency.

1.5 Our reference – the MultiSphere

During the discussions in the Think Tank it became apparent that we need a reference for the Wireless World we are talking about. It would be too early to call it a common model. It should, however, allow putting the issues and ideas into a common context. Driven by the horizontalisation introduced by 3G's mobile Internet, future vertical applications and services will draw together a multitude of wireless technologies in an ad-hoc manner. Those elements will be around us like a number of spheres in which we live.

In the following paragraphs the various spheres of this reference are introduced. As this should serve as a reference framework for our current thinking, any specific technology of today is not mentioned here. Furthermore the reference presented here reflects largely the discussions and opinions in the Think Tank and are not bound to a particular company's view.

1.5.1 MultiSphere Level ➀: The PAN

The closest interaction with the Wireless World will happen with the elements that are the nearest to us or might even become part of our body. Both in clothes and wearable items communication facilities will be built in. When requested they will start to discover each other and distribute a common virtual terminal over us.

This Personal Area Network (PAN) vision is certainly feasible in today's technology but needs much closer integration with the overall concept. As electronic communication will happen "at" our body both powering and radiation will be critical for PANs together with fast, flexible and automatic configuration and protection. We believe a lot of additional research is necessary for the evolution of PANs to full constituents of the Wireless World of tomorrow.

1.5.2 MultiSphere Level ➁: The Immediate Environment

At the next level we find the elements of the real world around us. Currently we do not interact with them but in future we will expect that they take notice of us, that they start to interact with us and turn into personalised items rather than general purpose devices. TV sets should know what programmes we are interested in, toasters might want to deliver toasts with the right level of toasting and fridges might want to tell us what we probably would like to re-order as we might run out of milk over the weekend.

Learning and adapting environments will start to address real and fundamental user needs, as the difficulty of using current technologies is irritating to many people. While personalisation as a technology might become part of nearly all devices in the future what will be important is the possibility to personalise several devices with a common approach or at the same time rather than individually. If, for example, you are a non-smoker or vegetarian you don't want to tell this a 100 times, in different ways, to all your devices. Similar you will expect at least consistent errors when interacting with devices using your speech. Therefore, we believe the immediate ad-hoc environment to be an important part of the Wireless World model.

1.5.3 MultiSphere Level ③: Instant Partners

One step further we interact with people around us as well as with more complex systems like cars. We may want to talk to them or just relaying information through them. It is believed, that in the future our wireless possibilities should enable an easier and maybe richer interaction with close by people than with people on the other continent. On the other hand, "closeness" can also be seen as being part of a close net of people with whom we want to be closely interconnected and where we would like to be kept informed about their wishes and thoughts quickly. Current chat communities are just a glimpse of what people might desire in the future.

1.5.4 MultiSphere Level ④: Radio Accesses

What has made mobile communication so successful was the possibility to rely on ubiquitous coverage of a wide area system. This will for sure remain a fundamental requirement. Either directly from the PAN or via the instant partners publicly accessible radio interfaces must be reachable.

Current infrastructures might be augmented by flying base stations, high-speed local media points or dedicated road technologies. For those, adaptivity to various terminals as well as an easy addition into the framework and low to zero operational cost will be key. One might expect more specialised radio interfases which are more horizontal components of the Wireless World and have shorter innovation cycles. How they can fit to the backbone structures and the legacy of terminals will be one of the critical issues.

1.5.5 MultiSphere Level ⑤: Interconnectivity

The value of communications technologies is often said to grow proportional to the square of the number of the connected devices. Therefore the universal wireless interconnectivity emerging from today's mobile Internet core networks will be one crucial tasks. To offer the right level of support for the various specialised radio interfaces and terminals will be a key requirement. One can therefore see an emerging need for both a radio convergence layer and a number of APIs beside the evolved IP transport and networking layers. Evolutions of interconnectivity in the wireless world will convey radio interface state specific information to applications and also allow for seamless integration of synchronous direct communication services with asynchronous message based services.

1.5.6 MultiSphere Level ⑥: CyberWorld

At the outest sphere, most remote from our immediate real world we find our CyberWorld. Looking at the explosion of services in this world today and the perceived reality of advanced games it can be assumed that in the future our presence in our self- created CyberWorld will be as important to us as the real world. In the CyberWorld we can stay in touch with our agents, knowledge bases, communities, services and transactions. The Wireless World will be the technology to allow us to become permanent residents in the CyberWorld. A deep understanding of this world is necessary to develop Wireless World technologies that really sastify fundamental user needs.

This is what we set out to do!

2 DESCRIPTION OF ISSUES

2.1 Trends in user interaction

The principal issue is user satisfaction. A major shift can be observed, from a device driven world to a service and experience centred world. It will become more and more important how the users perceive the service and the emotional impact and pleasure that the service creates and maintains.

Driving forces for user level interaction are rich digital content and personalised service. For digital content, the interaction bandwidth needs to be broadened and brought nearer and more compatible to our human sensing and acting mechanisms and mental models.

Personalisation means taking into account our personal preferences, needs and capabilities. The services need to fit our life situation and current mode of behaviour. The services should not interfere with our personal life and should not interrupt anything valuable. The services should be flexible and not make our business or private life more hectic than it already is.

2.1.1 Deviceless communications (invisible devices)

2.1.1.1 Description of Issue

The issue is to bring the increasing communication bandwidth and computing power into the personal vicinity of individuals.

Mobile terminals have been traditionally a trade-off between physical size, weight, functionality and usability. A reduction on size and weight can be achieved as long as usability is there, but by exceeding this limit it is becoming progressively difficult for people to use the terminal and the corresponding services. In particular, elderly people find it difficult to work with devices that are too small.

2.1.1.2 Potential Approach

A novel approach is proposed to resolve of the difficult trade-off between physical dimensions, functionality and usability: deviceless mobile communication services. The essential idea is to employ the technology being developed in the wearable computer field and hide the radio frequency and the computing part of the terminal into the clothing of the user. The traditional handset or access terminal disappears. However, the traditional user interaction devices, such as displays, loudspeakers, beepers, earplugs, keypads, buttons, need also to be rearranged or replaced with new concepts.

Ongoing and existing research on the subject seem to indicate that there are potential approaches using:

- body area networks

- augmented reality
- computer vision based image recognition, and
- head mounted see-through, or body mounted, projection displays that can be used to create virtual user interface, for example, to the users hand (see figure 2.1.1.1 below).

Users can act within the virtual service interface naturally without other people even noticing it. The ultimate goal being that advanced mobile services can become extensions to our natural senses and thus enriching our life.

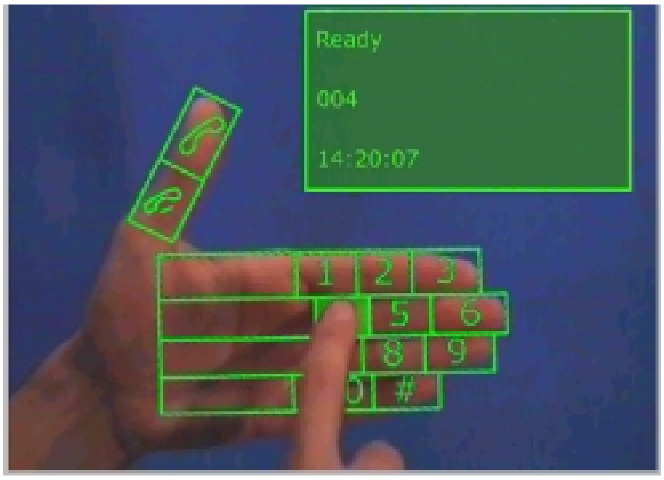

Figure 2.1.1.1: A novel metaphor for and sign language framework for personal mobile broadband user interfaces enables deviceless communication. (Courtesy University of Oulu, Paula Project)

2.1.2 Ubiquitous communication

Our living environment is becoming more intelligent with product containing small computers and wireless communication such as Bluetooth. "Ubiquitous computing" is a term coined to mean a situation, where small computational devices are embedded into our everyday environment in a way that allows them to be operated seamlessly and transparently. These devices are suggested to be active and aware of their surroundings so that they can react and emit information when needed. One implementation of ubiquitous computing are active badges, that can trigger automatic doors and give information about the location of a person. Communication can be between humans and intelligent products and between products. For example a left shoe can ask the right shoe what is his location, because the user wants to go out now.

2.1.3 Personalization and profiling

Ubiquitous communication will increase dramatically the number of small transactions dependent on our personal movements and action in our living environment. The challenge is to automate the handling of this message load and bring to the user attention only the relevant information according the users need and situation.

Also increasing richness of location-based services and content will need to be filtered and prioritised to the users attention so that his preferences and life situation is taken into account.

Basically this means assisted matching of available services, users location, user's needs and his paying potential. The user should be provided with best-fitting options to choose from. Since many of these issues deal with important market economy elements and are very close to personal integrity and human rights, so criticality of these issues is evident.

2.1.4 Augmented reality

Augmented reality is a research approach that attempts to integrate some form of computer media with the real world. When in ubiquitous computing there are many different active devices, in many cases each of them having their own display and interaction devices, the augmented reality approach usually uses much fewer devices and aims at a seamless integration between real and digital. The integration may be overlaying digital information (as a non-immersive virtual reality) on real world images. The overlaying of images may take place in several ways, like by using video projection by the means of small, hand-held video screens or palmtop computers, or by mixing surrounding reality by using head-mounted see-through or through haptic displays (Figure2.1.1.2).

Figure 2.1.1.2: Cyphone mediaphone concept is based on a binocular-shaped see-through display enabling services such as telepresence and location-based navigation (Courtesy Cyphone project, University of Oulu and J-P Metsävainio Design Oy)

2.2 Applications

2.2.1 Location and orientation dependent applications and services

2.2.1.1 Description of Issue

Location awareness will play a major role for future wireless network services. Currently, there are several projects working in this field, mostly about virtual tourist guides and similar scenarios. However, to exploit the full range of possibilities, major issues have yet to be solved.

Figure 2.2.1.1 below shows the main elements of a location aware system. Basically, some location tracking component is needed which can be either sensor-based (e.g., GPS, radio-cams, local beacons) or using specific location information available through the communication system (e.g., radio propagation measurements). Given this information, simple location aware services can be realised. However, it needs more to develop sophisticated solutions. First, a map component is needed to put the location information in geographic context. Also a personal profile (age, interests, etc.) which can be provided e.g., via a directory service like LDAP is necessary to give the user only the information he or she really wants to receive. Pure information overflow will make the services useless to any user. In Figure 2.2.1.1, the filter component is responsible for this task. A major enhancement of the location awareness is to regard the situation or the "context" which the user is in. Depending on this environmental context (e.g., time, speed, time of year, opening times of attractions, type of vehicle used, current companions, nearby equipment) specific information can be given to or be withheld from the user.

The main application area of location aware services will be in the mobile wireless field. As we will have to deal with less bandwidth (compared to fixed networks), the system also needs to be aware of the current network conditions. The applications and/or services have to detect changes in resource availability, and service negotiation has to be performed at connection set-up and possibly also within established connections.

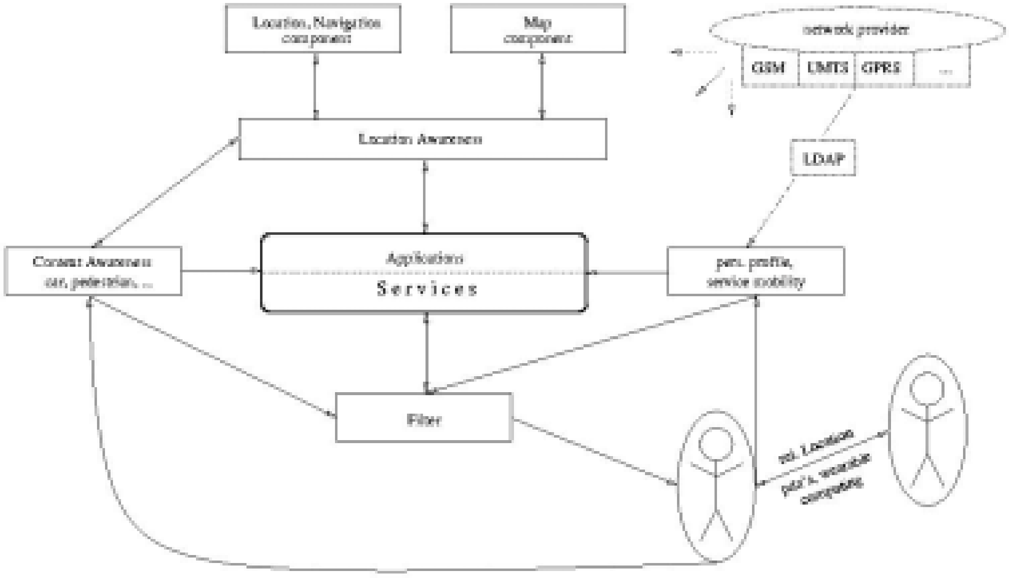

Figure 2.2.1.1.

2.2.1.2 Potential Approach

Work is required in the following fields:

- Location transparency: Network resources and services have to be accessed by a resource or service broker. This has to be transparent without configuration by the user.

- Location tolerance: If the link quality degrades, user-transparent service re-negotiation has to be performed by the system.

- Mobility awareness: Seamless integration of all components must be done. Difficulties in this point include consistency in distributed systems, security, unconventional sensors, abstraction and integration of sensor data and data from distributed and heterogeneous sources. Last but not least, the dynamic environment changes have to be detected in real-time to guarantee smooth working.

- Definition of user profiles and contexts: flexible and dynamic but still clear

- Support for (partly) disconnected operation

2.2.2 Micropayment system for content integrated in wireless systems

2.2.2.1 Description of Issue

Mobile content services and electronic commerce are expected to form a large part of value-added services for future mobile phone systems. There is a great need and potential for mobile terminals to become “electronic wallets” and media access devices for a large number of citizens.

A major issue to be solved is payment and charging. Current charging systems for mobile phones are mainly based on network mechanisms, i.e. connection time, transfer of amount of messages/blocks/bits, or transaction based charging. Also service bundles and monthly subscription fees are coming in the same manner as in the Internet.

What is missing clearly is service based charging. For example on-demand-content, such as MP3 audio, on-demand-movies, mobile games and entertainment are very potential services. The use patterns for mobile services can be very scattered, so people may use these services only short times during their travel and empty slots in their daily work, etc.

Micropayment is defined as a small payment, less than 1 Euro, which is too small to be charged immediately, and too big to be ignored. Micropayments are end-to-end visible, like money, so the receiver and payer can see, understand and trace their comings and goings. Potentially, large numbers of these payments need to be handled by the network and content producers, banks and customers. Micropayments are discrete in time, but a stream of micropayments can be used to charge continous streaming type of service. Micropayments can be positive (charging) or negative (earn by using a service), routed (someone else is paying the cost, for example sponsored service). Micropayments can be composite, so they can accumulate costs from lower level of ingredients, for example a MP3 pice of music can be charged with micropayments assigning revenue directly to the musicians.

[It is fair to state that other views are being expressed on the need for universal payment systems. In the US, in particular, flat rate charging is favoured and predicted to stay. Also, micro-payment systems offered on the market have not been successful. The evolution of this critical issue over the following years will have to be closely monitored.]

2.2.2.2 Potential Approach

Micropayment systems need to be well standardised in order to have wide acceptance. They need to be market-neutral, so they don't favour any of the existing players in the value chain. Micropayment systems need to be well integrated in any new network, so they can be handled cost effectively. Micropayment need to be safe and secure for the users and the players in the value chain who trust their business on the revenue from the micropayments. Openness is very important, so a small business can enter the contents provider market using the micropayment charging scheme without heavy contracts with portals or service operators, hence the free perfect competition and potential for employment generation may depend on the development.

To organise service based charging system for future mobile phone services is a vital task for the whole mobile business. The task is complex and the research and experimentation work should be started well in time to be prepared for launching the system along the content and mobile commerce services.

The European dimension is very strong, and it should be possible to use similar schemes in the member states of the Union, in free competition.

2.2.3 *"Open Source" paradigm adoption especially for 3rd party APIs*

2.2.3.1 Description of Issue

The Open Source paradigm means that:

(1) a cumulating body of source code is available to the developers free of cost

(2) a coordination function is put into place which tests and accepts the increments to the body, and

(3) voluntary developers participate to the development of applications based on their own business, learning or hobby motivations.

During recent years the Open Source software development paradigm has brought up surprisingly good results, such as the emergence of the Linux operating system, Apache server, and GNU compilers. Besides superior quality and innovativeness, the Open Source paradigm has brought a large number of young people into the development of new applications all over the world, thus heavily contributing to the business process. Besides software development, IC and processor core designs have been influenced by this approach recently.

Mobile communications systems have traditionally been divided into manufacturer/operator proprietary part, and into public interfaces defined in standards. Typically the proprietary part is where the differentations of the products and services are performed, giving a competitive edge to the manufacturers or service provider in question.

However, there are new classes of services that are very difficult to specify and implement by a single manufacturer or operator. For example, *mobile games* form a quite promising area where evolutionary development by the users and enthusiasts may create high volume of services.

2.2.3.2 Potential Approach

Nurturing Open Source paradigm in the context of 4G mobile systems requires to open up frameworks for

- Application programming interfaces (APIs)
- Ubiquitous access protocols (Bluetooth, etc.)
- Execution platforms (Mexe, Mobile execution engine),
- Service/software development environments (SDE)
- Setting up process for the coordination body (testing incrementing and maintaing the body of open source sode)
- Experimentation and testing procedures for the individual developers and the voluntary user communities
- Quality and safety procedures in heterogeneous development environment

- Distribution of open source code and service components in Napster-like voluntary server network

- Billing and service roaming issues

- Publicity, roles, responsibilities, and legal framework and exploitation

2.3 Generic and enabling services

2.3.1 *Service discovery*

2.3.1.1 Description of Issue

With the rising number of services and the convergence of IP and cellular networks, automatic service discovery will be a very important feature in future wireless network scenarios, e.g., in self-organising ad-hoc networks. With service discovery, devices may automatically discover network services including their properties, and services may advertise their existence in a dynamic way.

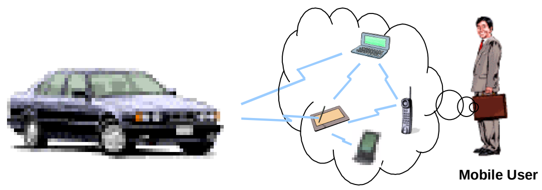

Figure 2.3.1.1: Wireless devices automatically discover services offered by a car.

Figure 2.3.1.1 above gives an example. A person brings his personal network-enabled devices into a rented car and connects them via a short range radio link to the car area network. With service discovery, installed services can be used without configuration. For example, in a “mobile office car” there would be a fax machine, a printer, a hard disc, and a colour display. Since the car’s air interface offers access to the world-wide Internet, the passenger’s devices may also detect services of his company’s corporate IP network.

2.3.1.2 Potential Approaches

The most well-known service discovery protocols currently under development are the IETF Service Location Protocol (SLP), Jini, which is Sun's Java-based approach to service discovery; Salutation, Microsoft's Universal Plug and Play (UPnP); and the Bluetooth Service Discovery Protocol (SDP).

