Advanced services over future wireless and mobile networks in the framework of the MIND project

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Abstract

Future wireless and mobile networks following the "always-on" approach require new functionalities and protocols both at the network and the application layers that make them a very challenging research topic. In such networks, new requirements like micro-mobility protocols, vertical handover support, adaptive applications and advanced QoS mechanisms come up. During the MIND project a testbed of such a network is being implemented to show how the integration of these concepts allows to offer advanced services in an efficient way.

Keywords: MIND, QoS, micro-mobility

1. Introduction

The MIND (Mobile IP based Network Developments; www.ist-mind.org) project is partially funded by the European Commission in the frame of the IST Program and brings together major players in the mobile domain working on a vision of "systems beyond 3G". The project partners of MIND are drawn from 3 key areas:

- Manufacturers: Ericsson Radio Systems AB (Sweden), Nokia Corporation (Finland), Siemens AG (Germany), Sony International (Europe) GmbH (Germany) and Infineon Technologies (Germany).
- Network operators: British Telecommunications plc (UK), France Telecom – R&D (France), NTT DoCoMo, Inc. (Japan) and T-Systems Nova GmbH (Germany).
- SME, research and academia domain: Agora Systems S.A. (Spain), Universidad Politécnica de Madrid (Spain) and King's College London (UK).

The overall aim of MIND is to facilitate the rapid creation of broadband multimedia services and applications that are fully supported and customized when accessed by future mobile users from a wide range of wireless access technologies. MIND is a follow up of the IST project BRAIN (Broadband Radio Access for IP based Networks).

The technical approach of MIND takes as a starting point the concept of an IP core, accessed by a variety of technologies. Research is conducted in the areas of services and applications, the access network architecture and the air interface. The project follows a top down approach. First, the scenarios that need to be supported by future wireless networks are detailed. Then, from these the requirements on the network and air interface are derived and potential solutions studied.

The project investigates new business models for "systems beyond 3G" mapping the value chain into the functional entities required for rapid and flexible multimedia service creation and support. Suitable mechanisms for authentication, security and accounting over novel network topologies are considered. These new topologies include ad hoc and self-organizing networks connected to a fixed full IP-based radio access network. The work done within the predecessor project BRAIN to provide micro-mobility and QoS in the radio access network will be extended and completed to support these new topologies during the course of MIND.

MIND is intended to complement other access systems (e.g., UMTS). To this avail, vertical handover (handover between different access technologies) is studied and multi-homing terminal concepts are analysed.

The MIND access network allows the connection of a generic radio interface to an IP core network. A layer 2-3 interface has been defined to hide the radio technology specific elements to the higher layers and yet provide them with the necessary information for an efficient management of mobility and QoS. The project centers its air interface investigations on HIPERLAN/2 as a technology for providing coverage to hot spot areas. Solutions for dynamic frequency and resource allocation mechanisms for supporting ad hoc and self-configuring networks are dealt with. A service specific convergence layer for IP for HIPERLAN/2 has already been specified. Proposals for extending range and supported velocities from HIPERLAN/2 are studied as well. The MIND network architecture is shown in Figure 1.

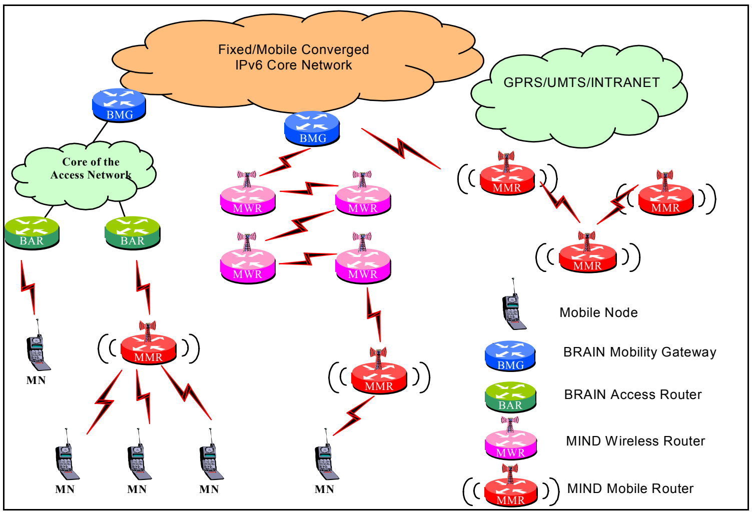

Figure 1. The MIND reference network architecture

Besides the conceptual work detailed above, the project is conducting trials on key concepts studied in the predecessor project BRAIN. Actually, the MIND demonstrations will implement selected key concepts of the architecture defined in the BRAIN project. The aim of these trials is to investigate the following issues:

- To integrate a trial environment including systems such as WLAN, UTRA and IPv6 based core network test beds.
- To validate and evaluate basic functions and protocols specified by BRAIN: vertical (at IP layer) and horizontal handover mechanisms and QoS related aspects.
- To show some key mobile applications and service aspects selected from the scenarios developed in the BRAIN project.

