Integrated Broadband Mobile System (IBMS) Demonstrator Environment

T. Assimakopoulos, A. Festag, F. Fitzek, S. Irmer , A. Wolisz [(1)]

Telecommunication Networks Group (TKN), Technical University Berlin

Secr. FT 5-2, Einsteinufer 25, 10587 Berlin, Germany

email: [thass|festag|fitzek|irmer|wolisz]@ee.tu-berlin.de

(1) Also with GMD-Fokus, Berlin, Germany

Abstract

*The vision of **I**ntegrated **B**roadband **M**obile **S**ystem (IBMS) is to build up a future broadband mobile communication system, covering both indoor and outdoor environments in a consistent and transparent way. The basic system approach is a trade-off between mobility and data rate in outdoor, between coverage and data rate in indoor, and a transparent migration between indoor/outdoor. These goals are provided by the integration of different transmission technologies, adaptive antennas, new methods of channel coding and improved protocols to support **Q**uality **of** **S**ervice (QoS) in both environments. A core testbed is described, which allows a flexible set-up and gives the freedom for experimental investigations. To verify the proposed system approach basic selected features will be demonstrated. Two of them, mobility support and the use of the Wireless Local Loop (WLL)-subsystem with the core network are explained.*

Introduction

Omnipresent wireless communication systems are designed for specific data rates allowing a maximum degree of mobility support. While personal communication systems at low data rates offer a high degree of mobility (GSM, IS95), there are other wireless communication systems that operate with high data rates offering only a low degree of mobility. Under the assumption that future services in mobile communication systems will become more and more heterogeneous, there has to be a smooth trade-off between data rates, mobility and networks. The objective of the IBMS [1], is to provide a unified way to support a variety of communication classes ranging from high mobility with low data rates towards portability at high data rates as an integral feature of a wireless communication system.

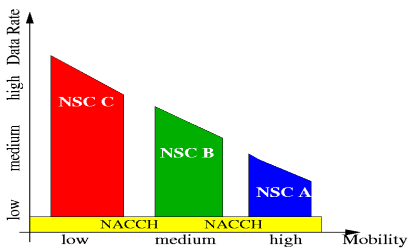

Figure 1. Trade-off between mobility and data rates

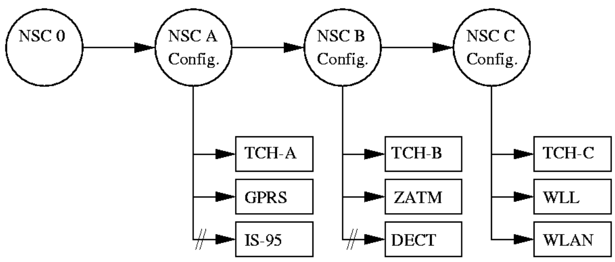

Figure 2. Network Service Classes (NSCs) in IBMS

The IBMS concept offers the wireless mobile user high mobility with small data rates up to high data rates restricting the mobility degree to moveable. Three ***N**etwork **S**ervice **C**lasses (NSC)* are defined (s. fig. 1), which reflect the trade-off between mobility and data rate. They are physically realised by ***T**raffic **CH**annels* (*TCHs).* Data flows of specific NSCs are mapped to TCHs, which allow channel bundling as well as channel sharing. The ***N**etwork **A**ccess and **C**onnectivity **CH**annel (NACCH)* supports permanent network access and basic signalling (NSC-0) in indoor as well as in outdoor environments. The NACCH is a logical channel, which might be mapped to a TCH-A or a logical part of a higher TCH. The permanent access to the NACCH is independent from the users mobility, enables the access to the IBMS own TCHs and allows the migration to/from existing mobile communication systems (e.g. GSM 2+, see fig. 2).

Within IBMS various research related problems are tackled. As an example, an innovative approach for error correction is followed. Recognising the increasing importance of CDMA in future wireless communication, QoS support can be enhanced by the use of ***S**imultaneous **M**AC **P**acket **T**ransmission (SMPT)* [4]. The SMPT approach supports QoS by parallel usage of multiple CDMA codes. In case of error prone links, while retransmissions in ARQ protocols are needed, the parallel use of codes can lead to stabilised link layer throughput. This has a strong impact on transport protocol entities, e.g. TCP, due to a minimisation of the delay variation.