All of them use similar system architectures but differ in their functionality, network transport protocol, and the possibility of code mobility.

The research and development work on service discovery protocols is not completed yet. Refinement and/or simplification is needed for more efficient service discovery. Furthermore, service discovery in IPv6 is still an open issue.

A very important topic is secure service discovery. Here, e.g., authentication methods and concepts for key distribution as well as protocols to prevent denial of service attacks and service spoofing should developed.

The variety of different service discovery methods makes it important to have bridges between the protocols to enable service discovery between devices that do not run the same protocol. A long-term goal would be to harmonize these approaches and achieve one or two protocols that interwork with each other.

Furthermore, interoperability and interworking of service discovery protocols with other directory services (e.g., with LDAP) must be achieved. It would also be interesting to combine service discovery with the feature of personalized services.

The problem of how to access and use a service (after discovering its existence) has not been solved yet. This is especially challenging for heterogeneous network scenarios and devices with low processing power and storage capabilities.

2.3.2 Terminals

2.3.2.1 Description of Issue

As future communication systems will be characterised by the convergence of different (existing and future) radio access schemes, future terminals will face significant challenges like vertical hand-over and adaptability. Furthermore, the need for global availability, performance, increase in data rates, and network independent services will determine the required technical capabilities of terminals. On the other hand, terminals are becoming more and more a consumer product, and the end user will consider factors like cost, size, standby time, usability and handling before acquiring a wireless terminal.

The main characteristic of future terminals will be their capability to adapt to different scenarios and environments.

This adaptability will specifically be required in the area of:

- Access technologies
- Radio Baseband technologies
- Application / services
- User Interfaces/I/O methods.

Access technologies

Future terminals will be used in several different environments and locations (home, office, car, train etc.) interfacing to a great variety of networks, for example:

- Wireless LAN (Ethernet, HIPERLAN/2 etc.)
- Personal area networks (PAN) like Bluetooth, IEEE802.15.3
- Cellular systems
- Fixed network with wireless access points.

Terminals will select networks depending on availability and application driven quality of service requirements.

To be able to achieve this, future terminals need to be able to support simultaneously different access technologies, like

- FDMA (frequency division multiple access)
- TDMA (time division multiple access)
- CDMA (code division multiple access)
- CSMA (carrier sense multiple access)
- SDMA (space division multiple access),

as well as the different duplex methods:

- TDD (time division duplex)
- FDD (frequency division duplex)
- SDD (space division duplex).

Radio/Baseband Technologies

One of the key areas of adaptability is the field of radio transmission methods, to support the different requirements of access technologies.

Future terminals will be required to be able to support a variety of radio standards simultaneously. This will lead to major challenges for components as well as architectures for future terminal radios. To enable software adaptable radios for terminals major hurdles in the area of:

- Broadband circuit design
- Antennas
- Receiver and transmitter architectures
- Signal processing
- Modulation techniques

need to be overcome.

Application / services

Especially in the areas of

- Control (health, home etc)
- Location orientation
- Entertainment
- Voice, audio and video communication

new services emerge. Each of these areas will have different requirements and need to be serviced by a future terminal.

User Interfaces/I/O methods

With the plurality of upcoming services and applications as well as with the change from pure voice communication towards data communication, the requirements for the I/O parts of terminals will change dramatically. A wide range of user interfaces, from voice only (voice recognition, acoustic output), to full keyboard input and "screen like" output, for example, for interactive games, will be needed.

Some of the key areas in this field are:

- Intuitive usage

- Adaptation of user interfaces to services and applications
- "Displays" (adaptivity, touch screens, video screens etc.)
- voice recognition, haptic
- Multi media audio capability
- Privacy for input and output.

Other challenges as continuously decreasing product life cycle, customer specific design and lowest power consumption show the wide area of terminal specific work items.

Conclusions

Future generations of terminals will face significant challenges with respect to their ability to adopt to all kinds of options. It is recommended to start research in the area of transmission technologies and here specifically on radio technologies, focussing on broadband components, signal processing and software defined radio.

2.4 Systems issues

2.4.1 Multi-access interoperability, roaming, and hand-over

2.4.1.1 Description of the Issue

Seamless Network Architecture

Future wireless communication systems beyond the third generation will be characterised by a horizontal communication model, offering different access technologies to the user terminals such as cellular, cordless, WLAN type systems, short range connectivity, broadcast systems, and wired systems according to figure2.4.1.1.

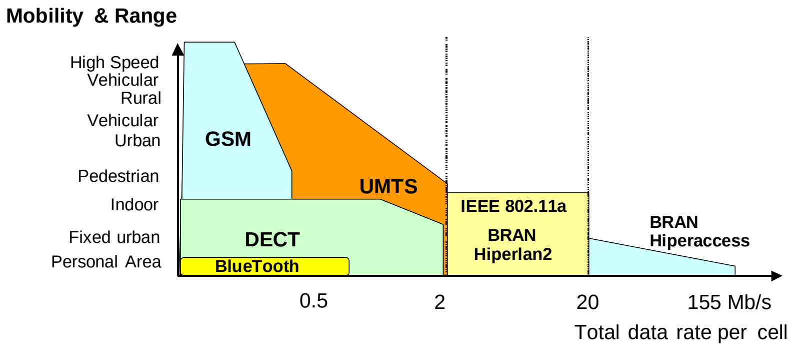

Figure 2.4.1.1: Example of bi-directional radio access systems as a function of the data rate, range, and mobility

They will be integrated into a common, flexible, and expandable platform to complement each other in an optimum way and to satisfy different service requirements in a variety of radio environments. These access systems will be connected to a seamless IP based core network

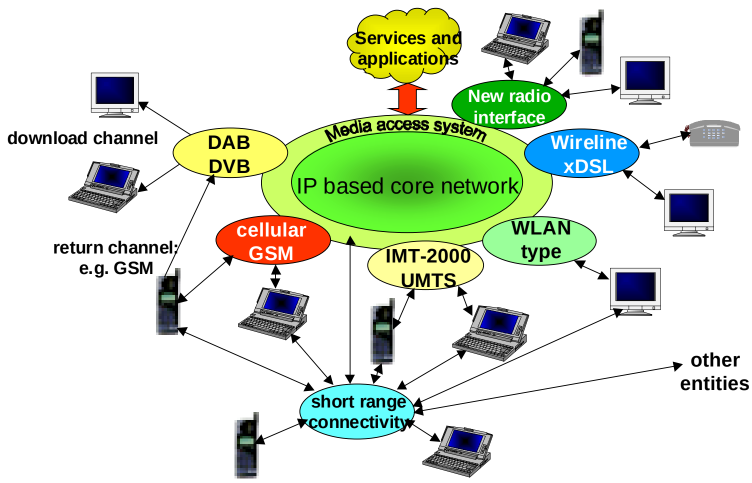

Figure 2.4.1.2: Seamless future network including a variety of access technologies

Users will have a single identity number, e.g., a telephone number, a PIN, or an IP address, for all access technologies. A new media access system (generalised access network) will connect the core network to the appropriate access technology. It also contains the mobility management. Global roaming is required for all access technologies. Other key requirements include the inter-working between these different access systems in terms of horizontal (intra-system) and vertical (inter-system) hand-over as well as seamless services with service negotiations including mobility, security, and quality of service. They will be handled in the newly developed media access system and in the core network. Figure 2.4.1.2 shows this vision of a seamless network that incorporates a variety of inter-working access systems that are connected to the common IP based core network. The media access system connects each access system to the common core network.

2.4.1.2 Potential Approaches

Layered Structure of the Access Technologies

- The different access systems are organised in a layered structure, which can be compared to hierarchical cell structures in cellular mobile radio systems. This concept facilitates an optimum system design for different application areas, cell ranges, and radio environments, since a variety of access technologies complement each other on a common platform. This layered structure is illustrated in 2.4.1.3. In this figure, the supported mobility and the covered cell size increase from the bottom layer (fixed layer) to the top layer (distribution layer).

- ***Distribution layer:*** The distribution layer contains emerging digital broadcasting (or distribution) systems such as Digital Audio Broadcasting (DAB), Digital Video Broadcasting (DVB), High Altitude Platforms (HAP) and satellite systems that have a global coverage and support large cells, full mobility as well as global access. Individual links are not necessarily needed for broadcasting services. But this technology can also be used as a broadband downlink channel to provide, for instance, fast Internet content. Basically all other access systems may be used as return channels for data requests and acknowledgement signalling in highly asymmetric services.

- ***Cellular layer:*** The cellular layer enables a high system capacity in terms of users and data rates per unit area. It will consist of second generation (e.g., GSM and its evolution) and third generation mobile radio systems (IMT-2000 / UMTS: UTRA FDD and UTRA TDD) for data rates up to 2 Mbps. The systems on this layer provide full coverage, full mobility, and global roaming. The cellular layer is well suited for small to medium bitrate multimedia applications and supports individual links.

- ***Hot spot layer:*** The hot spot layer supports individual links and is intended for very high data rate applications. It should be employed in hot spots such as in company campus areas, conference centres, and airports. The hot spot layer contains WLAN (Wireless Local Area Network) type systems like HIPERLAN/2, IEEE 802.11, or MMAC (Mobile Multimedia Advanced Communications). These systems are flexible with respect to the supported data rates, adaptive modulation schemes, and asymmetric data services, i.e., they provide different data rates on the uplink and the downlink. In contrast to cellular systems, this layer contains systems that are characterised by a shorter range and provide mainly local coverage with local mobility to facilitate an economic system deployment. Global roaming is possible and will be required. Full coverage, however, is not expected.

- ***Personal network layer:*** The personal network layer will mainly be used in office and home environments. Different equipment (laptops, printers, personal digital assistants, etc.) and appliances (refrigerators, toasters, washing machines, smart sensors, etc.) can be connected to each other to provide short range connectivity via systems such as Bluetooth, HomeRF, and DECT. These systems can also be used to connect the equipment directly to the medium access system or to multi-mode terminals that can also communicate on one of the other network layers and are, of course, also equipped with a short range connectivity system. This facilitates an efficient inter-connection between the devices as well as a connection from these devices to the public network. The systems of the personal network layer do, in general, not support mobility. Global roaming, however, should be ensured.

- ***Fixed (wired) layer:*** The fixed layer contains fixed access systems such as optical fibre (e.g., FTTx), twisted pair systems (e.g., xDSL), and coaxial systems (e.g., CATV). Furthermore, fixed wireless access or wireless local loops can be included in this category. Fixed access systems do not support mobility. However, global roaming is feasible and will be required. These systems of the fixed layer have a high capacity and do, in general, support individual links.

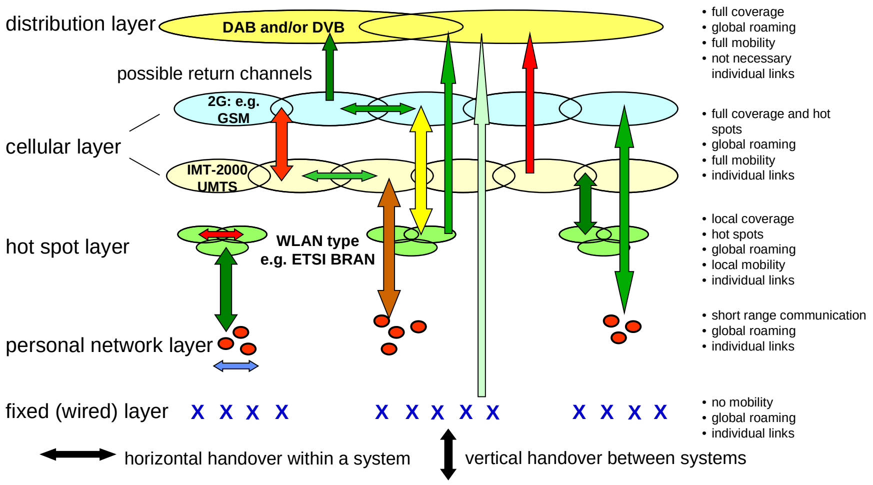

Figure 2.4.1.3: Layered structure of a seamless future network of complementary access systems for the fixed/wireless/mobile user terminal

The network ensures the interworking between these systems on the common platform by horizontal handover within an access system and, in particular, by vertical handover between different access systems. In general, vertical handover takes place between different layers of the common platform. Vertical handover is combined with service negotiations to ensure seamless service, because in general different access systems support different user data rates and other bearer and service parameters. The interworking, mobility management, and roaming will be handled via the medium access system and the IP based core network (Figure 2.4.1.2).

2.4.2 Application adaptability to ensure continuous service (bandwidth, display)

2.4.2.1 Description of Issue

The issue is to effectively overcome the problem of severely degraded channel conditions due to effects which are typical of the wireless and mobile world, e.g., fading and disconnects due to hand-overs, in an environment that needs to support a large variety of applications.

Many researchers have proposed middle-ware techniques, the main purpose of which is to shield the application from the impairments which are typically found at the lower layers, in order to guarantee transparent operation of the application itself regardless of the working conditions.

Another approach, which somewhat takes the opposite view, is to have the application have access to information about what happens down below and to make decisions about how the communications systems or the protocol stack can best be built in order to respond effectively to both the application needs and the environmental characteristics. It is even possible to think of applications which are able to modify these choices during a connection, making the protocol stack and the application itself truly adaptive.

In addition, the variety of traffic types and of quality of service requirements which can be expected in fourth generation systems, where all types of information transfer are to be supported, clearly calls for adaptive solutions, in which no design criterion can be decided a priori to fit all possible data transfers. Rather, the application should be smart enough to be able to build its own best scheme based on its own requirements and the instantaneous radio conditions. In order to do so, information about physical layer performance must be available at the application layer. Similarly, the application must have the ability to act on lower layers in order to select the transmission scheme which best suits its own needs.

2.4.2.2 Potential Approach

The classic approach to physical layer design is to minimise average bit error rates. Little consideration is given to a richer characterisation of the performance at the output of the physical layer, or to the effect of the resulting performance on higher layers. In many cases, knowing the average bit error rate after decoding is not enough to predict, e.g., the throughput at the TCP level, or the actual performance experienced by the application. This disconnect between lower layer design and quality of service perceived by the application must be bridged in some way if truly effective and efficient communications schemes are sought.

As an example, the fact that error control is to be performed through error correction coding and interleaving should not be taken for granted. Packet data transmission is very different from voice communications, and it may well be that the classic solution used to guarantee good quality voice transmission is an inefficient way to serve packet traffic. In this view, the flexibility and time diversity property of packet communications suggests that a more opportunistic was of using the channel can be adopted, instead of taking the worst-case approach and trying to guarantee sufficient quality at all times. In this case, the application which needs packet transport with relatively loose delay constraints should be able to turn off the coding/interleaving block, because this is an efficient solution for the desired service.

A possible vision for adaptive terminals for fourth generation systems is that of a "radio with knobs", in which the application is able to reach down to lower layers or even to the radio hardware and to reprogram them according to its needs. In this manner, efficient communications choices can be performed "on demand" and the protocol stack can be built "ad hoc" according to the best way to match the application requirements to the channel conditions.

2.4.3 System support for privacy and security, policy enforcement and repository

2.4.3.1 Description of Issue

Separation of the services from the infrastructure, together with the advent of IP has thoroughly altered the relationship between the end user and the incumbent service provider.

Putting this ultimate separation of services and transport of packets in control of the end user by means of Local Policy Enforcement of operator policies will further strengthen the position of the consumer.

Normally, this Policy Enforcement would be expected to be located in the local access server, or edge router, requiring substantial investments and many practical and legal arrangements with, and dependency of, access providers concerning policy enforcement.

If however the PEP is located in the customer premises, the service provider could bypass the access operator, and enforce its policies in the subscriber domain, lowering the threshhold investments required to become a service provider.

2.4.3.2 Potential Approaches

The concept of Local Policy Enforcement can evolve to a generic architecture that also supports mobile access

This architecture consists of a number of salient features, see figure 2.4.3.1 below.

- A Client-Server relationship

- A transparent IP based transport network and access network, transporting packets between Client and Server A Service Portal acting among others as a Policy Definition Point (PDP), residing in the server, defining policies with respect to services, authentication, authorisation and accounting.

- A Policy Enforcement Point (PEP) residing in the Client, enforcing policies with respect to services, authentication, authorisation and accounting at the terminal location.

- Separate charging models for IP based transport and Client-Server based transactions.

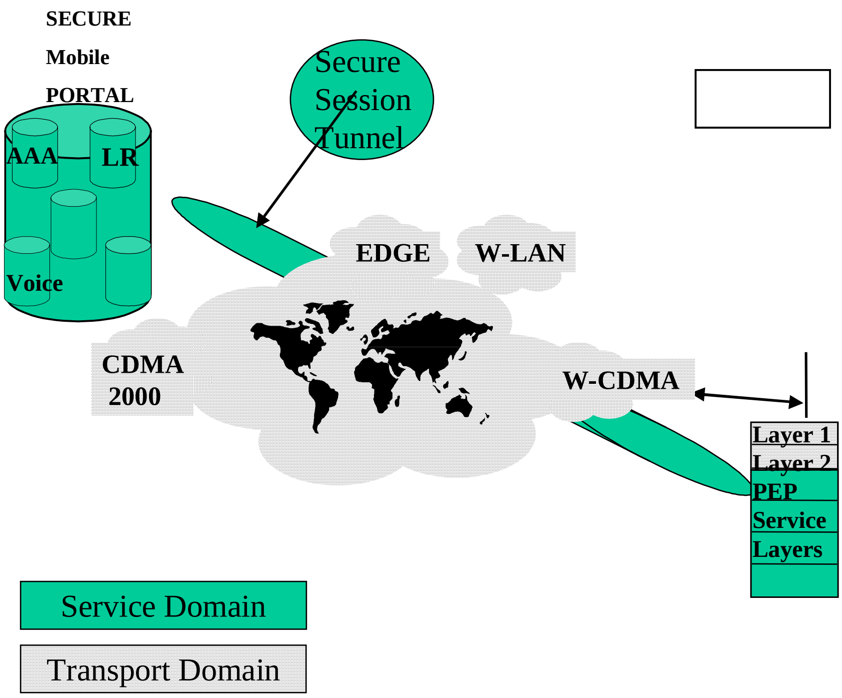

Figure 2.4.3.1: Generic architecture to supports mobile access

The Service Domain

The service domain, which covers the higher layers, consists mainly of a Secure Mobile Portal and a Local Policy Enforcement Point. These are interconnected by a secure session tunnel acting from the terminal during the execution of a session.

The Transport Domain (A Packet Pipe)

The Transport domain in figure 2.4.3.1 transports packets from the SMP to the LPEP. It adds no value to the packets, except that it classifies the packets according to QoS and transports these to the end destination, guaranteeing access to physical resources where this is appropriate.

The Terminal

Figure 2.4.3.2 below shows the terminal architecture.