These activities are reported in this paper, which is organised as follows: section 2 describes the new problems that come up when dealing with wireless mobile networks. Section 3 comments on the network and application layer developments and tests to be performed. Finally section 4 presents some conclusions and future work.

2. Issues in wireless mobile networks

One of the main issues in mobile networks is the handover. Handover is the process that occurs when a terminal changes the radio station through which it is communicating. Without special mechanisms to assist this process, this could lead to a terminal needing to change its IP address, which would automatically cause any sessions to terminate. Even if this problem could be avoided, packets could be lost or severely delayed as they tried to reach the new location. And, if these problems are not enough, other users served by the same access point might be upset that a large WWW download is now causing congestion on their low capacity link. That is why some new protocols like MobileIP[12] and MobileIPv6[13] have been engineered for dealing with mobile nodes. However, as MobileIP does not offer a very good handover performance, some micro-mobility protocols like Cellular-IP[14], Hawaii[15], HMIP[16] and BCMP[17] have been engineered. These protocols are thought of as a means for a mobile node changing its point of attachment to the access network to achieve better handover performance. The micro-mobility protocol is in charge of updating the access network topology so that the mobile node does not need to change its IP address and thus all its sessions are able to continue established. In addition, context transfer techniques between access routers allow the node to maintain its QoS guarantees, multicast group memberships and so on.

There are two types of handover. Horizontal handover occurs when the node moves between transmitters of the same physical type (as in a 802.11 network today). Vertical handover occurs when a node moves onto a new type of network - for example between 802.11 and Bluetooth, GPRS or UMTS. The later typically requires additional authorization procedures, and issues such as quality of service become more complicated. For example, suppose a video-conference session on a broadband wireless network suddenly moved to a GSM network. Thus, an special end terminal architecture with media adaptation capabilities as well as end to end QoS negotiation and signalling mechanisms (using SIP for example) will help us to overcome such big changes in the available bandwidth.

Wireless offers a number of new problems to those of fixed network communications. Wireless terminals have power restrictions as a result of battery operation. This battery power is quickly drained by communications with the network. These terminals often have reduced display capabilities compared to their fixed network counterparts. Wireless networks tend to have more jitter, more delay, less bandwidth and higher error rates compared to wired networks. These features may change randomly, for example as a result of vehicular traffic or atmospheric disturbance. They may also change when the terminal moves and handover occurs. Many of the assumptions that lie behind fixed network protocols and operation are not valid in the mobile world. For example, TCP assumes that all packet loss is a result of network congestion, and so, if packet loss is detected it reduces its transmission rate to a rate that can be supported by the network. However, if the packet loss is caused by transmission errors, this behaviour will simply result in a reduced throughput, with no gain by the network. Because the losses are so large, it is generally accepted [10] that wireless networks will need to provide link layer error control – the internet usually assumes that error correction can be left to the end terminals.

3. Advanced network and application capabilities

3.1 IPv6

IPv6 is characterised by the availability of an enormous amount of IP addresses, improved network layer security, efficient mobility mechanisms, better QoS support, autoconfiguration, etc. These properties make IPv6 an important tool for future wireless mobile networks based on the "all-IP" concept.

In future wireless mobile networks, the number of terminals connected to the network is expected to increase a lot. In this kind of networks, not only workstations and laptops are allowed to connect but also PDAs, mobile phones and many other devices able to communicate through wireless links. Thus, the use of IPv6 as the network layer protocol becomes a must.

In addition, these networks will implement the "always on" model. That is, the nodes will be always connected by means of performing handovers between different access networks as the mobile nodes move from one place to another. Thus, the use of the improved mobility mechanisms that IPv6 incorporates is also very important in these networks.

When a node moves from one network to another, it is important to have mechanisms allowing the network to authenticate it before granting IP connectivity. In addition, it is also very important for the node not to require user configuration every time the node changes the access network it is attached to. Therefore, the security and autoconfiguration features of IPv6 stress the need of IPv6 as the network layer protocol for future wireless mobile networks.