For investigations in complex and novel systems an open core testbed is defined. It allows a flexible set-up and gives the freedom for experimental investigations. Based on that core testbed the possibility is given to investigate new protocols, interoperability and usability of the proposed solutions, mobility, and signalling for all the different sub-systems developed by the various IBMS partners [3]. It will be used to verify the proposed IBMS system approach by demonstrating basic selected features.

The paper is organised as follows. First the core testbed is described. This includes hardware components, protocol options, applications and measurement tools. Then selected experiments, planned with the IBMS-demonstrator, are presented.

Core Testbed

The core testbed has an open architecture, which allows to obtain the desired high flexibility required by various scenarios including different sub-systems. The architecture of the core testbed supports extensibility, facilitates embedding in many different environments and technologies, and supports an easy implementation of novel or experimental networks. It enables development of general methods for high performance networks, active processing at gigabit rates, and deployment of active applications. As an example, the core testbed can be used as an ideal platform for investigations in active networks (the proper environment is under development, s. e.g. [7]). The aspects covered by this testbed range from the physical radio systems to multimedia user applications. The hardware components of the core testbed consists of an *ATM-**W**ashington **U**niversity **G**igabit **S**witch (WUGS)* and ***G**eneric **A**ccess **P**oints (GAPs*). Sub-systems are coupled to the WUGS through a GAP. The WUGS connects sub-systems with each other as well as with an ATM-Backbone. The hardware components allows various protocol options, two of them are considered in the IBMS demonstrator context. Applications and measurement tools are integral part of the core testbed and will be applied for verification, testing, evaluation and demonstration.

WUGS

The WUGS is a remote controlled eight port ATM switch, with an open, non-proprietary, full documented architecture, supporting up to 2.4Gbps per port. The separation of switching and control functionality facilitates remote control, dynamical protocol configuration and the implementation and modularization of software, e.g. high and low level measurement and analysis tools ,or new protocols which can be implemented and tested on various workstation platforms, not bounded on a vendor's switch control software. The use of direct many-to-many connections supported through cell-recycling, enables topology-aware reliable multicast, while overcoming many limitations which arise if a commercial switch is used.

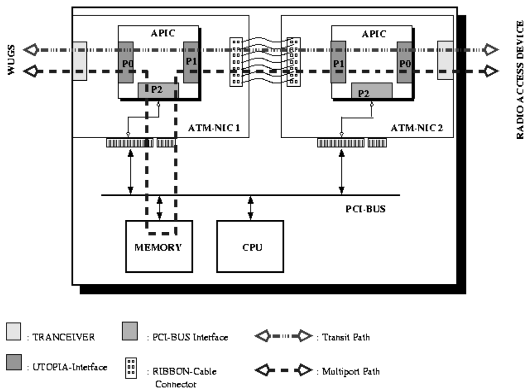

Figure 3. Generic Access Point (I)

GAP

The ***G**eneric **A**ccess **P**oint (GAP)* contains ***N**etwork **I**nterface **C**ards (NICs)*, based on a custom IC called ***ATM–P**ort **I**nterconnect **C**hip (APIC)* (fig.3, fig.4). The main functionality of GAP is: support of the required protocol options, packet-relay, routing/switching, monitoring/measuring, and interconnection of the various network access technologies to the switch in a transparent way. In case of wireless networks, handover control is also supported. Separation between signalling and user data is possible, while the signalling stream can be delayed. Custom-made devices, e.g. the radio access devices of the different IBMS sub-systems as well as commercially available products can be connected to GAP through the Utopia interface or via the PCI Memory Bus interface. As an example, GAP in conjunction with the fully programmable MAC controller which is under development in TKN, forms a platform for investigations in high-speed sophisticated networks. This will be an open and configurable development environment for prototyping and validating of MAC and higher layer protocols.

The APIC is a full programmable chip with two independent ATM ports (1.2Gbps per port with UTOPIA Lev. 2.0 interfaces) and a PCI-Bus interface. It performs segmentation and reassembly of AAL5 frames directly to and from the workstation's memory and supports several different operating modes, e.g. zero-copy data transfers using virtual memory page, remapping techniques, TCP checksum calculation, and direct user-level control. This latter feature makes it possible to experiment with user-level protocols and applications without requiring programming at the kernel level.