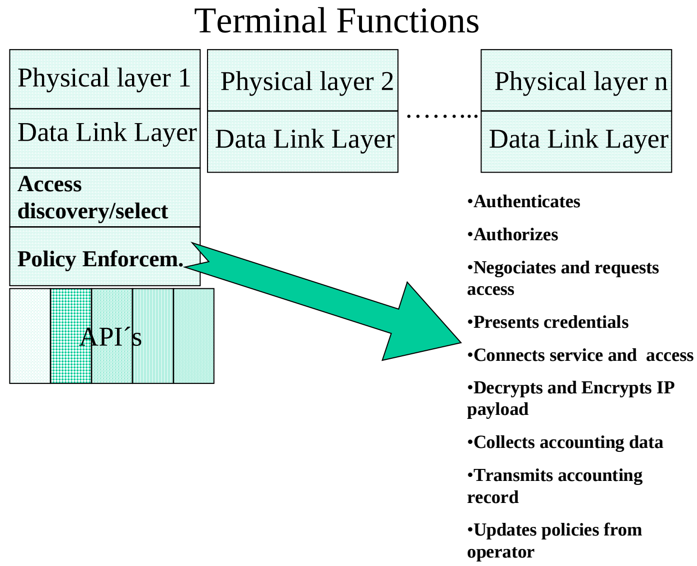

Figure 2.4.3.2: Terminal functions

The Access Part

The access part contains a number of access options numbers 1 to n. The access options can physically be located in the terminal itself, or in some other terminal, or just be a plug in the wall, providing access to a LAN or W-LAN, or Cable or Fixed xDSL access.

The terminal also contains an access management function.

The Service Part

The service part contains a Policy Enforcement Point, and applicable API´s for the services.

2.5 Technology

2.5.1 *Ad-hoc and multi-hop wireless access*

2.5.1.1 Description of Issue

A "mobile ad hoc network" (MANET) is an autonomous system of mobile routers (and associated hosts) connected by wireless links. The routers and hosts are free to move randomly and organise themselves arbitrarily; thus, the network's wireless topology may change rapidly and unpredictably. Such a network may operate in a standalone fashion, or may be connected to the larger Internet (Figure 2.5.1.1).

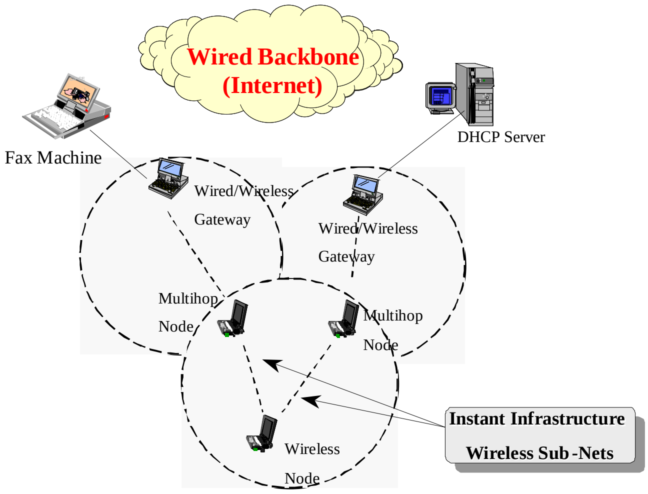

Figure 2.5.1.1: An integrated ad-hoc wireless system

In the current cellular system which are based on a star-topology, if the base stations are also considered as mobile nodes, the result become a pure adhoc network where a base station acts as the gateway in bridging between two remote ad-hoc networks or gateway to the fixed network. This architecture of hybrid star and ad-hoc has many benefits such as; self-reconfiguration and adaptability to highly variable mobile characteristics such as; channel conditions, traffic distribution variations, load-balancing, and help to minimise the mobile location estimation inaccuracies, etc.

However, comes with such benefits some new challenges which mainly reside in the unpredictability of network topology due to mobility of nodes, this coupled with the local broadcast capability, give a set of concerns in designing a communication system on top of adhoc wireless networks.

2.5.1.2 Potential Approach

- *Distribute MAC and dynamic routing support*: In a mobile ad hoc network, mobile hosts share the same frequency channel, like IEEE 802.11 and ETSI HIPERLAN Type 1, and 3G, operate without the aid of any centralized infrastructure or any centralized administration. As packet radios do *not* always have direct radio links to all other packet radios in the network and nodes are acting also as routers, a dynamic routing protocol is needed for establishing routing patterns among themselves.

- *Wireless Service Location Protocol*: To simplify or eliminate the configuration needs for users, with regard to service discovery, it is of increasing importance to mobile users, first because they experience frequently changing network service environments, and secondly because users are becoming more service oriented. A wireless Service Location Protocol that resolves requests for network services, by providing service handles to applications that ask for them needs to be designed.

- *Wireless Dynamic Host Configuration Protocol* that offers the capability of automatic allocation of reusable network addresses and additional configuration flexibility is also required for delivering node-specific configuration parameters.

- *Distributed Call Admission Control and QoS-based routing techniques*

2.5.2 Multi-hop broadband access to W-Internet systems

2.5.2.1 Description of Issue

Available Standards:

- ETSI/BRAIN HiperLAN/2 (broadband)
- IEEE 802.11/a/b (wideband/broadband)
- 3G DECT (wideband)

Issues related to Multiple-Hop Communications

- spectrum inefficient in general (multiple use of spectrum. for one comms. relationship)
- able to extent radio coverage (without fixed infrastructure)
- useful at locations where spectrum load is small
- necessary at frequencies where tx-power is limited and pathloss is high
- best suited for packet-based comms.
- QoS support is difficult to implement
- number of hops must be small, say less than 4

2.5.2.2 Potential Approach

Proposed Research:

- develop extensions to existent standards (see above)
- enable guarantee of QoS under multiple-hop comms
- develop new concepts
- develop introductionary scenarios
- enable service across multiple wireless networks domains (e.g. credit point based)
- extend cellular service by multiple-hop comms. for indoors usage

2.5.3 New radio interface offering 100 Mbit/s and more bandwidth

In addition to existing and emerging radio access technologies, new radio interfaces can also be integrated into a seamless network architecture. Research on new radio interfaces has already started in Japan and in Europe to increase the data rates of third generation mobile radio systems by more than one order of magnitude. Japan is proposing to reach at least 10 to 20 Mbps in a cellular environment and 2 Mbps for moving vehicles, having the multi-carrier CDMA (MC-CDMA) one of the candidate multiple access techniques.

Generalised multi-carrier (GMC) CDMA systems are capable of multi-user interference (MUI) elimination and inter-symbol interference (ISI) suppression, irrespective of the encountered wireless frequency selective channel. This channel independent feature can be obtained via special block-precoding schemes.

The European Commission started to support this type of initiative in 1992, with the Mobile Broadband System (MBS) project, within RACE II framework and later in ACTS framework through the SAMBA and MEDIA projects mainly. While the MEDIA project was targeting the wireless access at 150 Mbit/s, the other two were focusing on mobile cellular applications, also at 150 Mbit/s. The SAMBA project produced a trial platform with two base stations and two mobile terminals allowing to demonstrate the basic functions of a broadband cellular system, including handover, at 34 Mbit/s user bit rate per carrier.

Furthermore, new concepts like ultra wide-band transmission for short-range connectivity for are under discussion.

2.5.4 Reconfigurable radio

2.5.4.1 Description of the Issue

Network reconfiguration in wireless access networks comprises all network nodes, including the mobile terminal. The initial motivation for terminal reconfiguration was to provide a mobile platform ability to roam between all different access networks and to adapt to the different air interfaces by simply exchanging the configuration software. However, with the introduction of wireless broadband, the variety of services offered via these high bandwidth wireless access systems changes from voice <u>or</u> data to voice/video, data <u>and</u> secure trading information. Such services, either concurrent or single, provide different requirements for bandwidth, QoS, security etc., therefore the network has to be optimised, all the way between the communication end-points, for the current type of traffic.

2.5.4.2 Potential Approach

Definition of interfaces between the functional entities within network nodes (i.e., SDR) and definition of programmable interfaces for active networks (IEEE P 1520) are merely a starting point for mobile network reconfiguration. A major task for future research is the integration of the previously mentioned technologies and the introduction of a distributed reconfiguration control.

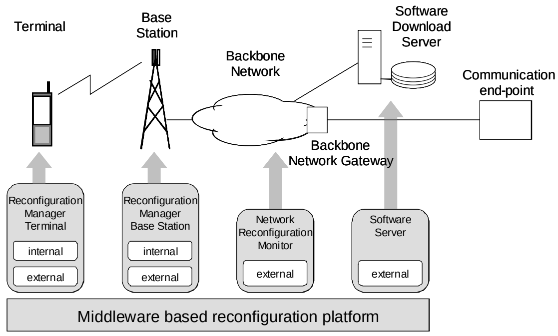

Figure 2.5.4.1 Reconfiguration of mobile communication networks

Reconfiguration of mobile communication networks has to be seen from two different perspectives, the internal reconfigurability of network nodes or terminals and the external configuration.

Target of internal reconfiguration must be to control the functionality of a network node before, during and after reconfiguration and to facilitate compliance to transmission standards and regulations.

External reconfiguration management has to monitor the current traffic requirements and to ensure that the means for transport between terminal and network gateway (or the other end-point) are synchronised (i.e., using the same standards). Furthermore, it has to provide databases for downloadable reconfiguration software.

Mechanisms to implement internal and external configuration are yet to be defined and points of interaction have to be clearly identified. Another major challenge is the design of mechanisms that ensure compliance of reconfigured network nodes (in particular terminals) with the regulatory standards.

2.5.5 High altitude platforms

2.5.5.1 Description of the Issue

High Altitude Platform Stations (HAPS) are not an alternative to satellite communications but a complementary element to terrestrial network architectures, mainly providing overlaid macro/micro cells for underlaid pico-cells supported through ground-based terrestrial mobile systems.

These platforms can be made quasi-stationary at an altitude around 21-25 km in the Stratosphere layer, projecting hundreds of cells over Metropolitan areas.

Due to large coverage provided by each platform, they are highly suitable for providing local broadcasting services. A communication payload supporting 3G and terrestrial DAB/DVB air-interfaces and spectrum can also support broadband and very asymmetric services more efficiently than 3G or DAB/DVB air-interfaces can individually. ITU-R has already recognised the use of HAPS as high base stations as an option for part of the terrestrial delivery of IMT-2000, in the Bands 1885-1980

MHz, 2010-2025 MHz and 2110-2170 MHz in Regions 1 and 3 and 1885-1980 MHz and 2110-2160 MHz in Region2. {Recommendation ITU-R M. [IMT-HAPS]}.

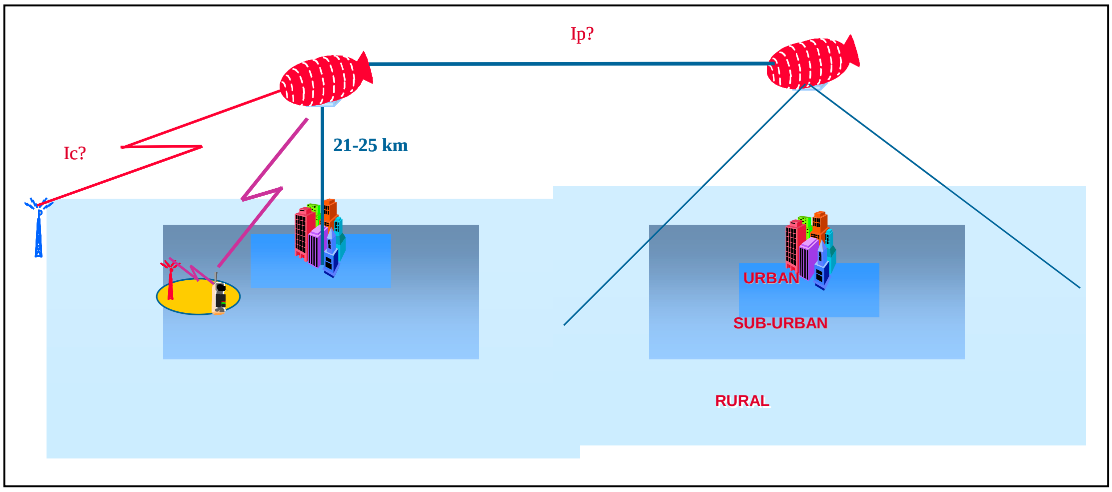

Figure 2.5.5.1: HAPS architectures complementing terrestrial network architecture in form of overlaid macrocell for delivery of integrated Mobile and Broadcating services

In addition to the above, there are following advantages that a HAPS network can offer;

- Ease the restrictions currently imposed on site availability;
- More environment-friendly than currently used macrocells, particularly in regards of possible RF radiation hazards;
- Helps much faster roll-out of services and country-wide coverage
- Provision of much higher elevation angles between a terminal and platform guarantees good channel environment particularly for multimedia services with stable QoS through minimisation of shadowing and required link margin.
- Support of hundreds of cells under the control of a platform can results in effective interference management across the cells and within a cell as well as reliable mobility management techniques.
- Can effectively support direct mobile-to-mobile links.
- Spectrally efficient delivery of Multi-casting, local Broadcasting and location-based services, and particularly mobile E-Commerce.
- Acting as macrocell component of ground-based cells, makes possible a cost-effective solution for provision of pico/micro/macro cellular architecture based on a single air-interface standard.
- Possibility of sharing the platform between a number of operators, particularly new operators, where the site availability could be an issue.

2.5.5.2 Potential Approach

There are however, a number of research issues that need be addressed on communications and platform structure itself. These should be carried out in consideration that the same terminal should be operable with both HAPS and ground-based cells seamlessly where HAPS is an extension of ground-based cellular network providing multicast/broadcast services and act as macro-cell element of the system. These research issues are:

- Coverage and service availability in the indoor environments
- Co-existence, spectrum co-ordination strategies with ground-based cellular networks
- Large phase-array antennas
- Integrated 3G and DAB/DVB payload architectures
- Specification of backhaul interface, Ic air-interface in figure 2.5.5.1. This depends on the level of network integration between two segments i.e., ground-based cellular network and the HAPS element.
- Specification of inter-platform interface, Ip air-interface in figure 2.5.5.1.
- Resource co-ordination and service mappings between 3G and DAB/DVB spectrum, and load-balancing between them
- Multicast service support in the 3G network
- Terminal positioning techniques in co-operation with Galileo or GPS
- Handover between HAPS and Ground-based cells.
- Solar-cell technologies, Fuel-cell technology, material
- Platform control, telemetry and control sub-system
- Characterisation of stratospheric layer.

2.5.6 Protocol design for energy efficiency

2.5.6.1 Description of Issue

Battery life has always been a concern in the wireless communications industry. We would like to avoid the need for frequent recharge of a portable device and the possible limitation in communications and processing capability caused by a depleted energy source. At the same time, we would also like to be able to power a device by means of a battery which is small, light and reasonably inexpensive. Unfortunately, the rate at which battery performance improves (in terms of available energy per unit size or weight) is fairly slow, despite the great interest generated by the booming wireless business. It does therefore make sense to look for alternative strategies to be employed towards the goal of power savings and energy management. In other words, instead of trying to improve the amount of energy which can be packed into a power source, one could try to build devices which can perform the same functions and provide the same services while using much less power.

2.5.6.2 Potential Approach

Better performance is being achieved by the components which are traditionally considered the most power-consuming portions of the device (e.g., the RF circuitry), and this brings other functions (e.g., signal processing) to play a significant role in the power budget.

The emergence of various applications and the need to support them in a wireless setting may open up new possibilities for energy saving strategies. For example, delay tolerant traffic may provide some degree of flexibility in that one does not have to fight bad channel conditions by just sending more power, but rather may defer transmission to better times by using channel-dependent scheduling.

The recognition that all levels of the communications device and protocol stack may contribute to this energy saving approach by intelligently using some knowledge about the behaviour of the processes, the traffic, the channel and the network, has led to a somewhat new approach to improving energy efficiency. Even the classic concept of ``battery life'' (essentially based on a circuit-switching mindset) is to be revisited, since the amount of data which can be reliably sent using a certain energy allocation may be more important than the actual time that the battery is ``alive.''

Solutions which have been discussed in the literature include error control schemes which try to opportunistically transmit when the channel is at its best instead of fighting deep fades through increased power, channel-dependent scheduling, MAC protocols where collisions are minimized in order to avoid power wastage due to frequent retransmissions, optimization of protocol parameters specifically performed by considering energy efficiency as the metric of interest and wireless channels as the operating environment (e.g., maximum window size or timeouts in TCP). Many of these solutions may work at their best when some awareness about the environmental conditions are available at different levels. In this view, the possibility of implementing communications among different layers of the protocol stack may be a valuable tool to allow smart optimisation of various schemes which must interwork to overcome serious impairments as caused by wireless channel conditions.

These topics of energy efficiency, interlayer communications, flexible and adaptive protocol stack implementation, are expected to play a major role in fourth generation wireless systems for a variety of reasons. In devices whose capabilities are continuously increasing, energy efficiency is key in providing reasonable operation times. Higher and higher data rates call for efficient use of the bandwidth, and this may partly be achieved at layers higher than the physical layer by minimising protocol overhead and by making protocols very efficient exploiting lower-layer information to make smart decisions. The type of traffic expected in 4G will make these solutions possible due to increased flexibility to time delay and jitter presented by data communications traffic as opposed to voice connections.

2.6 Spectrum issues

Summary

The current discussion towards spectrum assignment for extension bands to IMT 2000 is discussed in the context of the real needs of future multimedia based mobile radio services. Two unconventional methods are described to cover these needs: The first is co-farming of spectrum, where two operators agree to share a given frequency band alternating for different radio services under predefined conditions. The second is co-operation, where two organisations agree to make available part of their licensed spectrum to be combined in a way that a new radio service can be operated there by both of them together. Both methods contribute substantially to free spectrum for economically sensible usage and to reduce the scarcity of spectrum in general.

Introduction

ITU-R WP8F currently is discussing possible implementation and usage of the spectrum assigned by WARC-92 and identified by WRC-2000 for IMT-2000 family members to develop recommendations for the national regulation authorities of the different regions and countries. The main goal is to reach a maximum of international harmonization to prepare for global roaming.

The frequency bands under discussion internationally are not available for IMT2000 throughout all the regions. A consequence of this will be the demand for multiband and multimode terminals. The following is are mainly reflecting the contents of [1]1.

Spectrum identified today for IMT-2000 systems

Figure 2.6.1 shows a comprehensive overview on the frequency bands identified by WARC-92 and by WRC-2000 for IMT 2000 systems. ITU-R WP8F - Spectrums Group currently is discussing the usage of these bands. The bands shown are not available in all the member regions internationally:

The IMT 2000 extension band 2500 to 2690 MHz – devoted for terrestrial radio services in the range from 2520 to 2670 MHz – is not available in some countries of Asia and in North America. This band will become availabe in other countries between the years 2005 and 2010, e.g., in Germany the band will be available from January 2008 on.

Frequency bands in use today for first and second generation mobile radio services, e.g., 451 to 466 MHz (C-Net in Germany), 806 to 960 MHz dependent on region and country (GSM900) and 1710 to 1885 MHz (GSM1800) will be available for IMT 2000 after the respective licenses will have expired or after the regulation conditions will have been changed accordingly. New assignments of these bands will be possible in Germany for 440 to 470 MHz in the year 2001/2002 and for the GSM bands from the year 2015 on.