All the above mentioned characteristics and the new and improved QoS mechanisms provided by IPv6 have made us think of IPv6 as the base network layer protocol to be used in our test-beds.

3.2 Vertical Handover

Another important issue that is going to be demonstrated during the MIND trials is the vertical handover. That is, handover between different technologies. Special emphasis is going to be put on WLAN-UMTS handovers. There are different kind of vertical handovers:

- No coupling approach. In this case, the involved networks are independent and may belong to different operators. When a node has no longer WLAN connectivity it connects to the network using UMTS. Different IP addresses are allocated, different AAA policies are used in both networks, new QoS reservation are needed, etc.
- Loose coupling approach. In this approach, the operators of both networks could still not be the same. However, some properties like the AAA databases and policies could be shared, and thus maintained during the handover process.
- Tight coupling approach. In this case, both networks belong to the same operator. Thus, IP addresses at the mobile node can be maintained as well as AAA policies, QoS guarantees, etc. In fact, may be that even a micromobility protocol could be used for doing such handovers just as a change in the point of attachment to the network.

In the MIND trials we will focus on the no coupling and loose coupling approaches. Figure 2, shows a no coupling approach in which the mobile node use Mobile IP to switch from the WLAN network to the UMTS one as long as it detects that it has no more WLAN connectivity.

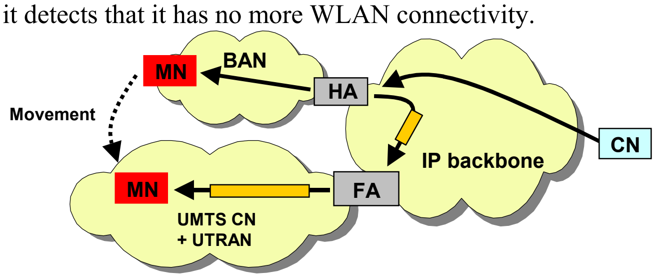

Figure 2 Vertical handover with no coupling between WLAN and UMTS

The case of vertical handover with a loose coupling approach in which the AAA databases for authenticating mobile nodes are shared between the two networks involved in the handover is shown in Figure 3.

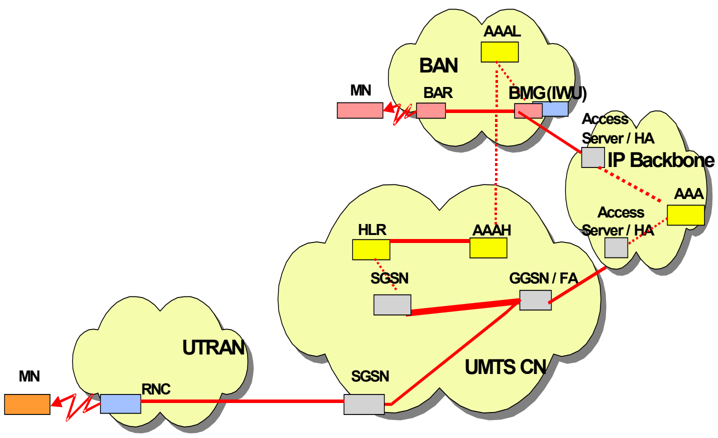

Figure 3. Vertical handover with loose coupling between WLAN and UMTS

3.3 Micro-mobility

During the BRAIN project most of the micro-mobility protocols were studied according to a protocol evaluation framework. These studies allowed us to identify the main advantages and weaknesses of the different protocols. As a result, a new micro-mobility protocol called BCMP (Brain Candidate Mobility Protocol) was engineered. In BCMP the handover process:

- Is planned, but can fall back to an unplanned handover
- Is mobile controlled but network supported

- Does not require any layer 2 support

In addition, idle mode terminals are supported as part of the BCMP design and it can be run on top of both IPv4 and IPv6.

Figure 4illustrates a BRAIN network that implements the BRAIN Candidate Mobility Protocol (BCMP). The network consists of legacy IP routers with added mobility aware functionality in just two types of nodes. Anchor Points (ANPs) own and allocate IP addresses, authenticate users, maintain user records, and tunnel packets towards Mobile Nodes (MNs). Brain Access Routers (BARs) terminate tunnels from ANPs and forward packets to/from mobile hosts. BRAIN Mobility Gateways in the Candidate Protocol need not have mobility specific functionality - their role is to shield the rest of the BAN from the exterior routing protocols and distribute traffic within the BAN to the correct ANPs.