Depending on the required protocol options, the cells flow through the GAP : i) transparently, from Utopia to Utopia (*transit path*, s. fig. 3), ii) to the PCI Bus for further computation and then fed back to Utopia (*multiport path*, s. fig. 3) and iii) to/from the PCI Bus and then to/from other devices, (*memory path*, s. fig. 4).

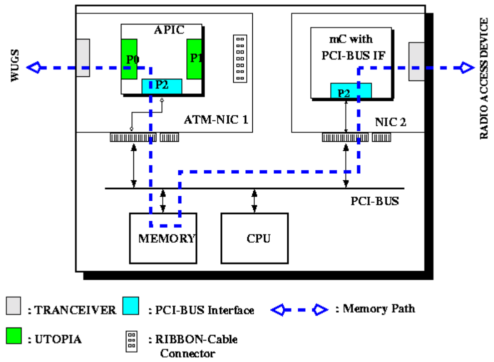

Figure 4. Generic Access Point (II)

Protocol Options

Various communication protocols can be supported within the core testbed. The options range from Native ATM, Internet protocol stack (TCP/IP), combinations of IP and ATM, up to future IP over pure cell switching. For a specific set-up the choice of the protocol deployed depends on the decision whether the WTs should support ATM services or not. In the IBMS demonstrator two general options are considered: i) end-to-end ATM, and ii) non-ATM wireless link. Having in mind that most user applications are Internet-based, the ***Classical IP** over ATM (CLIP)* approach, or the ***Re**mote **So**cket **A**rchitecture (ReSoA)*, [2], (Fig. 5), are consideredIn case of non-ATM wireless links, either the Internet protocol stack (TCP/IP) in the WT or the ReSoA approach is used.

Remote Socket Architecture, ReSoA, [2]

Although the Internet protocol is designed for heterogeneous networks, end-systems suffer an inefficient communication while connected via a wireless link. Most applications running in WTs use *Service Access Points (SAPs*), provided by the socket interface to access the services of the underlying protocol stack. In the ReSoA approach the desired protocol functionality is located within the base station, while the services are exported to the wireless terminal by means of a lightweight ***L**ast **H**op **P**rotocol (LHP)*, which is optimised for the characteristics of the wireless link. The ReSoA disburdens the WT by exchanging the lower half of the socket interface as well the underlying transport and network protocol with a new protocol architecture, while the SAPs to the applications remain unchanged. ReSoA results in small wireless devices relieved from the processing of a full protocol stack, increased performance and stable throughput on the wireless link. Since the syntax and the semantic of the socket calls are not affected, no modifications in existing applications are needed. We have a ReSoA implementation supporting TCP sockets.

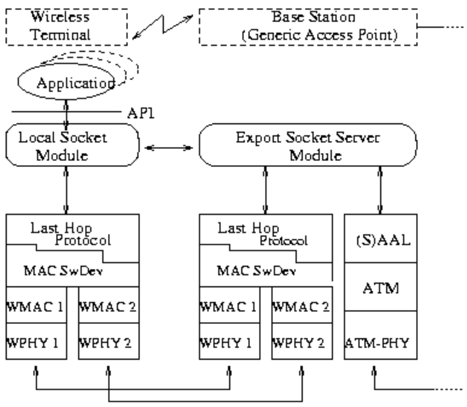

Figure 5: Remote Socket Architecture (ReSoA)

Last Hop Protocol, LHP

The LHP provides a reliable service between the export socket server and the local socket module. Reliable means packet delivery *in-order* with no duplicates. The design of LHP is tuned to the services provided by the MAC layer. Three MAC service classes can be distinguished: i) reliable transmission. In this case the LHP does not need to provide an error correction functionality. ii) Non-reliable, without error-notification to higher layers and iii) non-reliable with error-notification. In the last two cases error control mechanisms are embedded in the LHP. A flow control mechanism is implemented. Unrecoverable errors (e.g. maximum number of retransmission reached, link failure) are signalled to the upper layer. In order to observe the link state (either connected to the base-station or disconnected) during idle periods of all sockets the LHP implements a keep-alive functionality. Further the LHP instance on the base-station is responsible for the demultiplexing of socket requests from different WTs.