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[1] Werner Mohr: Alternative Vorschläge zur Spektrumsnutzung für IMT-2000 / UMTS, Spektrumsworkshop der ITU-R, 19.-20. October 2000, Genf

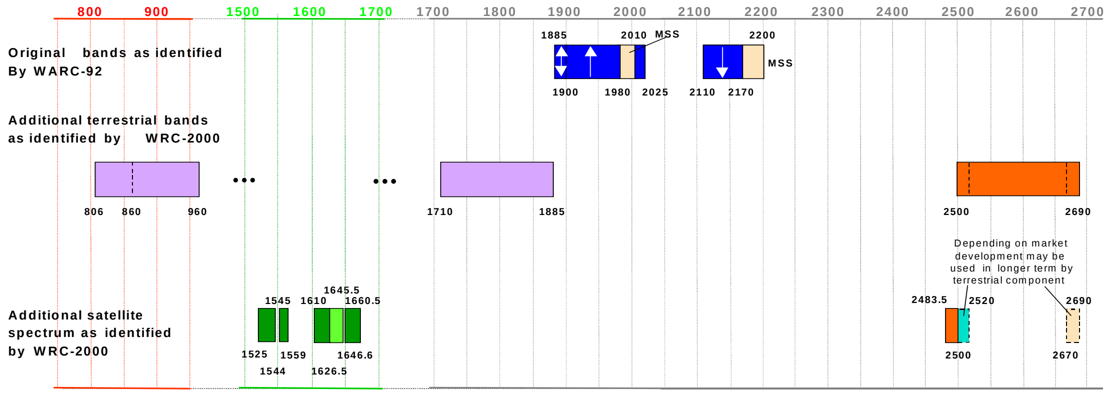

Figure 2.6.1: Overview on the frequency bands identified by WARC-92 (Source: ITU)

Asymmetric traffic characteristics of up-link and down-link usage

The higher the transmit rate of a service the higher is the expected asymmetry of usage of the up-link and down-link channels, making the down-link a bottleneck in IMT 2000 systems. The UMTS Forum has published a projection of the future usage of IMT 2000 systems and has identified the spectrum needed for the specific services, see Figure 2.6.2. A substantial asymmetry of the expected average traffic has been predicted there especially for Medium and High Multimedia traffic. The grade of asymmetry dependent on the services used might change from cell to cell over time and has to be taken into account when considering spectrum allocation for the extension of the currently available bands of IMT 2000. It would be optimum to be able to adapt the asymmetry of the spectrum load to the occupancy of the spectrum dynamically, dependent on the current load situation in a cell and on the development of the usage of services in a mobile radio system.

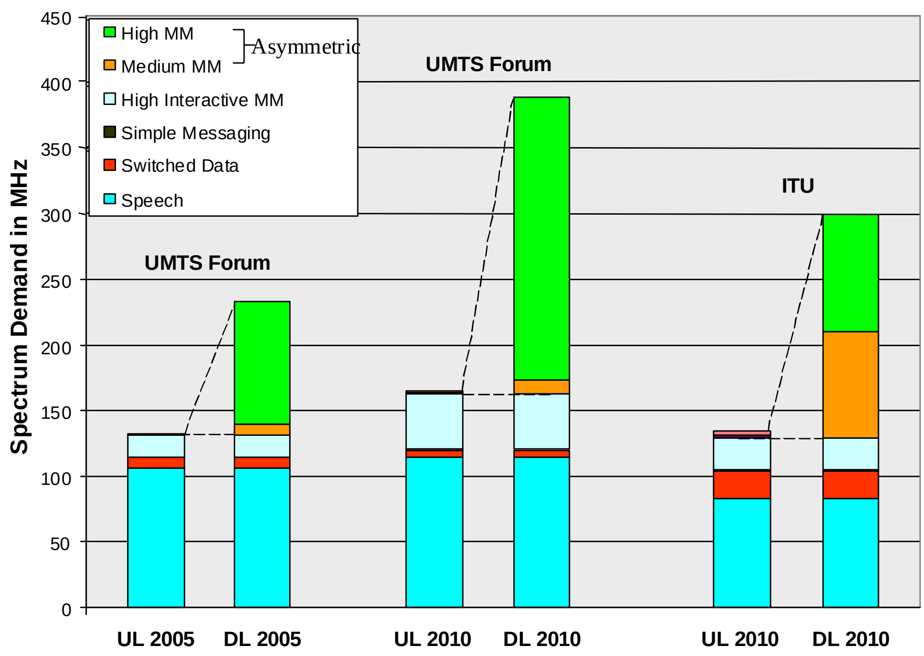

Figure 2.6.2: Projection of the future usage of IMT 2000 systems (Source: UMTS-Forum, Report No.6 and ITU-R Report M.[IMT.SPEC])

Two different approaches are under discussion to enable IMT 2000 systems to support a higher percentage of asymmetrical traffic that have been made from different angles of view:

Proposal by Advocates for More TDD Spectrum

The phases shown in Figure 2.6.3 are resulting from a proposal made by Siemens and can be described as follows:

- Phase 1: The IMT-2000 Core-Band is used for IMT-2000/UMTS according to the current licensing practice with
  - 2 x 60 MHz für FDD and
  - 20 + 15 MHz für TDD (in Germany the whole 25 MHz has been licensed for TDD).
- Phase 2: The extension band 2520 - 2670 MHz is proposed to be assigned to cover the needs of TDD-systems to serve asymmetrical data traffic. This band will be available in Europe between the years 2005 and 2010, in Germany the band is available from January 2008 on. In some Asian countries and in North America this band is not available.
- Phase 3: The GSM-1800 band is proposed to be re-allocated to be used for FDD-systems, this will be possible in Germany from about 2015 on.
- Phase 4: In this phase it is assumed that software radios and adaptive systems will be available to allow flexible use the spectrum in the subbands for both, FDD- and TDD-systems according to the market needs.

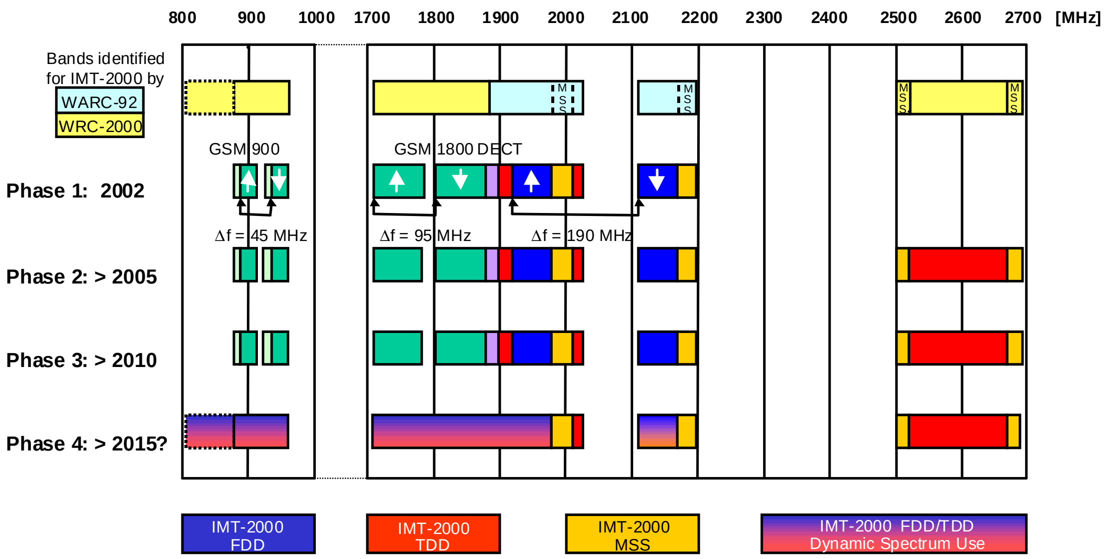

Figure 2.6.3: Assignment in favour of more TDD spectrum (Source: Siemens)

By this approach a de-coupling of the separated sub-bands of the spectrum will be possible.

Since there will be no time related dependencies between the subbands and their use for FDD or TDD, no problems related to the availability of spectrum for the one or the other mode of transmission will arise then.

In addition, the demand to support an asymmetrical traffic load needs can be responded in a flexible way.

Proposal to introduce an asymmetric operation of the FDD Mode

Figure 2.6.4 describes the basic ideas of how to introduce extension bands mainly to serve the UTRA-FDD mode of operation.

- Phase 1: This phase is identical to Phase 1 in Figure 3 and does reflect the current licensing plans and agreements.
- Phase 2: Here, the extension band does contain more downlink channels in addition to be able to support the needs of asymmetric traffic. By this a maximum degree of the mean asymmetricity of 1:3,5 can be realised by fixed channel allocation, that cannot be changed dynamically if needed. A consequence is that the air-interface must be able to handle a variable duplex spacing, since up-link and down-link channels will be grouped in a region or country according to the local decisions made by the regulation authority.
- Phase 3: The GSM-1800 band is now allocated to be used as an FDD up-link. Thereby, the asymmetry gained in Phase 2 will be turned the other way around: In case the duplex spacing between the GSM-1800 up-link-- and down-link of today is completely assigned as an FDD up-link, in fact there will result an allocation with more spectrum assigned to the up-link then for the down-link. In addition, the current band for the GSM-1800 down-link will have to be switched to become an up-link band. It is expected that this will result in co-ordination problems at country boarders throughout Europe and in other continents and will make difficult to avoid adjacent band interference there.

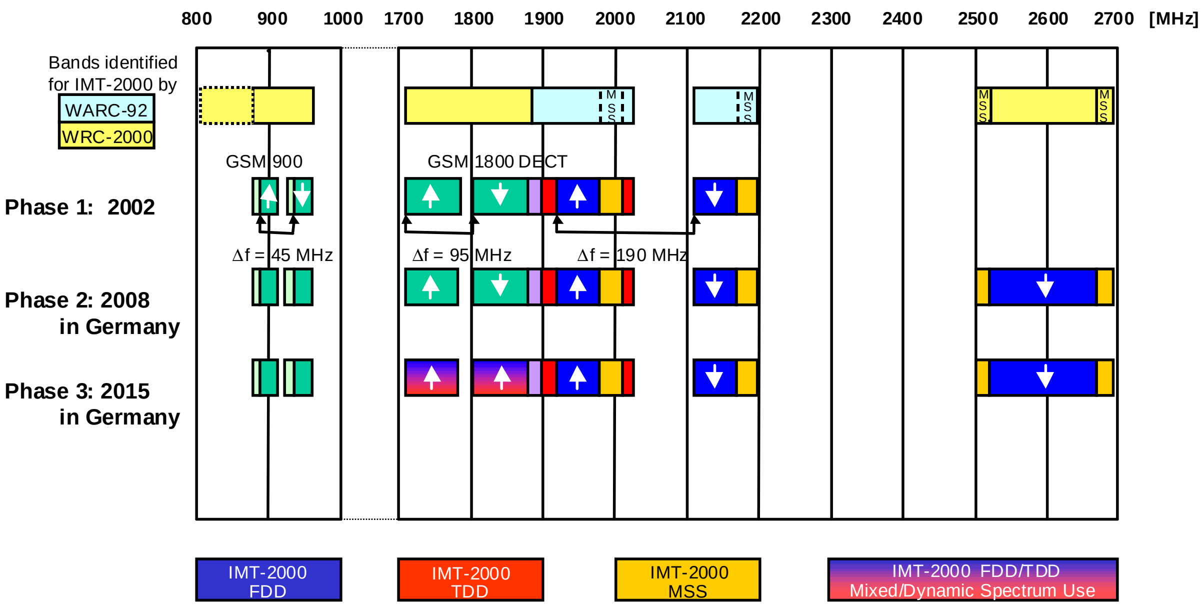

Figure2.6.4: Assignment in favour of more spectrum to asymmetrical FDD operation (Source: ITU)

In the following two unconventional methods are described to cover the needs for more spectrum to especially serve asymmetrical traffic streams: The first is co-farming of spectrum, where two operators agree to share a given frequency band alternating for different radio services under predefined conditions. The second is co-operation, where two organisations agree to make available part of their licensed spectrum to be combined in a way that a new radio service can be operated there by both of them together. Both methods contribute substantially to free spectrum for economically sensible usage and to reduce the scarcity of spectrum in general.

2.6.1 Co-Farming of Spectrum by the Defence Community and Public Cellular Operators

We propose to perform an in depth investigation of the practicability of the time-shared use „co-farming“ of spectrum assigned by WRC, Nato, EC, and national governments to the defence community by both, wireless/cellular operators and the defence community. The approach in part also applies to the relation between broadcasters and cellular operators.

2.6.1.1 Description of Issue

State of the Art of Spectrum Allocation

From the Detailed Spectrum Investigation (DSI) Process Phase III (862-3400 MHz) of ERO of July 1998, (available from http://www.ero.dk/eroweb/DSIinfo.html)

- it is clear that in the fixed network the relative load by data has exceeded that of voice in 1998 (see page 21), a development that experts expect to happen a number of years later also to wireless and mobile radio networks

- „Trends and Developments for the Military Services“ within the DSI range can be found (NATO unclassified), see page 106-114.

The Green Paper on Radio Spectrum Policy (distributed by EC, Brussels, 09.12.98 COM(1998) final) distinguishes

- five radio-based sectors and activities (see Table 1 on page 5)

  - Telecommunications

  - Broadcasting

  - Transport

  - Government (comprising Defence, Emergency, Law enforcement, Space science, Applications under international commitments)

  - Research & Development

- three parts of the spectrum, i.e.,

1. 9 kHz to 1 GHz
2. 1 GHz to 3 GHz
3. GHz to 30 GHz

As an example UK “Defence“ owns 29%, 31%, and 38% of the frequency spectrum in parts 1, 2 and 3, respectively. The situation is similar in other member states of the EU. The future growth of wireless and mobile applications will lead to a dramatic shortage in radio spectrum for public use. The government as the owner of the spectrum has assigned more than 30% of the available spectrum to the defence community.

The Current Situation in Spectrum Use by Public and Non-Public Users

Periodic negotiations are performed on the national and European levels between regulatory authorities and the respective defence community representatives aiming to re-farm sectors of the spectrum used by the defence community for public telecommunications use. The arguments have been repeatedly exchanged and the process will not end with significant changes of the current allocations. This is partly owing to convincing arguments of the defence representatives and partly to a lack of motivation of the defence community to release a given band and carry the cost to reallocate the respective radio equipment to another band.

A close look on the usage of the defence bands reveals that substantial pieces are only rarely used and some parts are not used, being reserved for a case of need, e.g., the tactical bands.

2.6.1.2 Potential Approach

Public telecommunication operators in most cases receive their licensed spectrum against fees for limited time duration, e.g., from an auction controlled by a national regulation authority. UMTS spectrum, for example, in some countries in Europe has been licensed from auctions for a fee of up to 3 to 4 billion US $ per 5 MHz block (duplex) for a duration of 20 years.

It is proposed to study the co-farming of suitable frequency bands of the defence community by time-shared use of public and defence users. In a time-shared use most of the time the public operator will have free access to the respective bands, but under well-defined conditions the owner of the band (members of the defence community) may withdraw the band for its own usages for some time interval. This idea is a small modification of the current situation: operators of public cellular radio networks, e.g. in Germany, have been contracted to close down or reduce their services and give spectrum to the defence community on request, e.g., in times of crisis.

Time-shared use can be seen as equivalent to co-farming a band or to frequency borrowing and could happen under, e.g., the following set of agreements:

1. Co-farming of a given band with a public operator is under the control of the owner (that might be the government or its representing department of the defence community), i.e. the owner may claim a temporal partly or exclusive use of the respective band under certain previously agreed circumstances (typically a rare event) and the band may then be withdrawn from the public operator.

2. A public operator using a co-farmed band would have to pay a license fee to the owner or its representative, the amount of which depends on the true market value, i.e., the defence community will receive a compensation for making a band to a limited extent available for public use.

3. The public operator must own a license for a wireless or mobile radio system based on a public band and may enlarge his service capacity by using a co-farmed band; the offered service should be engineered by the operator in a way to be able to guarantee a reduced service to its customers when the co-farmed band during some time intervals would be not available for the public service.

4. The owner of the co-farmed band must use the revenue raised for the modernisation of its own radio equipment.

These items are examples only and should be complemented to cover all eventualities foreseen. The proposal is to leave the defence bands under the control of the defence community but make some of the bands available to the public under a fair sharing agreement – against payments. Figure 2.6.1.1 gives an example how to extend the traffic capacity of a cellular operator of, e.g., a GSM900 system by co-farming the spectrum owned by a number of military organisations. Two cases have been differentiated: symmetrical and asymmetrical extension of the cellular operator's capacity by co-farming a symmetrical or asymmetrical band, respectively. The main ideas presented are applicable also to the co-operation of radio broadcasters and public cellular operators.

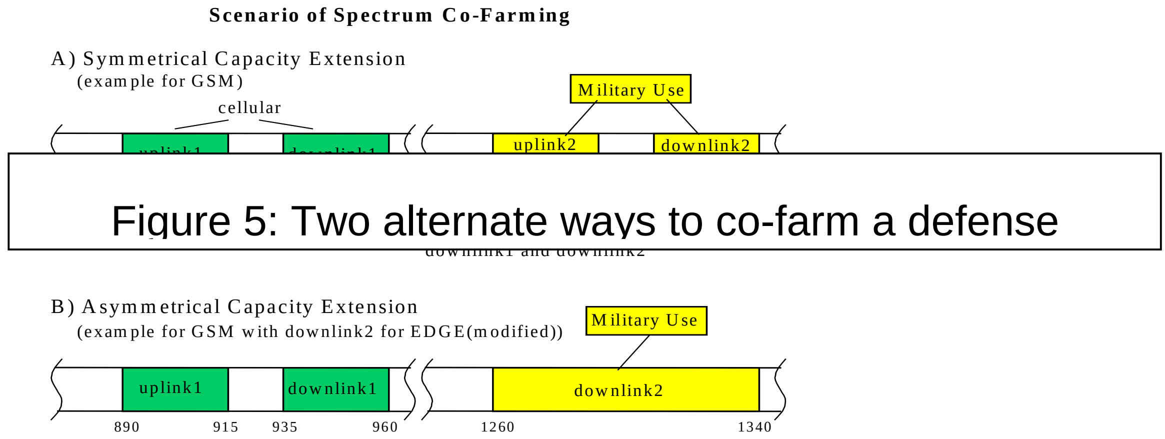

Figure 2.6.1.1 Two alternative ways to co-farm a defence community owned band by a public cellular operator, A) symmetrical, and B) asymmetrical

Preparatory and Validation Steps before Introducing Spectrum Co-Farming

The proposed co-operation between public and defence operators needs a validation of the practicability before introducing it into practice. This validation of practicability and the development of measures to secure the guarantee of full control of the defence community over their allocated bands should be performed as part of a 5th framework project. Besides others, the candidate bands have to be identified and the practicability of the proposed co-farming and service quality reduction when the borrowed band is withdrawn have to be investigated. Further, the relation of licensed and borrowed band of a public operator under the conditions of its service mix being offered have to be developed. It appears advantageous to co-operate with defence community representatives and manufacturers of military radio equipment to better understand the problems and find adequate solutions. Besides that, commercial and competitive aspects have to be studied.