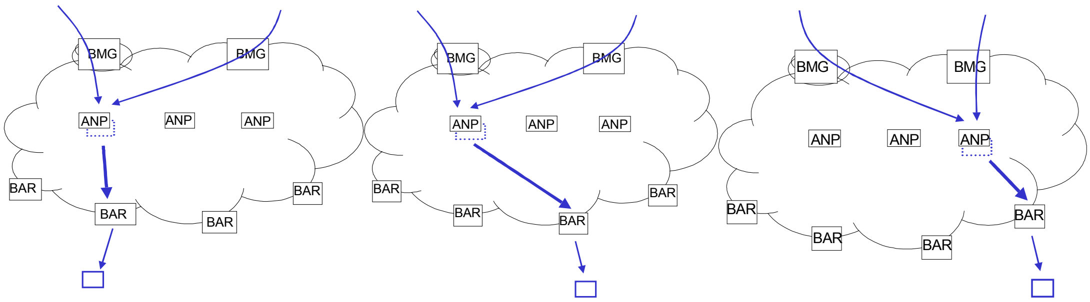

Figure 4. Outline of the BRAIN Candidate Mobility Protocol in a BAN

Anchor Points have globally routable address space and they allocate IP addresses to Mobile Nodes when they log in to the BAN. This address is kept constant, despite handovers. The pool of IP addresses owned by an Anchor Point is advertised using legacy IP routing inside the BAN and towards external IP networks. This ensures that packets addressed to a Mobile Node's locally obtained address are prefix-based routed to the Anchor Point that allocated the address. Anchor Points, in turn, tunnel packets to the BAR where the destination MN is located at the moment. Anchor Points must maintain up-to-date location information of MNs they have allocated an address for and must update this information when 'their' MNs change BAR (i.e., handover).

During the trials, the BCMP protocol will be implemented and evaluated in terms of performance in a real testbed against some of the other micro-mobility protocols like HMIP.

3.4 QoS

Quality of service is about satisfying application and user requirements for communications. From a networking perspective it is a set of techniques to manage network resources. For example, the packet delay can be controlled so that users can communicate naturally using voice of video in real-time. Currently, there is little QoS within the Internet, and little in the way of real-time communications. Real-time voice however is the biggest application in use on mobile wireless networks, so the network needs to be enhanced to support these services.

Whilst there are a number of different mechanisms that have been proposed to provide QoS within the Internet, the most interesting is that based upon the framework for Integrated Service operation over Differentiated Services networks [1] developed within the IETF (ISSLL Integrated Services over Specific Link Layers). This approach provides scalability to a large number of flows and strict service guarantees simultaneously. RSVP[2] messages are exchanged end-to-end across the network. At the edge of the network, for example over a wireless region, these messages are interpreted on a hop by hop basis as in standard IntServ. However, pure DiffServ [3] regions can also be used within the path. Here, the RSVP messages are only interpreted at the edge of the Diffserv region. These nodes map RSVP reservation requests to DiffServ forwarding classes, keeping a record of the session identifier and the required DiffServ class. Once data begins to flow using the reservation, these edge nodes will map the packet headers to session identifiers in the packets and confirm that the correct DiffServ Code Point (DSCP) is being used. Once within the network all packets are forwarded according to standard DiffServ operation. This is the basis of the architecture for a BRAIN Access Network [6].

In addition to the per-flow signalled reservations, the BRAIN architectural solution also allows normal DSCP marking to support prioritisation QoS for applications that are not able to quantify their resource requirements. Where required, Service Level Agreements (SLA) agreements can use used to ensure the correct marking for the packets.

However, this approach to QoS is not sufficient in a mobile, wireless Internet. There are two key problems.

Firstly seamless handover is not achieved. Although RSVP has a local path repair process which can repair reservations disrupted by path changes, this process should only occur after the new route to the mobile has stabilized, leading to a long period when QoS is not guaranteed. This process will always involve the mobile node in additional signalling, which needs to be avoided. Indeed, as RSVP is a soft state protocol, there is already a significant signalling load on the mobile terminal and wireless link. In general, mechanisms to achieve seamless handover with strong QoS guarantees lead to increase processing complexity and signalling load.

Secondly, QoS is not yet widely available within the fixed networks, yet any wireless, mobile network will need to provide QoS because mobile networks have a much lower QoS than fixed networks. Thus there is a need to provide QoS localized to the mobile network. This needs to be compatible with any QoS mechanisms provided within the fixed network.