Applications and Measurement Tools

In the core testbed, multimedia user applications, such as the ***N**ative **ATM** **V**isual/**A**udio **T**ool (NATM-VAT*), the ***U**niversal, **S**calable **M**ultimedia Services in the **Int**ernet (USMInt)* [8], and MPEG Video are used. *SNUFFLE* [5], developed by TKN-TU Berlin, is applied for measurement and monitoring.

Demonstrator structure

The integrated IBMS demonstrator, schematically depicted in fig. 6, consists of various sub-systems connected to the core testbed, allowing the validation and demonstration of different IBMS key-features, such as QoS and NACCH negotiation.

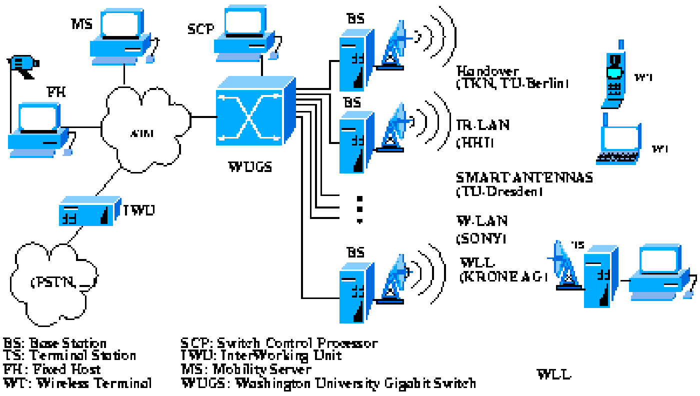

Figure 6: Demonstrator setup

The sub-systems, provided by the IBMS-partners, form the radio access segments of the demonstrator. Key features to be demonstrated are: i) high speed wireless communication for indoor and outdoor environments, and ii) adaptivity of transmission rate. The latter is achieved by i) switching between radio access systems, ii) switching between different modem modi, and iii) using smart antennas. For the indoor environment following radio front-ends are provided: i) an OFDM, dual frequency (5/25GHz) modem capable of supporting up to 34 Mbps, by SONY (Europe) GmbH, and ii) an infrared modem, offering a spot diffusing and an auto tracked directed modus, which supports up to 155 Mbps, by Heinrich Hertz Institut (HHI). For the outdoor environment, the Technical University Dresden provides a smart antenna system which can act adaptively to environmental influence by changing data rates, and the KRONE AG provides a Wireless Local Loop (WLL) system which is capable to transmit data at 2Mbps supporting bandwidth on demand.

Experiments

Two selected experiments are described: the *Handover-Demonstrator*, dealing with NACCH, and the *Wireless Local Loop- Demonstrator*, showing QoS support in individual transmission options.

Handover

The demonstration environment will be used to investigate mobility issues. The IBMS architecture assumes wireless cells of different size and data rates, which form a hierarchical structure of overlay networks. A WT might be equipped with multiple wireless interfaces. The aimed continuous communication is achieved by horizontal and vertical handover (s. fig. 7). For horizontal handover the WT changes cells of same hierarchy and for vertical handover between overlaid cells. These handovers as well as the internal change of the NSCs is controlled via the NACCH. The planned investigations addresses the following issues: i) Minimising the impact of horizontal handover ii) Support of vertical handover and iii) Mobility support in ReSoA.