Example of Withdrawing of a Co-Farmed Band

Although it can easily be imagined that a defence band, being borrowed to operate the down-link of a public radio service, can be easily freed by closing the respective frequencies used by the base stations under central control, it can also be imagined that mobile terminals can be operated in borrowed bands and can be switched out of the band, e.g., by means of a pilot tone issued via the broadcast control channel under central control from the defence community. (The protocols for this function have to be developed). Since military organisations are used to live with jamming their spectrum, it could even be acceptable if some of the mobile terminals would ignore the busy tone and would continue to temporarily issue attachment signals.

Advantages of spectrum co-farming for the defence community

The defence community is assumed as part of this proposal to raise money from borrowing spectrum to public operators during co-farming.

If the defence community is contracted to modernise its radio equipment operated (rarely) in the borrowed band, it might be advantageous when modernising the equipment to switch from a military air interface standard to an ETSI/ITU-R standard used in the public system operated in the co-farmed band. During an intermediate stage, where current and modernised equipment is used in parallel, the public band might be used by the respective defence organisation.

As a result, the defence community would in the medium to long term, after a complete phase of modernisation, use the same air-interface standard in the borrowed band as is used in the corresponding public band (of cause the security measures will be kept at a much higher standard). This would contribute to dramatically reduce the cost of military radio equipment, since it would follow the standards of the mass market and therefore would accelerate the modernisation of the military radio equipment. Although this might not be the interest of the respective manufacturers, it appears to be the interest of the taxpayers.

More carefully looked into the resulting scenario it would become clear that a distinction between borrowed band and public band would disappear, because it would be much better for the military communications traffic, when generated, to virtually disappear in the high volume traffic of the public users instead of applying costly and spectrum consuming spreading and security measures to avoid detectability and observation of defence related traffic. The public traffic in Erlang is estimated to be about thousand times higher than the defence related traffic even in a military hot spot. In fact, even no traffic flow analysis of the military spectrum use would be possible and eavesdropping would become practically impossible without any cost.

The scenario described is in line with the philosophy followed anyway by the defence community in these days. Off-the-shelf (standard) equipment (e.g., Ethernet and PCs) is used wherever possible. And this philosophy has not only proved in many cases to be superior to the use of dedicated military equipment but also has proved to be in many cases the only possible way to keep pace with the technical progress in the respective domains.

2.6.2 Co-operation to co-farm a broadcasters licensed spectrum with a cellular operator

2.6.2.1 Description of Issue

Broadcasters have been assigned excessive spectrum for radio and television broadcasting, e.g. 368 MHz in Germany that they are currently unable to use efficiently: In most places of the country substantial parts are not being used.

The number of subscribers using terrestrial television services, e.g., in Germany is about 8%; the others are accessing these services via cable or satellite. The pure operations costs of terrestrial broadcasting in Germany are about 500 Mio. DM per year. This amount of money would be sufficient to grant all the users linked to the terrestrial television broadcast service a satellite antenna plus decoder to switch to satellite reception and cut-off from terrestrial television broadcast services. Even if part of the costs would remain then to operate the terrestrial radio broadcast service, the spectrum assigned to television would be free for new usage.

The economic value of the spectrum usage by broadcasters is very questionable. The spectrum, e.g. in Germany, is licensed to broadcasters for free, based on an Article of the „Grundgesetz“ guaranteeing access to broadcast information for every citizen in Germany to be able to „make up his political mind“. With 8% of citizens only that use this terrestrial service offer, and considering that alternate service provisions are easily available based on satellites and cabled systems, the sense of the allocation of such huge amount of spectrum in the best part of spectrum is very questionable.

Mobile cellular radio operators all together currently have been licensed about 365 MHz of spectrum for which they had to pay substantial fees to the national regulation authority. One argument was that spectrum is very scarce and a fair market value of spectrum at best can be found by means of an auction. Mobile radio operators raise big economic values out of the spectrum they are using

Since more spectrum is needed for mobile radio operation, frequency re-farming of spectrum allocated to broadcasters should severely be discussed. It should be clear from the initial that the goal is not to take-over the whole spectrum currently licensed to broadcasters by mobile radio operators, but to get access to a substantial portion of it to be able to cost-efficiently provide radio coverage in rural areas of the country.

There currently exist plans of governments in Europe to re-assign the television spectrum in steps to be used for digital broadcast transmission based on the DVB-T standard. Since the terrestrial customers affected by this decision would then have to decide whether to buy a new digital (DVB-T) terminal equipment or to buy a satellite receiver to keep their existent terminal operational, there is a high risk of this process that terrestrial broadcasters would experience a decline of their market share from 8% to, say 0,8%.

Lessons learned from UK

In UK a model has been developed and exercised that allows industrial companies to operate a commercial digital pay-per-usage service on about 20% of the former television bands using DVB-T on the down-link and various networks to provide an up-link channel back from the customers to order services from the commercial companies. DVB-T terminals that can receive the whole television radio band have been given for free to the customers by the commercial service providers.

The UK-broadcasters by means of this trick have solved the problem to survive the switching from analogue to digital transmission and not to loose their terrestrial customers.

As a result there now exists a competition between public cellular operators and operators of DVB-T-with-back-channel services established by the UK government that mainly offer multimedia contents that otherwise would have been carried by UMTS operators in UK.

The question is whether or not this model can be ported to other European countries, e.g. to Germany and thereby establish competition between government-supported operators that use television bands for countrywide bi-direktional services and UMTS operators that have recently paid much to get an UMTS license. My guess is that this will be difficult to repeat elsewhere in Europe.

2.6.2.2 Possible Approach

Alternatives to Co-farm Television Spectrum by Cellular and Broadcast Operators

The current situation of spectrum usage for television services between 470 and 838 MHz as shown in Figure 6 will be reconsidered in 2003 by WRC for the years beyond 2010. It can be seen that between 838 and 862 MHz a military band exists adjacent to this band. The channel width is 8 MHz for the television channels. The channels from 814 to 838 MHz are reserved for transmission using the new DVB-T standard for digital television broadcasting.

The scenarios 1 to 3 shown in Figure 2.6.2.1 have been developed by the COMCAR2 and DRIVE3 projects that perform research towards the integration of television services offered via the broadcasting bands and of services offered from public cellular operators. Since it would be optimum for a radio terminal to make use of spectrum bands that are closely neighboured, in Scenario 1 an example is shown where the cellular radio band (shown in dark/blue) is operated in channels of the military band 814 - 862 MHz.

[2] Communication and Mobility by Cellular Advanced Radio, funded by the Federal Minister for Education and Research in Germany

[3] Dynamic Radio for IP-Services in Vehicular Environment, funded by CEC in the Information Society Technology Programme

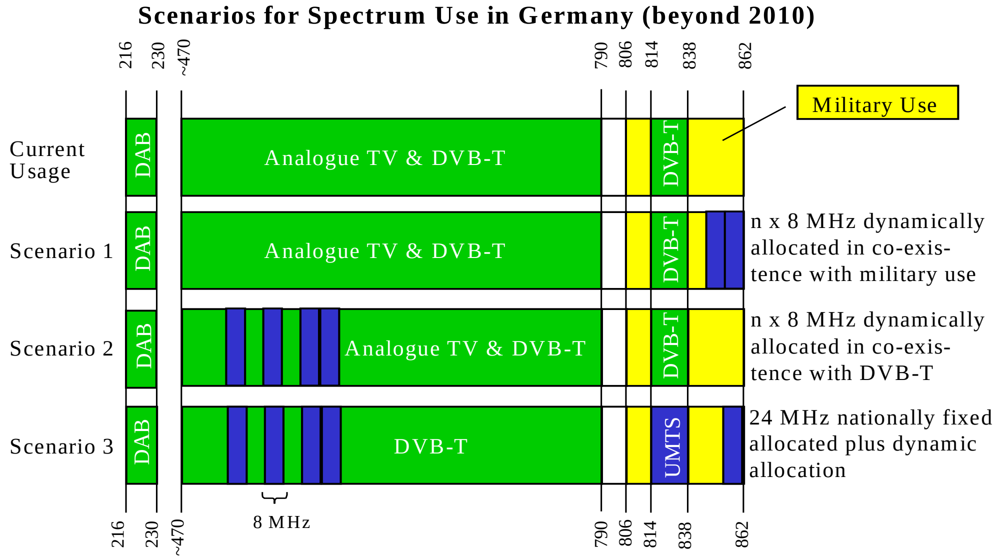

Figure 2.6.2.1: Proposed usages of broadcaster's and military spectrum by cellular (UMTS) radio as studied by the projects COMCAR and DRIVE

A Scenario 2 shows alternate spectrum usages to operate the public cellular radio system somewhere in channels of the spectrum currently allocated for television broadcasting. It should be kept in mind that the usage of the television band is different in the different states of Germany, dependent on the locations and that the position of free television channels for cellular radio use needs therefore to be location dependent. The different radio services namely analogue TV, digital TV and cellular will have to coexist in a way that no unacceptable interference would result from introducing, e.g., UMTS transmission via an 8 MHz channel of the television band. This appears to be possible since UMTS has a channel width of 3.8 MHz that is typically embedded into a 5 MHz channel to avoid neighbour channel interference.

Scenario 3 is going even beyond what is proposed by Scenario 2: a number of TV-channels have been permanently allocated to serve cellular radio. In addition, the ideas presented in the other two scenarios are kept as part of Scenario 3, namely co-farming of military spectrum and of television spectrum by cellular radio.

The hope of the activities is to get experience with the combined operation of different systems and to convince television operators, regulators and government responsibles that it is a good idea to join the forces of TV-broadcasters and cellular operators, say, by means of a common subsidiary company to operate the combined service. This would enable broadcasters to make more efficient use of their spectrum than nowadays.

The author had developed and communicated the ideas presented in this paper since summer 1998 and since then has experienced much interest and support from different parties involved, namely members of the defence community, the regulation authorities of different countries, manufacturers and operators of mobile radio systems and broadcasters.

2.6.3 Co-existence rules for unlicensed technologies including the possibility for real-time services

2.6.3.1 Description of Issue

With the introduction of HiperLAN/2 systems as a transparent wireless extension of ATM, UMTS, IEEE 1394, and IP-based networks to wireless terminals, quality of service requirements have been asked for as known from the fixed ATM network. The introduction of IEEE 802.11a that is basically as wireless Ethernet, has raised the question how to guarantee fairness of spectrum usage and enable the individual systems to guarantee QoS throughout a communication phase, since both systems are operating in the same frequency band.

Since 4G services will require large bandwidths, the W-LAN systems may have to use frequencies that are spread over several compounds that are sufficiently free of interference. Further, to allow the new systems to share the frequencies with other new or existing systems, the new systems should possess innovative measures that make them more capable to survive in extreme situations where a small spectrum is available only.

2.6.3.2 Potential Approach

Frequency Sharing Rules (FSR) must be defined to allow various systems to coexist. They will drive the further development of the telecommunication markets by allowing the different systems to co-exist in deregulated bands. Only systems obeying a defined etiquette and, thus, applying the respective FSRs, will allow to provide QoS, as there will not be a spectrum reserved exclusively for any type of system.

In the 5 –6 GHz band, HiperLAN/2, IEEE 802.11a, to a certain extent the Japanese MMAC, satellite communication systems and scientific radio applications will have to share the spectrum. All these systems operate in an unlicensed band, uncoordinatedly. They all individually need to be protected. As the adhoc and infrastructure-based systems are likely to work on their own, without any synchronization to other systems operating in their vicinity, HiperLAN/2 must be protected against HiperLAN/2, IEEE 802.11a against IEEE 802.11a, as well as both the different systems against their foreign counterparts. There is no reason to argue that if two customers both purchased HiperLAN/2 and a third one decided to use IEEE 802.11.a, that the first two are interested to coexist but at the same time not allowing the third system to work simultaneously. In other words, any system is expected to try to get as much radio resources as possible (if required by the offered traffic) and all other systems will be interpreted as competitors. In a conservative approach, all systems would try to be very selfish, leading to non-cooperative non spectrum-efficient operation. Well designed FSRs will be the means to achieve cooperation among the uncoordinated systems and contribute much to increase spectrum efficiency substantially.

The proposal is to start research in co-existence rules for wireless systems operating in the same spectrum.

3 ANNEX – CONTRIBUTIONS RECEIVED FROM THE “CALLS FOR CONTRIBUTIONS”

3.1 Contribution by Professor Ephremides

WIRELESS BEYOND THIRD GENERATION

Panel Chair and Professor of Electrical Engineering University of Maryland College Park, MD 20742 - tony@mintaka.isr.umd.edu, tel: 301-405-3641, fax: 301-314-9281.

As a result of the research that a Panel I headed performed last year on behalf of various United States research-supporting agencies for the Assessment of the Technologies that affect Wireless Communications, I was able to formulate some conclusions on what lies ahead. The results of the Panel's work are available in a report that is just about to be released by WTEC (World Techno- logy Evaluation Center) which was the entity that provided planning and logistical support for the Panel's work.

The conclusions pertain only to technical issues and concern the dominant directions of research that we feel will be needed to realize the envisioned services and applications. In summary they are as follows:

1. There will be a need to integrate on a chip most of the components of the wireless transceiver. The technology exists to permit this but certain breakthroughs will be needed to fully realize it. The "reach" of this bold statement encompasses not only the RF components of the transceiver but also the processor the antenna and the link communication system elements.

2. The importance of spatial diversity to increase capacity and flexibility makes the development of adaptive directive antennas absolutely necessary. Already major breakthroughs are being achieved in this regard and more are on the way.

3. The design of handsets, base-stations, and other transceivers will have to be based on an architecture that transcends the traditional networking "layers" and , instead, integrates across these layers. The concept of the "software defined radio" is a first step in this direction. In fact, the software radio platform will be a perfect tool on which to perform this integration These three major conclusions are elaborated upon in much greater detail in the WTEC report of our Panel. As stated earlier the report is on the verge of its public release and can be contributed to the WSI. The aforementioned summary is intended to only "hint" at what the vision that emerged from our work comprises.

The assumptions and background that led to these conclusions are that the driving applications are mobile high-rate data communications, military needs, personal communications, and specialized applications such as telemedicine, law enforcement, etc. Also, the bottlenecks are clearly the bandwidth and quality limitations of the wireless channel as well as the lack of interoperability among the existing systems. Finally, the need to extract maximum communications out of a finite amount of energy seemed to us to be of paramount importance.

The Panel consulted "in situ" with over thirty major companies and institutes in the United States, Europe, and Japan, and consolidated its findings after considerable deliberation among its members that included a total of seven technical experts as well as another seven representatives of the funding agencies. The report will be supplied to the WSI forum as soon as it becomes available.

3.2 Contribution by Lajos Hanzo

Burst-by-burst Adaptive Fourth-generation Wireless Single-carrier, Multi-carrier and CDMA Transceivers

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Motivation

The fundamental limitation of wireless systems is constituted by their time- and frequency-domain channel fading, as illustrated in Figure 1 in terms of the Signal-to-Noise Ratio (SNR) fluctuations experienced by a modem over a three-path channel. Over these channels no fixed-mode transceiver can be expected to provide an attractive performance, complexity and delay trade-off. Encouraged by already available evidence disseminated for example in [1] further research is required in adaptive transceivers, as outlined below in more detail.

Explicitly, it is necessary to contrive a suite of near-instantaneously adaptive or Burst-by-Burst Adaptive (BbBA) wideband single-carrier [22,24,25], multi-carrier or Orthogonal Frequency Division Multiplex [1] (OFDM) as well as Code Division Multiple Access [23, 26] (CDMA) transceivers with the aim of com- municating over hostile mobile channels at a higher integrity or higher throughput, than conventional transceivers. A further fundamental objective is to disseminate the results as widely, as possible, for our industry [6]- [8] **and to contribute to 4th-generation standardisation.**

The full document is available in Postscript format under www.ist-wsi.org

[4] For related papers on the topic please refer to http://www-mobile.ecs.soton.ac.uk

3.3 Contribution from the BRAIN Project

The IST Project BRAIN and its contribution to form systems beyond 3G

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Abstract

Mobile communication systems and the Internet are key technologies for the development of the information society, in which access to applications and services of high quality is provided in a seamless manner so that the user is not aware of the nature of the underlying network technologies. Wireless systems beyond 3G will contribute to the implementation of such a user-friendly communication platform by the integration of different access networks and the convergence of mobile and fixed networks.

The IST project BRAIN, which is partly funded by the European Commission, is working on an open architecture which allows to integrate second and third generation cellular systems and broadband radio access systems through a common IP network platform. Horizontal and vertical handover between these systems provide seamless service. This paper gives an overview about the work carried out in the BRAIN project and outlines how the BRAIN is contributing to the development of systems beyond 3G.

3.3.1 Current trends and visions

The Advisory Group of the IST Programme (ISTAG) of the European Commission describes in its report “Orientation for Workprogramme 2000 and beyond” [1] a vision for the work which will be carried out under the IST Programme. This vision highlights the importance of mobile communications and network infrastructures and promotes the rapid and complete convergence of fixed and mobile applications and services.

The UMTS Forum shares also this vision by stating that the foundation of the development for the information society is laid by the convergence of communications, information, entertainment, commerce and computing [2].

These views are based on observations of market trends and current and emerging technological developments.

Mobile phone growth has been exponential in the last decade and is supposed to continue at this pace. The number of users of mobile services worldwide will be higher than 400 million by the year 2000 and will grow up to more than 1700 million by 2010. Advanced mobile multimedia services are becoming available with the deployment of second and third generation of mobile systems. These systems will provide high bandwidth of up to 2 Mbps.

The second trend involves the Internet. It started 30 years ago as a research network connecting just a small number of nodes. In the early 90ths, the World Wide Web (WWW) service was released by CERN, the European Organisation for Nuclear Research. This service provides the user-friendly interface which made the Internet accessible to everyone and publicly known. Today, the Internet is a still rapidly growing global network. The number of hosts on the Internet is doubling roughly every 8-9 months [3]

Simultaneously with the exponential growth of the mobile and Internet market the users' expectations on services and applications with high Quality of Service are increasing.

These trends and requirements are affecting the vision of future systems beyond third generation. The seamless provisioning of services and applications across heterogeneous access systems will play a key role in future communication systems. IP will provide the common platform not only in the core network, but also in the access networks. The new expected data services are highly bandwidth consuming. This results in high data rate requirements for future systems.

3.3.2 The IST Project BRAIN

These trends towards systems beyond third generation, the limitations of second and third generation systems in terms of available data rate and spectrum and the goal of seamless service provisioning across different access systems are the main drivers for the BRAIN project. The project is partly funded by the European Commission under the IST (Information Society Technologies) programme of the fifth framework programme for research and technological development.

BRAIN is developing an open architecture which allows the integration of existing and emerging access technologies. This architecture can be considered as a broadband extension of third generation mobile radio systems and, therefore, will address systems beyond third generation. The access network supported by BRAIN will be based on IP. The BRAIN objectives are:

- To develop seamless access to existing and emerging IP-based broadband applications and services.
- To develop an open architecture for wireless broadband Internet access
- To create new business opportunities for operators, service providers and content providers to offer high-speed (up to 20 Mbps) services complementary to existing mobile services.
- To contribute to global standardization bodies.

Project partners are from the different areas:

- **Manufacturers:** Ericsson Radio Systems AB (Sweden), Nokia Corporation (Finland), Siemens AG (Germany) and Sony International (Europe) GmbH (Germany).