A large number of approaches to solve these problems exist in the literature. [7][8][9] The BRAIN project identified which were most suitable (one criteria being those solutions that required fewest changes to IETF standards), and described their implementation within a mobile, IP network. Thus, in addition to implementing the basic architecture, in the MIND trials we will further investigate the following concepts:

- Bounded Delay [4]

This is a DiffServ PHB (per hop behaviour) that can be used for hard real-time services, whilst still maintaining the simplicity of DiffServ scheduling mechanisms. In particular, per-flow information on existing flows is not needed for either admission control or scheduling decisions.

- DiffServ Handover Markings

These can be used to enable handover traffic to access static guard-bands – bandwidth reserved for the use of handover traffic. This is low overhead mechanism to ensure that some level of QoS support can be provided during the handover process. Depending upon the admission control architecture, the size of these guard bands may be dynamically adjusted.

- Protocol coupling

Small changes to RSVP can speed up the restoration of QoS reservations after handover has occurred, whilst minimizing the signalling load over the wireless link. This requires some level of coupling between the mobility management and QOS architectures.

- Localized QoS signalling [5]

This allows a mobile node to request QoS within the mobile network, for both incoming and outgoing traffic. It requires minimal changes to RSVP, these changes would be backward compatible with existing RSVP infrastructure.

The implementation allows us to verify that the solutions proposed are sufficient and complete. Further, by focussing on the complete problem, we can verify that different aspects of the solution do not interact in unforeseen ways, and build a network that can be used to deliver real-time packet transport services to applications.

3.5 Service level concepts

In addition to the previously mentioned network layer trials, we are also very interested in studying how does mobility affect the mobile nodes' architecture. During the BRAIN project a Brain End-Terminal Architecture (BRENTA[11]) was proposed. It was identified that and end-node should be able among other things to:

- Manage its own resources for providing more predictable QoS
- Manage network resources to provide bandwidth guarantees
- QoS management to manage and coordinate local and end-to-end QoS guarantees
- Mobility management for being able to influence the handover processes
- Support for adaptation mechanisms to offer a good quality to the user even when handovers take place.

For the MIND trials we have focused on broadband services like video on demand (VoD) and videoconferencing which are the most challenging to be used in our testbeds. The ISABEL[18] application has been considered because of its videoconferencing capabilities as well as collaborative support, which raises specially interesting issues when dealing with mobile networks. The service level trials conducted in MIND will focus in prototyping the functionally defined by BRENTA and integrating it with ISABEL. These trials will allow us to demonstrate how BRENTA can help the applications in dealing with changes due to terminal mobility.

The main problem with mobility is that of adapting data transmitted to or received from the application to the characteristics of the different networks, including throughput and delay concerns. Adapting the stream in real-time to somehow guarantee a minimum service can be dealt by modifying the way components process the information: two ways to achieve this should be taken into consideration: *Codecs* and *Sampling Rate*.

- **Codecs.** Coders/Decoders used in both the sender and receiver ends are the most determining part both for Audio and Video. Actually the application may handle contents encoded according to several standards such as H.263 or Motion JPEG (MJPEG) for video, or G.711/G.722/G.726 for audio, and different levels of encoding quality. Each standard has its own restrictions and parameters, and the application may choose among them at user request or based on information from the mobility layer.
- **Sampling rate.** Also management of rate at which pictures are sampled, sent and displayed can be adapted to match the requirements of the network in use. In term of Audio, quality can be varied from the lowest level of intelligibility to crystal clear, if enough resources are present.

Thus, the application should be able to dynamically (and in real-time) being able to adapt its behaviour to the node's or network resources available. In addition, dynamic buffer allocations for playing out the audio and video contents would be desirable. For example, before performing and handover, the micro-mobility layer would inform the application and it would be able to enlarge such buffers so that the minimum content losses occur. Thus, as Figure 5 shows, an interface between the micro-mobility protocol (BCMP) and the application layer to make ISABEL to be mobility aware is being implemented.