At small wireless cells, handover causes frequent service interruptions. In the IP-over-ATM protocol option, ATM Virtual Circuits (VCs) in the backbone have to be re-routed to the new base station. In i) the service interruptions will be minimised by sophisticated mechanism using multicast. For the case that a service at the same hierarchy level is not available, a vertical handover is executed. To enable a WT to switch between multiple wireless interfaces, a *MAC Switching Device* is implemented to allow switching between multiple interfaces in a WT and choose the proper transport technology (s. fig. 5). This MAC Switching Device routes packets to the appropriate interface, depending on availability of service and upper layer requirements. In iii) the ReSoA has specific implications on mobility: a ReSoA enabled base station holds IP addresses on behalf of the WTs. A mobility scheme, which makes use of Mobile IP and Network Address Translation (NAT) [6] is under consideration. Different handover types will be demonstrated . For horizontal handover the re-routing of ATM VCs will be shown. The WUGS acts as an anchor switch which sets up a new VC segment and tears down the old one. To minimise the overall handover duration, an ATM point-to-multipoint VC to the actual base station and its neighbouring base stations is set up. These neighbouring base stations buffer data. When a mobile is associated with one of them, the base station will forward the data. It can be demonstrated, how the effort will shorten the service interruption. When a horizontal handover fails, e.g. due to insufficient coverage, a vertical handover is executed. In case of an IP subnetwork, the vertical handover will be demonstrated by link-level mechanisms, implemented in the MAC Switching Device. A handover between subnets is handled by a ***Mobility Server*** *(MS)*. Signalling messages necessary for a handover are transported via the NACCH, which is always available. In the case of upward handover from indoor to outdoor cells the mobile may simply fallback to the outdoor interface, since it is assumed to have full coverage. Data will be forwarded to the outdoor cell via the indoor base station. For downward handover the mobile is notified via NACCH about the availability of an indoor service. In conjunction with the horizontal handover, both cases of vertical handover are performed with rate adaptation of applications.

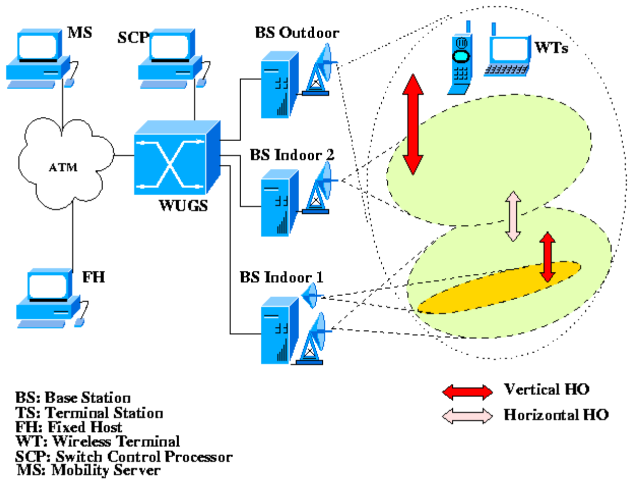

Figure 7: Handover demonstrator setup

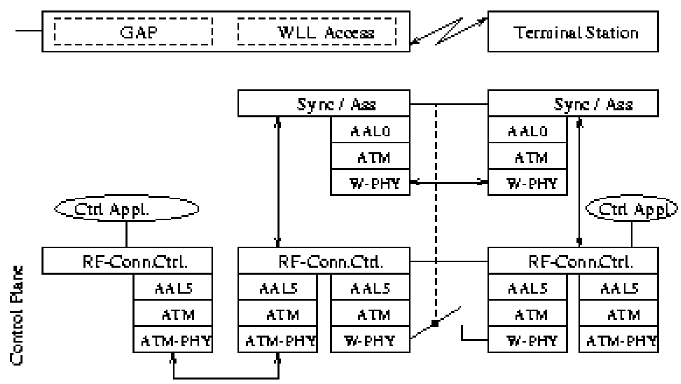

Figure 8. Extended Control Plane for WLL

Wireless Local Loop

In the Wireless Local Loop Demonstrator a QoS aspect, the bandwidth on demand feature over an end-to-end ATM network, is demonstrated. In this setup the base station services up to three Terminal Stations (TS), each with a maximum of four CDMA channels. Each connection normally starts using one channel. Additional channels are switched on if more bandwidth is required. The functionality of the extra layer on top of the ATM control plane in the base station and in the terminal stations allows separation and delay of the signalling flow until a new channel is assigned (or refused) to the requester. This process evolves without interruption of the current connection and is controlled by an application running in GAP and in TS.

Conclusions

An open core testbed, which provides a flexible hardware, protocol and software structure, is presented. It allows experimental setups for investigations on networking and it is permanently extended with new facilities supplying the possibility of investigations in novel technologies.

The core testbed will be used to create a demonstration environment Within IBMS it enables testing of the different technologies of front ends under realistic load mixes and experimentation on protocol and signalling issues. Furthermore the proposed IBMS system solutions will be demonstrated. Thus the IBMS project outcome will support ongoing efforts on investigation of future global communication systems as UMTS, on Wireless LANs and on broadband systems, utilising ATM backbone.

Acknowledgements

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