- **Network operators:** British Telecommunications plc (UK), France Telecom – CNET (France), NTT Mobile Communications Network, Inc. (Japan) and T-Nova Deutsche Telekom Innovationsgesellschaft mbH (Germany).

- **SME, research and academia domain:** Agora Systems S.A. (Spain), INRIA (France) and King's College London (UK).

3.3.3 Technical Approach of BRAIN

The BRAIN architecture allows to integrate cellular systems with the broadband WLAN type system HIPERLAN 2 on IP access networks (Figure 1).

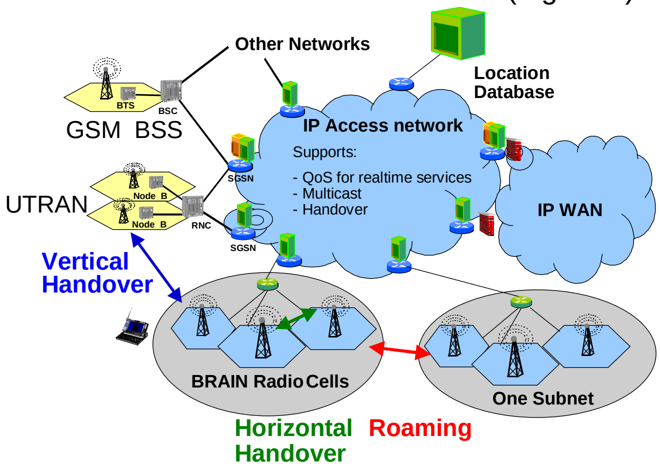

Figure 1 BRAIN network architecture

By that, the architecture supports the coverage of different application areas with a range from public and private environments to corporate environments and public hot spots like conference centers, airports, and railway stations [5].

The architecture will support horizontal handover within the same system and vertical handover between different systems. This will enable the seamless provisioning of services and applications across heterogeneous access networks.

IP will provide the common network platform. It is used in the core network as well as in the radio access network all the way down to the access point (Figure 2) and the mobile devices. IP traffic and the QoS requirements will be mapped onto the radio link via an IP convergence layer.

This convergence layer is responsible for hiding the nature of the underlying layer 2 access technologies and, thus, represents a common interface to the IP layer. The concept of a convergence layer will allow to support a range of different access technologies including WLANs and mobile cellular systems without affecting the IP layer above. The BRAIN work will address in particular HIPERLAN 2 systems.

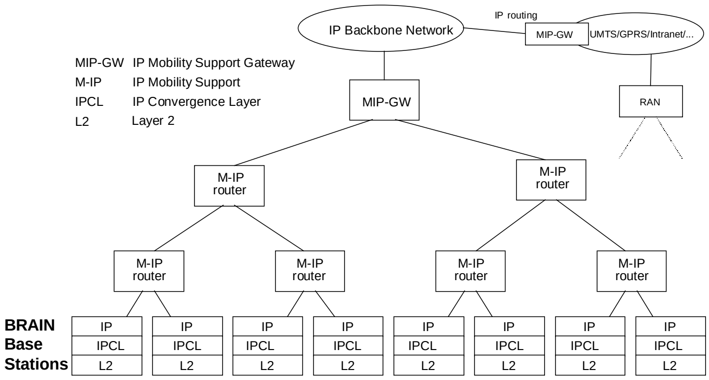

Figure 2 Example of a BRAIN network scenario

The common IP network layer will provide a service interface to the application layer. This service interface will support a wide range of application types with different control and management mechanisms for QoS. This includes applications with limited QoS capabilities as well as applications based on sophisticated middleware solutions for handling QoS.

The QoS requirements of all these application types will be mapped onto the network layer via the service interface and from the network layer onto the radio link using the functionality provided by the IP convergence layer (Figure 3).

The BRAIN architecture separates clearly the various layers of the protocol stack. This clear separation of layers follows the concepts of an all IP network (see [6]) and results in a modular and flexible architecture. This architecture allows to add easily new protocols, access networks, and new types of applications with support of end to end QoS.

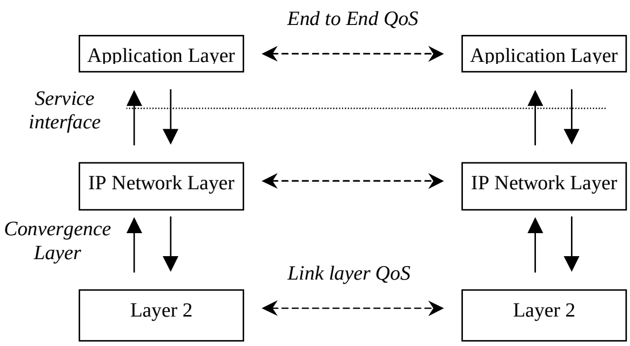

Figure 3 Main protocol layers of mobile devices of a BRAIN access network

3.3.4 Conclusions

The BRAIN Project adopts a top-down approach starting with service and application requirements and mapping them to access network and radio interface requirements in order to focus on the crucial points in developing the BRAIN architecture.

Local and global mobility support at IP level (roaming and handover) will be provided based on the concepts of the modular and open BRAIN architecture. Seamless access to broadband IP networks with end to end QoS will be supported. The BRAIN work on network aspects started with the IETF's approach and protocols. Improvements will be developed and proposed where necessary. Results will be contributed to the activities of relevant standardization bodies like IETF and ETSI BRAN. In addition, techniques for enhanced system capacity – especially for the broadband radio access system based on HIPERLAN 2 - will be investigated.

By this work, BRAIN will contribute to the development of systems beyond 3G, which are characterized by the integration of different access networks, the convergence of mobile and fixed networks, and the provision of a common user-friendly communication platform which allows the seamless provisioning of services and applications.

Acknowledgment

This work has been performed in the framework of the IST project IST-1999-10050 BRAIN, which is partly funded by the European Union. The author would like to acknowledge the contributions of his colleagues from Siemens AG, British Telecommunications PLC, Agora Systems S.A., Ericsson Radio Systems AB, France Télécom - CNET, INRIA, King's College London, Nokia Corporation, NTT DoCoMo, Sony International (Europe) GmbH, and T-Nova Deutsche Telekom Innovationsgesellschaft mbH.

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3.4 Contribution by Lie-Lian Yang and L. Hanzo, etc

Blind Soft-Detection Assisted Frequency-hopping Multicarrier DS-CDMA Systems

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Abstract

A slow frequency hopping, multi-carrier direct-sequence, code-division multiple-access (SFH/MC DS-CDMA) scheme is proposed and investigated, which has the potential of providing a joint framework for 2nd generation narrow-band CDMA, 3rd generation wide-band CDMA and high-rate broadband access networks. Blind soft-detection of the SFH/MC DS-CDMA signals is investigated, assuming that the receiver has no knowledge of the associated frequency-hopping (FH) pattern involved. The system's performance is evaluated over the range of Nakagami multi-path fading channels. The results show that the blind soft-detection not only achieves the required bit-error-rate performance, but it is also capable of blindly acquiring the FH patterns employed. This assists the mobile in accessing the network without the knowledge of the FH patterns or during soft hand-over.

The full document is available in Postscript format under www.ist-wsi.org

[5] For related papers on the topic please refer to http://www-mobile.ecs.soton.ac.uk

3.5 Contribution by Ralf Keller, Thorsten Lohmar, Norbert Niebert, Ralf Tönjes, Jörn Thielecke

Convergence of Cellular and Broadcast Networks - towards Future Wireless Generations

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3.5.1 Introduction

The demand for cost efficient provision of mobile multimedia services is faced with the reality of scarce radio resources. The requirement of spectrum efficiency has driven the development of various digital radio technologies (DAB, DVB, GSM, GPRS, UMTS, etc.[6]) that have been optimized for specific services, namely for broadcast or for mobile communication. However, existing and emerging multimedia services exhibit challenging requirements in terms of asymmetry, interactivity, real-time, and multicast communication. This paper describes an IP based multi-radio infrastructure that enables the co-operation of existing radio networks to combine their capabilities to ensure a spectrum efficient provision of high-quality mobile multimedia services.[7]

We define Multi-Radio as the capability of a system to select and combine radio services out of a set of available services to fulfil the user service requirements. The selected set might consist in the simplest case of one radio service, offering as close as possible the required capabilities. In more advanced configurations, a combination of two or even more radio services is required at the same time to do the job. The decision criteria in the selection process are first of all the service requirements of a user, in terms of, e.g., throughput, delay and cost. However, also network load or other system parameters might be included. But for all these radio service combinations, spectrum is required to enable them.

Today, radio networks operate with fixed long-term spectrum allocations. Systems like the Global System for Mobile Communication (GSM) [7] are available all over the world in exclusively allocated spectrum. The same will hold true for the Universal Mobile Telecommunication System (UMTS) [6] when it will be introduced. However, the required spectrum varies both over the time and over the location. For example, in many regions there is more demand for mobile voice and data communication during business hours than during leisure time. The same relation is often seen between crowded business centers and sparsely populated areas. The actual required spectrum for a radio service changes with time and location. Therefore we

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[6] See also Section 7 for the acronyms.

[7] This work has been partially supported by a grant from the German Ministry for Research and Education (BMB+F) within the project “Communication and Mobility by Cellular Advanced Radio (COMCAR)” and by the European Commission within the IST project “Dynamic Radio for IP-Services in Vehicular Environments (DRiVE)”.

are investigating a dynamic allocation of spectrum to radio services instead of a fixed allocation as it takes place today [3]. Note that we refer to aggregated user requests when we talk about more demand for a service; individual requests can be demanding, of course, irrespective of time and location.

In this contribution we first summarise the requirements for a future system. We than describe the architecture and features of a Multi-Radio system in more detail and point to required more research. Mobility as a key feature in such a system is analysed in more depth in the following paragraph. Finally we present conclusions on the approach so far.

3.5.2 The Wireless Generation(s)

The upcoming 3G could be labelled the first real wireless generation as it enables all kinds of services and clearly dominates future network evolution activities on all levels with the adopted challenge to merge wireless and Internet. This attention is attracting now a lot of research which addresses issues beyond (or beside) 3G. As objective on Future Generation at this time it is assumed that it is of prime importance to

- highlight both evolutionary steps from 3G as well as new business opportunities with Future Generation
- Introduce a real mobile internet solution based on 3G
- focus research around future business opportunities

One of the major driving forces foreseen will be new service demands and the need to address more specifically different special environments like home, office, vehicular,…

3.5.2.1 Future Generation Business Idea

While the future business will evolve it will start with the ideas currently approaching the market. Partly future generation systems will be faced to deliver what initial 3G will not fully be able to do: provide cost effective bandwith to mobile users.

Providing seamless mobile Internet services accessing personalised information spaces and mobile-commerce

The future system will be based on the 2G and 3G spectrum allocations including the extension bands, integrating with broadcast services and the indoor wireless technologies. The main business idea is the same as for 3G with an increased focus on increased individualisation, content and commerce.

The death of distance, and low cost high bandwidth provisioning in the fixed network, will create expectations for the mobile service provisioning that will have to be faced. It will drive the need for mobile specific optimisation, with respect to bandwidth and content formatting.

Operators may based on their main asset – guaranteed access to regulated spectrum –complement their service offers by indoor and/or franchised access connected to their core service network.

The air interfaces will evolve leading to higher capacity, flexible allocation in any part of the assigned spectrum and the ability to efficiently handle asymmetric services. Primary access is based on Bluetooth, W-LAN etc and will be Always Best Connected to some infrastructure by WCDMA /EDGE/GSM/CDMA 2000 and fixed access.

Consistent mobility and security are strategic, and solutions must be offered at the link, transport and application levels, in a coordinated manner.

The same applications are expected to be available in all environments using intelligent application layer adaptation technology to cope with widely variable bitrates.

One of the major new approaches is the more flexible way of dealing with access to the regulated spectrum harmonised with the needs for broadcast services. This so called "Multi-Radio" system is described below.

3.5.3 Functionality and Architecture of a Multi-Radio System

Multi-Radio requires a system architecture that enables the selection and combination of radio services out of a set of available services to fulfil the requested service requirements of a user. Especially, the multi-radio architecture must provide means for simultaneous access via different radio systems. However, global and continuous coverage is not guaranteed: In contrast to today's cellular networks, the spectrum of some radio access networks is not allocated nation-wide or continent-wide. Moreover, availability and used spectrum is a matter of change.

The general multi-radio architecture is depicted in Figure 1. Each radio access network covers one region with a unique radio service. Location dependency could imply that RAN2-1, e.g., a UMTS Terrestrial Radio Access Network (UTRAN), operates in continent-wide allocated spectrum, whereas RAN1-1 and RAN2-2 cover only limited regions with a specific radio service. In one specific region, more than one radio service might be available; hence the coverage area of different RANs might overlap. Temporal dependency could imply that the radio service offered by RAN2-2 is not accessible at all times.

The dynamic multi-radio environment requires that the system announces which radio services are available and which spectrum they use. Because of the dynamic nature of this environment, the information content may change over the time and may vary in different regions, hence the system announcements must be regularly repeated. One useful generic means to provide this information is a Common Coordination Channel (CCC) [3]. The CCC is a logical channel. At least one system in each participating area must transmit the CCC. Preferably the system that is available in most regions should provide the CCC. It can provide information on available services, service capabilities, used spectrum, and traffic characteristics. However, the contents can depend on the involved systems, the actual location, and the time of day.

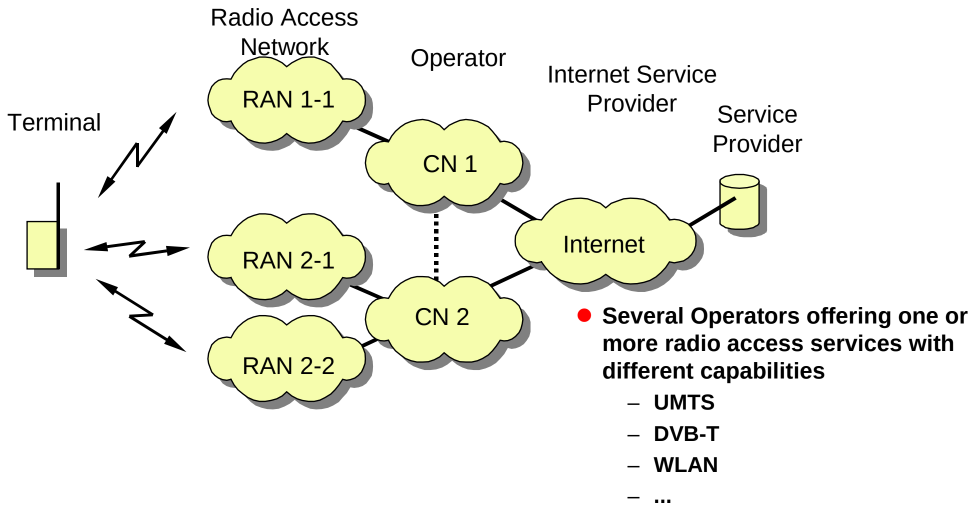

Figure 1: General multi-radio architecture

The regional dependent availability of radio services imposes high constraints on mobility. The availability of regional radio services must be announced to the mobile users, entering the coverage area. In addition to that, the sessions of individual users may not be interrupted or stopped while leaving the coverage area of such a radio access network (RAN). This means, that the architecture shall support some kind of continuity of service. For example, the traffic flows of leaving users can be redirected via other, still available radio access networks before the radio service becomes too bad for transmissions.

An efficient traffic control is needed to support simultaneous transmission via several RANs and to provide a certain quality of service. The traffic control is the entity that is responsible for directing the user's traffic via different RANs. Traffic control might exploit different control parameters, such as user preferences (e.g. minimal costs), terminal capabilities (e.g. display resolution), system capabilities (e.g. bandwidth, delay), the traffic and link status (e.g. network load), the application preferences and capabilities (e.g. min./max. /preferred bandwidth), and operator preferences (e.g. network utilization). The components of the traffic control are distributed over the entire system. The position of each traffic control component depends on the evaluated control parameter.

Additionally, the architecture must contain an entity that controls the Dynamic Spectrum Allocation (DSA) for the radio systems. The DSA entity can be centralized or multiple cooperating entities can be distributed over the system.

3.5.3.1 Definitions

Dynamic Spectrum Allocation (DSA) is responsible for the distribution of spectrum on the radio access networks (RANs), which might be negotiated beforehand between different spectrum owners, e.g., cellular and broadcast operators. The DSA functionality can be centralized in one entity or multiple cooperating entities can be distributed over the system. The final DSA output should be a carrier frequency for each transceiver; both new assignment of a new carrier frequency and activation/deactivation of a fixed assigned carrier frequency are possible.

Traffic Control (TC) is responsible for the distribution of Mobile Node traffic connections on the RANs. If this function is performed on the user service level, we call it User Level Traffic Control (UL-TC). If it is performed on the transport service level, we call it Transport Level Traffic Control (TL-TC).[8]

3.5.4 *Mobility in a Multi-Radio System*

The grade of mobility support varies between the different levels of multi-radio systems. In general, a hierarchy of mobility levels can be distinguished. Starting from mobility within one radio access network (intra-RAN-mobility), over mobility between radio access networks of one systems (inter RAN mobility or intra-system mobility, respectively) up to mobility between different systems (inter-system mobility).

Cellular systems offer usually intra-system and intra-RAN mobility, i.e., handling the mobility of terminals and users entering or leaving the coverage of the specific system and handover between radio access nodes. For example inter-system mobility between cellular systems can be implemented with Mobile IP [2]. In contrast to that, broadcast systems offer today no intra-system mobility support, because by definition all users receive anyway the same content and must select required content from that which is offered.

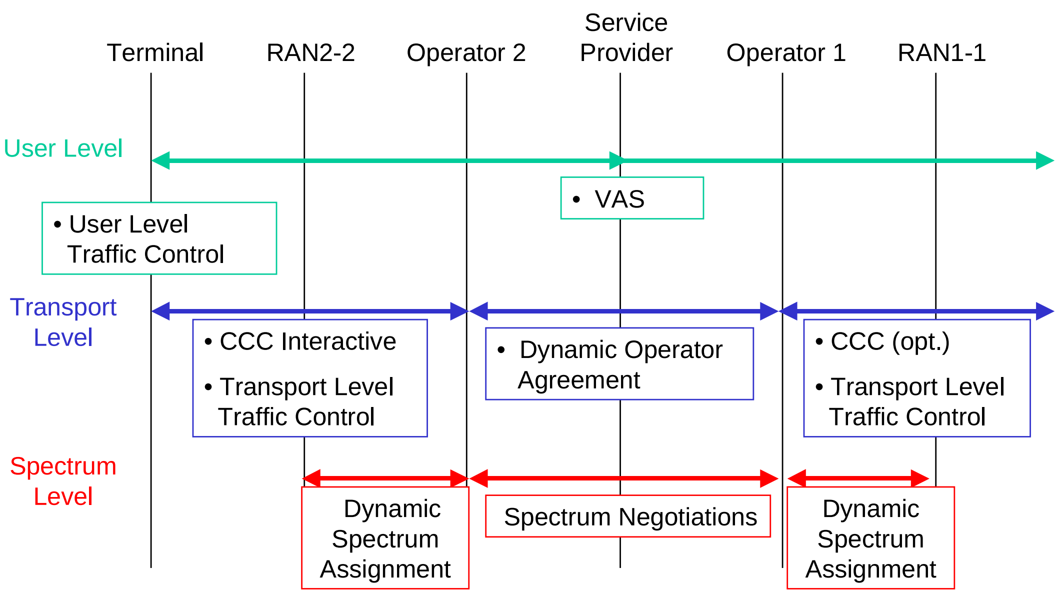

Figure 2 Interactions in Dynamic System Coordination

8 Note that in mobile networks usually two levels can be distinguished, which are named differently in existing architectures, but fulfill basically always the same tasks. One level provides transport service, including mobility and the other level provides "end-to-end" user service. Also similar in many architectures is, that IP is used on both levels. Examples for those architectures are UMTS as currently specified within ETSI and 3GPP, and Mobile IP, as developed within the IETF.