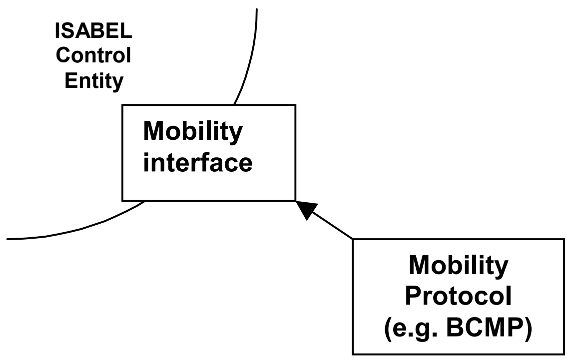

Figure 5. Mobility interface to ISABEL

In addition, part of the QoS functionality defined by BRENTA is being implemented. The idea is to build a QoS wrapper which will be in charge of performing all the QoS reservations and monitoring. This QoS wrapper will abstract the applications from the specific QoS mechanisms available in the mobile node. Thus, a QoS interface between ISABEL and the QoS wrapper is being implemented as shown in Figure 6.

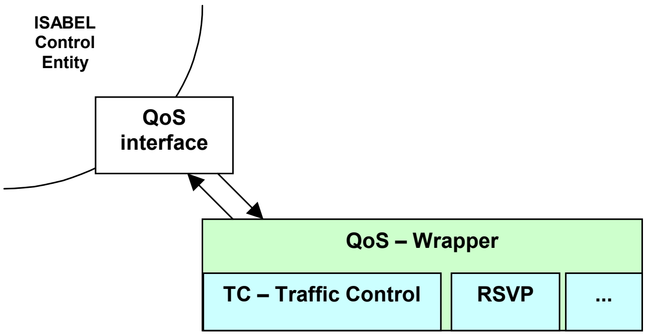

Figure 6. QoS wrapper

Thus, once the application layer is enabled to receive information about mobility, request QoS reservations and receive QoS information, a new "intelligent" logic is incorporated into ISABEL to make it able to take auto-adaptation related decisions. The application can use several triggers:

- Micromobility information received though the mobility interface
- QoS violations received through the QoS interface
- QoS renegotiations received from the other end using some signalling mechanism like SIP
- RTCP reports coming from the other participants

The main goal is making the application to continue offering a good quality even when handovers between technologies offering very different bandwidth occur. To achieve that, all the network layer protocols and mechanisms and the application layer auto-adaptation mechanisms should work together.

4. Conclusions and future work

The trials conducted by the MIND project plan to show how different network layer and service layer concepts when integrated to work together can offer a very good performance in mobile wireless networks based on the "all-IP" paradigm. The concepts identified and defined during the successful BRAIN project which are being implemented have been presented and described. In addition, it has also been explained how the integration of different technologies (like WLAN, UMTS,…), different mobility protocols (macro-mobility like MobileIP, micro-mobility like BCMP), different service layer protocols (like RTP, RTCP, SIP, …), a QoS architecture at all layers and a QoS and Mobility aware applications (like the extended ISABEL) can offer a good performance solution for such an "always-on" architecture.

During the trials, all this elements will be tested a real mobile network scenario. In addition, some of the trials will consist on the comparison of different approaches like different micromobility protocols, different ways to auto-adapt multimedia flows, different QoS mechanism, etc. The results of the trials will serve us as an input to identify possible weaknesses or fails as well as to revise the BRAIN concepts definition and possible redefine some parts or behaviours.

5. Acknowledgements

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7. Vitae

Pedro M. Ruiz graduated from the *Universidad the Murcia* (Spain) with a degree in Computer Science in 1999. Until April 2001 he worked at the Spanish National Research Network (RedIRIS) where he was leading some R&D projects related to the deployment of advanced services like IP Multicast, and Streaming. He was also involved in several Dante and RIPE Working Groups as well as some Terena Task Forces. During this time, he has been also teaching at the Dept. Telematic Engineering at the *Universidad Carlos III de Madrid.* Presently Pedro M. Ruiz works at Agora Systems S.A. as R&D manager.

Enric Mitjana obtained his Master of Science Degree at the *Universitat Politècnica de Catalunya* in Barcelona, Spain in 1997. He completed his dissertation thesis at the Universität Kaiserslautern, Germany within the scope of the ACTS FRAMES Project. Since 1997 Enric Mitjana has been with Siemens' Information and Communication Mobile Group. He was involved in the UMTS standardisation in the ETSI SMG2 and 3GPP. In 1999 Enric Mitjana was delegated to Beijing, China, to set up an R&D centre concentrating on the TDD mode of IMT-2000. Enric Mitjana is at present the project manager of the IST MIND project.

Louise Burness graduated with a degree in physics in 1988, and obtained her Master of Computer Science from *Essex University* in 2001. She currently works for BTexact Technologies where she is a senior researcher in IP mobility.