In statically coordinated systems, multi-radio mobility is implemented in an external node. This multi-radio service provider has to control the mobility functions on multi-radio level, i.e., all movement of terminals entering or leaving the coverage of one of the supported radio system. The intra-system mobility of the connected systems is unaffected.

From flexible coordinated systems on, all radio access networks should implement their own mobility management, preferably self-contained, i.e., with no direct support from an interconnection or core network. By this the coordinated system has to care only about mobility between radio access networks. In case the radio access network has no self-contained mobility management, then the core network has to implement the needed mobility functions. Already in flexible but latest in fully coordinated systems we see that the mobility support is seamlessly provided within a multi-radio system, i.e., movements of terminals and changes in the spectrum allocation require only adaptations to varying quality-of-service but do not lead to disruption of service provisioning.

3.5.5 Conclusion and Outlook

Cellular operators and especially UMTS operators will gain if spectrum for mobile multimedia communication services can be allocated more flexible or more dynamic. It can thereby be ensured that the mobile communications success story will not be hampered by a lack of suitable harmonised spectrum. In addition to that, the cooperation with broadcast systems can put additional load on the uplink of cellular networks, without limiting normal mobile services and hence revenues for cellular operators are increased.

Broadcast operators, in particular, are urgently looking for an answer to the question how interactive services can be enabled. These interactive services are recognized as the value-added service for broadcast networks that will ensure profitability on the long run. The combination of broadcast systems with a mobile return channel could enable new service models, especially if mobility is also taken into account in the broadcast system.

This co-operation enables new business models combining broadcast and mobile communication services for companies having both UMTS licenses and access to broadcast spectrum. Examples are Deutsche Telekom AG and France Telecom. Also agreements between friendly operators would support these new business models. Embracing these needs will offer successful new features for future generation systems and will require more research.

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3.6 Contribution by Ph. Charras, Ericsson

Access in an IP World, Local Policy Enforcement, unbundling of the Local Loop

Introduction:

Global roaming between dissimilar networks is today made difficult by virtue of the fact that three components need to be tied together in order that a service shall be executed. These are the Subscriber, The Operator, and the Access provider. Dissimilar networks often have dissimilar IP tunnelling protocols , for example Mobile IP and GPRS Tunneling protocol (GTP), dissimilar authentication and authorization mechanisms, dissimilar service definitions, and dissimilar ways of mapping QoS requirements on available access resources. One can conclude that there are a number of hurdles that need to be overcome before global roaming becomes feasible.

This contribution deals with the concept of Local Policy Enforcement of Authentication, Authorization and Accounting as a method to open up the access network and provide support for Global Roaming, and guarantee end to end security between the subscriber and service provider.

The full document is available under www.ist-wsi.org

3.7 Contribution by Pasi Kuvaja, Petri Pulli and Jouni Similä

PRODUCT FOCUSED SOFTWARE DEVELOPMENT PROCESS FOR MEDIA PHONE SERVICES

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Abstract

In this paper the principles and contents of a new product characteristics driven software development approach for media phone services is introduced. The paper outlines the shift from normal PCs to media phones that offers new platform for software use and how this trend will change the nature of the software development. The new approach is currently developed through experiments in a national Finnish R&D project called MONICA (Approach for MObile telecommuNICAtion's value-added service development in multi-provider environment). The approach contains new processes that cover the "playground" of many providers in competitive and partnership relationship with each other, supported with appropriate methodologies ensured techniques and tool environment. The approach was developed through an experimental approach in two case experiments aiming at commercial products both in company internal and public use.

3.8 Contribution by C. Bettstetter, Wolfgang Kellerer and Jörg Eberspächer

Personal Profile Mobility for Ubiquitous Service Usage

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Abstract

In this paper, we present personal profile mobility as an enabling concept for ubiquitous usage of customizable applications. Our proposal considers global access to profile servers, provided by IP-based wireless communication systems. It is not limited to telecommunications or IT applications. In fact, we illustrate our concept with scenarios in the automobile environment and discuss technical requirements as well as business aspects.

3.8.1 Introduction and motivation

The idea of service mobility is to give users access to services independent of the used network provider and terminal. For example, the VHE (Virtual Home Environment), which has been designed for UMTS, defines a distributed processing environment to enable worldwide access to personal wireless telecommunication services.

Service mobility also includes the functionality that users can utilize their personalized service settings (e.g. profiles for desktop layout, email address book, Web bookmarks, or calendar data) at different terminals and with various services.

In current solutions where service profiles are made available to various services, those profiles are usually stored locally, e.g. in the user's terminal (GSM SIM card, PDA, or personal computer). The profiles are then synchronized manually among the services (e.g. Palm-Netscape synchronization). There also exist solutions where profiles for specific services are stored centrally in the local network, but these solutions are focused on a particular network. General solutions spanning different networks, services, and terminals are missing.

As a result, today's users have many personal databases that contain the same information. For example, users store their telephone numbers in their cellular phone, SIM card, office phone, PDA, and in their Web browser's address book.

It would be much more convenient to have only one "personal profile" that is independent of the terminal and application. We call this feature "personal profile mobility," and consider it as a step toward ubiquitous service mobility. It should be possible to access one's personal profile anytime and anywhere, independent of the used network. Future wireless communication is the enabling technology for personal profile mobility.

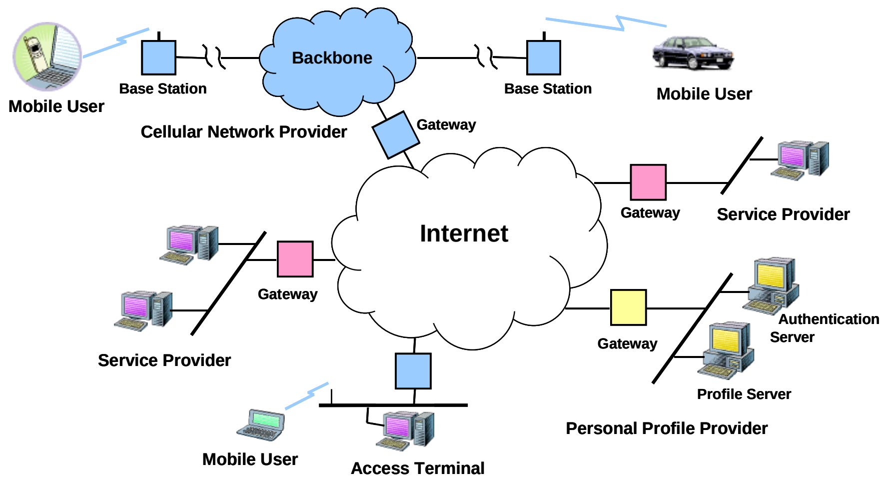

Figure 1: System architecture

3.8.2 System architecture

A system architecture for such a concept mainly consists of three instances (see Figure 1): The *mobile user* and his/her terminal, a *service/application* (which must be configured with certain user-specific profiles), and a central *profile server* (which stores these profiles). The communication paths between these instances are not defined statically, but wireless communications in combination with Internet access provides a suitable means for ubiquitous access to personal profiles.

3.8.3 Scenarios

In our opinion, personal profile mobility goes even further than just storing configuration settings of networked applications. Profiles could also specify stand-alone applications that are only connected to networks in an *ad hoc* fashion. In principle, profiles may contain any kind of settings that are useful for their owner. Profile mobility may then be utilized in all scenarios where the same person needs his/her personalized settings at different places and in different environments.

There are many straightforward examples for such scenarios, e.g. office applications. Here, we would like to briefly describe a scenario in a car environment. Profile mobility will be useful if one car is shared by different drivers, e.g. in car rental, car-sharing pools, and company fleets.

For example, a car rental company installs a profile server, where customers may store personal settings for the car environment. This could include settings for seats, steering wheel, mirrors, and air conditioning, as well as settings for communication devices inside the car (Web browser, navigation system, radio, phone). Before using a car, drivers may download these settings to the car for configuration. E.g., a customer may store his/her favorite radio stations on the profile server, and radios of different cars may download them on the user's request.

A system architecture for this scenario can be set up using existing network technology: Personal customer profiles are stored in a central LDAP server, which acts as authentication and profile server. The LDAP server is accessible worldwide through the Internet. Each car has a GSM/GPRS device installed, which is used for wireless communication with the customer and with the profile server. In order to rent a specific car, customers send a Short Message from their mobile GSM phone to the car's number. In addition to the message, which consists of a command and a personal password, the car will automatically receive the caller's number. This number can be used for identification of the driver. In order to check the customer's permission and to download his/her profile, the car then contacts the rental company's LDAP server by establishing a GPRS session. It downloads the driver's profile to the car and initiates the rental process.

3.8.4 Business aspects

Offering highly customized services will enable service providers to differentiate from competitors.

With the deployment of profile mobility, also the new role of a "profile provider" will come up. Such a provider would offer storage and maintenance of personal profiles and guarantee interoperability with various selected services/applications. It would create "profile templates" for specified applications, in which users could store their data.

Moreover, a combination with charging/billing providers in mobile e-commerce seems to be very interesting.

3.8.5 Required research and enhancements

Besides basic profile mobility functionality, the following requirements are of major importance: Security, authentication/authorization, high availability (time, location, and access method), easy access by various applications, and trustiness. In the scenario of Section 3, security can be achieved by using GSM-inherent ciphering, authorization, and authentication, and by using IPsec.

Possible enhancements of the concept could include the introduction of access scopes (e.g. public/restricted, office/private/both) and local caching and synchronization techniques. Creating mirrors of profile servers (e.g. inside UMTS core networks) could reduce network load.

Moreover, new wireless access technologies (e.g. Bluetooth) may be used for the user - application interface.

3.9 Contribution by M. Huemer, C.C.W. Ruppel, L. Reindl, A. Springer, R. Weigel

Single Carrier Transmission with Frequency Domain Equalization for Ultrabroadband Communication Systems

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C.C.W. Ruppel - Siemens AG, Corporate Technology, ZT MS1, Munich, Germany

L. Reindl - Institute of Electrical Information Technology, Technical University of Clausthal, Germany

3.9.1 Introduction

The spectacular growth of video, voice, and data communication over the internet, and the equally rapid pervasion of mobile telephony, justify great expectations for mobile multimedia. The demand for broadband wireless mobile communications and internet/multimedia communications is growing exponentially. Future mobile multimedia services will likely be based on high data rate wireless communication systems with channel bandwidths of some hundreds of Megahertz. These new generations of wireless systems put severe constraints on performance, cost, size, power and energy. The challenge is immense and research in different areas of wireless circuit and system design, e.g.

- high speed and high resolution A/D and D/A converters
- low power transceiver concepts and algorithms
- software defined radio
- systems on a chip
- low complexity and low power consuming receiver algorithms (e.g. for equalization)
- smart antennas

is required. A promising but compared to conventional techniques rarely investigated solution for ultrabroadband communication systems is the concept of single carrier transmission with frequency domain equalization (SC/FDE). This approach combines the properties of OFDM and single carrier transmission advantageously. Due to the use of single carrier modulation schemes the constraints on the transceiver’s analog components are relaxed compared to OFDM systems, and due to the use of FFT operations the receiver complexity is kept significantly below the complexity of conventional single carrier systems with time domain equalizer structures.

The equalization problem in high data rate communication systems - SC/FDE, a promising solution

One of the most challenging problems in high data rate wireless transmission is to overcome the time dispersion caused by multipath propagation. High data rate mobile radio channels in indoor or microcellular environment can exhibit large relative time dispersions, that is, intersymbol interference (ISI) smears each individual data symbol over several subsequent symbols. The solution to the ISI problem in single carrier systems is to design a receiver that employs a means for compensating or reducing the ISI in the received signal. The compensator for the ISI is called an equalizer. Different types of time domain equalizer structures, e.g. the MLSE (maximum likelihood sequence estimation) detector, the linear filter equalizer, and the DFE (decision feedback equalizer), have been extensively studied in the past. The common problem with all these equalizers is the fact, that the computational complexity grows at least quadratically with the bit rate. A completely different approach to overcome the problems of time dispersion is the use of OFDM (Orthogonal Frequency Division Multiplexing). In OFDM systems intersymbol interference is eliminated almost completely by introducing a guard time between consecutive symbols. Equalization reduces to simple multiplication operations in the frequency domain. The equalization complexity of the FFT based OFDM concept merely grows slightly faster than linear with the bit rate. Consequently, in terms of complexity, OFDM is more attractive than conventional single carrier systems, if the bandwidth-delay spread-product exceeds a certain value. This complexity argument was one of the crucial points to choose OFDM as the basis for the physical layer of the new high speed WLAN (Wireless Local Area Network) standards (Hiperlan/2, IEEE 802.11a) in the 5 GHz band.

The SC/FDE concept highlights similar low complexity properties as OFDM. SC/FDE shows strong analogies to OFDM systems, where equalization is also performed in the frequency domain. Similar to OFDM, SC/FDE systems make use of efficient FFT operations, the transmission is carried out blockwise, and a cyclic extension (guard interval) is added on the individual blocks in order to mitigate interblock interference. Due to the use of efficient FFT algorithms the digital signal processing complexity of SC/FDE systems is comparable to the complexity of OFDM systems , while sensitivity to carrier frequency offsets and phase noise, and nonlinear distortion problems inherent to OFDM can largely be alleviated.

The main features of SC/FDE are as follows:

- Different modulation schemes can be used (e.g. QPSK, π/4-DQPSK, higher order QAM or PSK, MSK). The use of constant envelope modulation schemes allows for non-linear distortions, therefore power efficient amplifiers can be used.
- Equalization complexity is about twice that of OFDM (equalization in SC/FDE is performed by FFT, multiplication, and IFFT operations).
- In contrast to OFDM no FFT is needed at the transmitter, simple Nyquist (e.g. root raised cosine) filtering can be applied.
- Pilot aided channel estimation can be performed in the frequency domain similar to OFDM, therefore no large header for convergence of adaptive equalizer training techniques is needed as is the case for most time domain equalizer concepts.

- The frequency domain equalizer corresponds to a time domain equalizer with an infinite number of taps, so
  - the question of optimum equalizer length is no longer a subject,
  - the FDE can cope with any degree of intersymbol interference as long as interblock interference is kept to a minumum by the guard interval .
- Delay spread resistance is similar to OFDM.
- The influence of clock phase and carrier phase is compensated for by channel estimation/equalization similar to OFDM, no fine tuning of phase and sampling time is necessary. Furthermore, only a coarse timing synchronization is needed to optimize the temporal position of the FFT-window.
- Compared to OFDM the concept is less sensitive to carrier frequency offsets and phase noise.
- The concept can easily be extended for antenna space diversity.

3.9.2 Required research

To optimize broadband communication systems based on SC/FDE techniques, additional research among other things (see above) is required on the following topics:

- Fast and power efficient FFT hardware implementations
- Fast and bandwidth efficient synchronization algorithms for SC/FDE systems
- Optimum coding for SC/FDE systems
- Multiple access techniques for SC/FDE systems

3.10 2nd Contribution by Lie-Lian Yang and Lajos Hanzo

Intelligent frequency-hopped multi-carrier schemes for 4th-generation wireless systems

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Introduction

With the substantial increase of Internet users and with the development of new services high-speed access in the future generations of wireless systems is an important requirement. Consequently, broadband systems with bandwidths significantly wider than that of the 3rd-generation systems are sought for meeting future requirements. Hence, compatibility with both the emerging Broadband Access Networks (BRAN), which have opted for a multi-carrier, Orthogonal Frequency Division Multiplexing (OFDM) based solution and the existing 2nd- and 3rd-generation CDMA systems is an important consideration. Furthermore, with the deployment of the 3rd generation mobile communication systems, which can provide a wider variety of services with higher QoS than the 2nd generation systems users will move from the 2nd generation's band to the 3rd generation's band. Consequently, the bandwidth assigned for wireless mobile communications cannot be evenly and efficiently exploited, unless new multiple access schemes are employed.

A potential candidate multiple access scheme meeting these requirements has been proposed and investigated. The multiple-access scheme is constituted by frequency-hopping (FH) based multi-carrier DS-CDMA (FH/MC DS-CDMA), where the entire bandwidth of future systems can be divided into a number of sub-bands and each sub-band can be assigned a sub-carrier. A substantial advantage of FH/MC DS-CDMA systems is that they constitute software re-configurable schemes. According to the prevalent service requirements, the set of legitimate sub-carriers can be distributed in line with the instantaneous information rate requirements. FH techniques are employed for each user, in order to evenly occupy the whole system bandwidth and to efficiently utilise the available frequency resources. Specifically, slow FH, fast FH or adaptive FH techniques can be utilised depending on the system's design and the state-of-the-art. In FH/MC DS-CDMA systems the sub-bands are not required to be of equal bandwidth. A sub-carrier could deliver a narrow-band IS-95 type service or - similarly to the emerging multi-carrier assisted cdma2000 system [5] - it could invoke a number of carriers, while employing a variety of different spreading factors. Hence existing 2nd- and 3rd-generation CDMA systems can be supported using one or more sub-carriers, consequently simplifying the frequency resource management and efficiently utilising the entire bandwidth available. This regime can also remove the inefficient spectrum segmentation of existing `legacy' systems in to a number of band dedicated to different operators and/or standard systems, while ensuring compatibility with future BRAN and un-licensed systems. Furthermore, a number of sub-channels with variable processing gains can be employed, in order to support various services requiring low- to very high-rate transmissions, for example for wireless Internet access.

The full document may be reached through the web-site www.ist-wsi.

3.11 Contribution by Raúl Bruzzone

A Vision of Mobile Communications

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3.11.1 Summary

This paper intends to contribute some initial elements for discussion on a long term Vision of Mobile Communications.

Two parallel approaches are followed:

- A Top-Down analysis, trying to identify potential applications, that might be translated into 3G+/4G Service Requirements

- A Down-Top approach, highlighting possible research challenges that may become realistic within the terms of technology development in the 2000-2012 time frame

3.11.2 Top-Down Approach: Advanced Applications

A future system will allow the applications designer to implement concepts not originally foreseen by the research scientist who defined the basic toolbox. This is the so-called paradigm of Open Architectures.

How can be possible to achieve this objective?

A possible way forward is to expose the research community with highly demanding challenges that would be fulfilled by the future system. If the system is able to support those demands, the range of to-be-discovered applications will be enlarged.

To substantiate this approach, four target applications have been selected:

- The Virtual Assistant
- Advanced Video Conference
- Historical Register
- Augmented Reality

These applications are described in the sequel.

3.11.2.1 The Virtual Assistant

A distinctive characteristic of human beings is the capacity to act on the basis of past and current experiences. This is what we called our *decision capability*.

After the press invention by Güttenberg, decisions may be taken not only on the basis of own experience, but also taking advantage of what other people have discovered and registered in written form.

Databases available at the World Wide Web have significantly increased the know how available to anybody having a networked computer. In general, if more information is available, better decisions *might* be taken. Unfortunately, human processing capacity is limited, and so is time for that. Computer can help in the decision process if a user friendly interface is provided.

It is suggested that, in the long term, a computer-powered being with the aspect and communication duties of a human being will share all-day situations with each one of us. Let this artificial companion be called *Virtual Assistant*.

Virtual persons, whose precedent may be found today in Microsoft Applications Help, will have a human aspect[9].

It will communicate with the user through different means:

- Voice: speaking and listening to the user through dissimulated headphones and microphones.

- Image: superimposing its image to the environment seen by the user. For that purpose, special glasses[10] or retinal devices[11] might be used.

The Virtual Assistant will be preferably supported locally, using resources available at a portable computing device. This hardware platform will have wireless communication capabilities, enabling the virtual assistant to retrieve information from Internet databases whenever required.

What applications may be the Virtual Assistant used for ?

The user may be interested to be guided in a new street, shopping mall or airport, in order to reach his or her final destination. The Personal Communicator will detect user's position and heading[12], and using geo-referenced information retrieved from Internet, a path will be planned. The information might be provided by means of voice or superposing images (e.g. arrows) on his normal vision.

Depending on the emotional status of its human companion, the virtual assistant would select different interface types: e.g. voice-only with reassuring tone, video-image leading his way, etc.

The Virtual Assistant will also learn about the habits of its owner. How many times have you gone to the grocery store but left the grocery list on the fridge door? Wouldn't it make more sense to get a reminder to buy groceries when in the geographic proximity of the store and have the list delivered to you there[13]? An application may exploit location, a main feature of mobility, to provide context-aware

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[9] Kismet: A Robot for Social Interactions with Humans. See: http://www.ai.mit.edu/projects/kismet/
[10] http://www.wearcam.org
[11] htt!p://www.mvis.com/
[12] See, for example, the RADAR research project at http://research.microsoft.com/~bahl/MS_Projects/projects.html#radar

[13] ComMotion: a context-aware communication system (MIT Media Lab Research project). See: http://www.media.mit.edu/~nmarmas/comMotion.html

messaging for mobile users. A behaviour-learning software agent determines the salient locations in the users life, and analyses patterns of mobility.

From a hardware viewpoint, virtual assistants will require the best balance between data rate of the radio interface, and computing capacity at the personal platform. Selection of these two basic requirements will mainly depend on how many Gips (giga-instructions per second) might be affordable in the latter at the horizon 2012. See more on this aspect in the second part of this paper (the Down-Top approach).

3.11.2.2 Advanced Video Conference

As higher data throughput at the radio interface might be available, videoconference might be increasingly used due to the following reasons:

- Face to face contact allows emotional contact not attainable through voice or text-only. This kind of communication would be especially important in the family environment.

- Virtual assistants will probably not reach in the 2010-2020 time frame all the advice capacities of human counterparts. In this sense, many decisions will benefit from the real-time participation of other people.

In the case of videoconference with one or more people, their tri-dimensional images might be conveniently superimposed with an actual image. In order to recreate image changes at the other party (for example, when the user moves his head) a tri-dimensional model of the remote party should be stored in the Personal Platform[14]. This synthetic image will be animated using information extracted by pattern-recognition from the other side. This procedure will also allow conceal eventual virtual-reality glasses used by each party, rendering the natural face.

3.11.2.3 Historical Register

The Personal Platform will store a register of sound, video and digital information exchanged during the user's life.

This memory capability might be used, for example, it could refresh about face and name of people met in a previous time.

A smart database system would help the user to retrieve information (i.e. *help-me-to-remember* service). A 360-degrees coverage video recording capability would probably be required.

One month memory could be done locally, and older information might be stored in the user's server located somewhere in the net.

[14] Parameter-based facial animation and 3D face models synthesis is described in the following sites:
http://www.research.att.com/~osberman/AnimatedHead/
http://www.eurecom.fr

3.11.2.4 Augmented Reality: Navigating in Realspace + Cyberspace

Human senses (we are here basically addressing vision and hearing) are the result of at least one billion of genetic evolution. Many properties of Nature have been applied, but one is missing: radio in the GHz /THz range. Mainly thanks to Maxwell, Hertz and Marconi, we are using this possibility since a century ago to communicate voice, sound, video and data. It is suggested that 4G would enable to convert radio in the support of new senses. Today, it may be possible that we don't find a place to park our car, while there is room some meters away right turning the corner. Traffic cameras may also be taking a picture of that place, but we cannot benefit from this information.

In the future, present webcams that show traffic in highways and avenues will be generalised. Moreover, technical information required e.g. to assemble furniture kits will be available on-line using VRML format.

The set of real-time images and synthetic objects available in the net might be taken as the definition of Cyberspace.

It will take several decades15, probably much more than 4G life, in order that Cyberspace become an alternative to what can be captured and acted upon by means of human senses (what we could call Realspace).

In the meantime, Cyberspace will be increasingly superimposed onto Realspace.

For example, an e-mail would be overlaid to the actual image of a desk, giving the impression that it is really over there.

A possible Service Capability paradigm for 4G might be stated as:

"4G will be the wireless technology enabling the user, in an un-obstrusive way, to be present in Cyberspace, which will be superimposed to Realspace".

3.11.3 Down-Top Approach: Evolution of Wireless Communication

For 3G, the paradigm has been: "To provide multimedia wireless communications anywhere, anytime"

This objective will probably be achieved by means of IMT-2000. However, if only cellular networks are used, the cost will be too high for widespread consumer applications. For example, with medium-term technology, a 2 Mbps connection will exhaust most of the radio resources available to a base station.

Taking into account the high cost of radio spectrum, medium and long term solutions are suggested:

3.11.3.1 Medium Term (3G+)

- Objective: to increase spectrum efficiency and traffic capacity

[15] The Age of Spiritual Machines. Ray Kurzweil. Viking Penguin Ed.

- Technologies in the Mobile Station:
- Interference Cancellation
- Joint Source/Channel Coding
- More efficient (higher compression) source coding
- Internetworking capability (e.g. UMTS/HiperlanII/Bluetooth)
- Exploit UMTS-TDD for Internet access, wherever possible (due to TDD's higher spectral efficiency in asymmetric applications)

3.11.3.2 Long Term: Mobile Communications in 2012 (4G)

- Home and office access will be provided by fixed networks (e.g. copper local loop, TV coaxial cable, fibre-to-the-curb, fibre-to-the-home). The fact that no radio spectrum is required for corded access will always make this method less expensive (for the same data rate) than a wireless counterpart.
- Corded access will continue to provide higher data rates than wireless.
- Generalisation of Voice/Video-over-IP will make that the cost of an international call will be basically the same of a local call.
- Switching core networks will be based in packet (datagram) technology (i.e. routers will replace switching exchanges)
- Flat tariffs will be charged to wired and wireless best-effort (i.e. all-time-on) services.

3.11.4 A paradigm for 4G networks

3.11.4.1 Core Network Evolution

Today: two superimposed networks, one for 64 kbps circuit switching, and other for packet switching.

Tomorrow: a single packet switching network[16]

3.11.4.2 Wireless Access Network Evolution

Today: 2G circuit + 2G packet

In 2002: 2G circuit + 2G packet + 3G circuit/packet + WLAN; personal cells (10 m radius)

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[16] An overview of UCSD's Center for Wireless Communications - A. Acampora – IEEE Personal Communications Vol. 6 No. 5 October 1999

Tomorrow: pico-cells (approx. 100-m radius) will take most of the traffic. Lamp post miniaturised base stations will cover most outdoors traffic. Home Gateways (probably evolving from set-top boxes) will cover the indoors, home environment.

3.11.5 Some of the Unknowns

How much computing capacity might be deployed, in the long term, in a Personal Platform?

Would it be enough to locally support advanced applications (like virtual assistants) or this entity will be (partly ?) located at a personal server in the fixed WWW ?

If the radio interface will be mainly associated with line-of-sight communication, what is the most spectrum efficient modulation scheme?

If computing capacity slows down with reference to Moore's law, should it be possible to implement high radio data rates (e.g. 1 Gbps) in a consumer platform ?

3.11.6 Conclusions

- Mobile communications will dramatically evolve in the next decades, becoming the link used by human and artificial beings in order to dialog between them.

- The current Mobile Telephone will evolve into a personal hardware platform supporting both local processes (e.g. virtual assistants) and wireless communication.

- Pico-cells will be required to provide ultra-high data rates, privileging line-of-sight radio communication as the tetherless mechanism.

Finally, 4G technology should be sufficiently flexible to facilitate inexpensive communication to the five out of six people in the world that today are still waiting for the opportunity to make his or her first (wired or wireless) telephone call.

3.12 Contribution by Helmut Boelcskei and Arogyaswami Paulraj

Title: Mobile Multi-Antenna Wireless Systems

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3.12.1 Description

Future mobile wireless applications will require significantly higher data rates and higher quality than 3G. Such requirements on data rate, link quality, and mobility are hard to meet with conventional single-antenna systems. Multi-antenna (MIMO) systems (i.e. multiple antennas at both ends of the wireless link) offer much greater promise. In particular, multiple antennas can be used to increase data rate through a technique called spatial multiplexing [1,2], and to improve link quality through diversity [3]. Current research efforts focus on idealistic channel models which do not properly describe real-world channels. In fact, the ability to employ spatial multiplexing and diversity techniques strongly depends on the properties of the MIMO mobile channel. Extensive fixed MIMO channel measurements are currently being carried out by the Smart Antennas Research Group at Stanford University. The group has also developed a MIMO wireless testbed which operates in the 900 MHz band and has fully flexible modulation, coding, and diversity provisions.

Extensive mobile MIMO channel measurements are the basis for the development of mobile MIMO physical layer and higher layer algorithms. Furthermore, the development of mobile MIMO channel models which accurately describe real-world channels is proposed. These developments will be based on previous research conducted by the Smart Antennas Research Group [4,5]. Finally, the measurement results will be used to extract model parameters and to devise standardized mobile MIMO channel models. Besides being able to develop standardized channel models, our research shall consider the following aspects of mobile MIMO channels:

- Use of polarization diversity and its impact on spatial multiplexing and diversity techniques. This issue is of great practical importance, especially in mobile MIMO systems since antenna spacing requirements in the terminal advocate the use of polarization diversity.

- Influence of antenna spacing at the transmitter and the receiver on multiplexing and diversity.

- Influence of mobility on the performance of MIMO algorithms.

- Ability of real-world mobile MIMO channels to support multiplexing and diversity.

- Optimum choice of signaling technique for given channel characteristics.

We expect the outcome of our research to serve as a basis for making a decision on whether the use of MIMO techniques in next generation wireless links is feasible and what the performance-cost tradeoff would be.

3.12.2 Timeframe

We expect this research to be carried out by June 2001.

3.12.3 References

[1] A. J. Paulraj and T. Kailath, “Increasing capacity in wireless broadcast systems using distributed transmission/directional reception," U. S. Patent, no. 5,345,599, 1994.

[2] G. J. Foschini, “Layered space-time architecture for wireless communication in a fading environment when using multi-element antennas," Bell Labs Tech. J., Autumn 1996, pp. 41-59.

[3] V. Tarokh, N. Seshadri, and A. R. Calderbank, “Space-time codes for high data rate wireless communication: Performance criterion and code construction," IEEE Transactions on Information Theory, vol. 44, no. 2, March 1998, pp. 744-765.

[4] H. Boelcskei, D. Gesbert, and A. J. Paulraj, “On the capacity of wireless systems employing OFDM-based spatial multiplexing," submitted to IEEE Trans. Communications, Oct. 1999.

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3.13 Contribution by M. Teughels, J. Theunis, E. Van Lil, A. Van de Capelle

Wireless Socket: Convergence Beyond Third Generation

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Abstract

The Systems beyond the Third Generation will offer a mobile access to the future broadband converged backbone network. A broad range of access systems will be offered to the subscriber to answer a variety of user requirements. Hence different access systems have to be integrated with the backbone network, from which the architecture is an open issue. Up to now, tremendous effort has been spent discussing this future network architecture, whether it is to be connection-oriented, connectionless or something in between. The defacto network architecture today is IP, and therefore connectionless. Future applications, especially mobile services, urge a higher degree of connection regognition by the network. To short-cut this discussion the Wireless Socket is proposed: different network architectures can be invoked by the applications directly, whithout tunneling or stacking of one network protocol over the other, or whithout the introduction of a new protocol family. The default TCP-IP application interface is maintained and therefore off-the-shelf network applications can be used. To address different network architectures, the Wireless Socket is open to the whatever transport and network layer protocol: fixed IP, Wireless-Mobile IP, ATM, Wireless Mobile ATM, GSM, GPRS, UMTS, etc. can all be addressed. A demonstrator setup, replacing the network architecture while maintaining all office network applications (NFS, SMTP, FTP, HTTP, H.323, etc.) with the original software packages is currently under development.

Network convergence

With the hype on Network Convergence many evolutions in telecommunication networks is covered: the border between fixed and mobile networks as well as between voice and data networks is blurring, driven by the applications as these do not respect a separation between networks. The target is a network where from whatever access infrastructure and whatever terminal the user can access its application, if required with an adapted user interface.

Today the different networks are interconnected, but not integrated. The data network is based on IP, offering a best effort connectionless service. The voice network is a POTS or ISDN network, with a 64 kbit/s connection oriented architecture. Second generation wireless networks (like GSM) offer a connection-oriented constant bandwidth service. The data extension to these networks (like GPRS) offer a connection-oriented best-effort datagram service: a connection is established and data is transmitted along that connection. Third generation networks intend to integrate with the fixed data network, and therefore connectionless best effort IP service is put forward as a target network architecture.

However the fixed broadband network evolves as well. It is therefore hard to define today with what network architecture the Systems Beyond the Third Generation will converge in the future. Even more the extension of the network architecture from the fixed backbone to the wireless mobile access network may not be ideal, as mobile networks have a stronger tendency towards connection oriented architectures than fixed networks have at present: -First of all the mobility control, especially the hand-over can easily be performed on a connection oriented network, but is not as easy for a connectionless service, as the network has no knowledge on the data streams to be rerouted. -Secondly the hughe bandwidth availability of the backbone is not present in a wireless access infrastructure. With the prices paid for licenses for third generation systems, the billing by the network operator has an influence on the choice of the network architecture. As billing is much simplified in a connection-oriented network, where the network has the knowledge on the delivered services, a minimal of connection recognition can be usefull. -Finally the drive for the Systems Beyond Third Generation is supposed to come from interactive high-bandwidth applications. As these challenge the network infrastructure with large data transfers network architectures recognising such flows are currently under study, as an evolution of IP like MPLS, or from ISDN like with ATM.

Wireless Socket

Hence there has been a lot of confusion on the different kinds of network infrastructures. It is however unlikely that applications have to be developed dedicated to one network architecture. This is why the Wireless Socket is proposed. It is compatible with all existing TCP-UDP network applications, as the interface between the socket and the applications is maintained. The socket itself has a dedicated part towards the different network architectures. Hence the applications can be served from whatever network infrastructure with the appropriate Wireless Socket.

To demonstrate the feasability of this mapping of IP based applications on a connection oriented network, an ATM socket is currently under development in the Telemic research lab. As ATM is the opposite of IP on the discussion on network architectures, a great deal can be learned from the operation of classical network applications this way. The ATM Socket can subsequently be extended to wireless access systems. With the introduction of adaptability, a true Wireless Socket is finally obtained: the socket is then able to select the appropriate access system and the total network infrastructure is presented to the user as a converged and integrated system.

Required research

Year 1	Year 2	Year 3	Year 4
ATM Socket, Initial Development	Architecture evaluation (CO-CL)	Wireless access integration	Adaptability, functionality Evaluation

3.14 Contribution by David M. Shotton

VIDOS, a system for video editing and format conversion over the Web

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VIDOS is a new prototype ***vi****deo* ***do****wnload* ***s****pecification* system developed to meet the need for convenient, flexible and user-friendly digital video editing over the Internet or local intranets [1-3]. In line with the growing trend away from mass consumption of standardized media items, and towards the selective personalized use of customizable data resources, *VIDOS* permits the user to edit and customize a personal version of any digital video available anywhere on the Web, including videos stored on the user's own Web server or in a *VIDOS*-enabled video database/archive.

Using *VIDOS*, the user can select an area and time period of interest, specify the zoom factor, the frame rate and the video format, and choose the nature and quality of digital compression to be applied, before downloading the customized video. The *VIDOS* system uses standard client-server protocols to provide a powerful and user-friendly environment in which these things are possible. The *VIDOS* client interfaces utilize platform-independent Java applets that runs in a Web browser environment, by which the user can select a video and specify the parameters to be used in preparing the customized version of it. These customization parameters are then passed to the main *VIDOS* program running on the distant *VIDOS* server. Also written in Java, this program utilizes standard software libraries and utilities to produce the desired edited and personalized version of the video, which can then be downloaded to the user.

This makes it possible to adapt the video to suit the user's preferences or the intended end use of the video, or to match the video playback software that is available. By permitting the creation of an edited and highly compressed video file, VIDOS has the potential to speed the downloading of the customized version of a video. Despite continuing overall improvements in Internet bandwidth, many people remain connected to the Web by modems of only moderate speed. In such circumstances, by enabling the size of digital video files to be reduced, VIDOS has the potential to improve personal and institutional efficiency by reducing bandwidth requirements, speeding network transfers and cutting disc storage requirements. For similar reasons, VIDOS may also be of importance for users of future video-enabled mobile wireless devices. Since all the numerically intensive computations are performed on the VIDOS server, this is all achievable without the need for the user to upgrade to install costly video editing software, empowering him or her to undertake sophisticated spatial and temporal video editing, and video format and compression conversion that would otherwise be impossible to achieve.

With the enormous projected growth of digital video traffic on intranets and on the Internet for personal, business, educational, governmental, scientific and home entertainment purposes, we anticipate that *VIDOS* systems will prove to be of significant usefulness for the editing and format conversion of videos from a wide variety of sources, with the potential to speed up transfers and substantially reduce the volume of digital video data to be moved and locally stored, while enabling the videos themselves to be adapted to suit their intended end uses.

VIDOS is patent pending technology [4, 5] owned by Isis Innovation Ltd, the intellectual property company of the University of Oxford (http://www.isisinnovation.com). We are continuing to develop the capabilities of the *VIDOS* system beyond those of the prototype system described above, and have funding to make *VIDOS* widely available to the UK and US academic community in the near future. At present we are seeking suitable partners and corporate users to launch *VIDOS* services for the European and Asian academic communities, for private intranets and general Internet use, and to adapt it for mobile wireless systems. We welcome enquiries from interested parties.

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