# Air Interface of a Wireless ATM System

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*Abstract* — **In general, the users of wireless ATM terminals request the same functionality and *Quality of Service* (QoS) as users of wired terminals. Thus, the protocol stack at an ATM air interface has to behave like a usual ATM multiplexer [1], which has to co-ordinate the access to the shared radio resources in such a way that the QoS of all ATM service classes can be guaranteed for each established virtual channel connection (VCC).**

**The multiplexing function is distributed between a central access node and the wireless ATM terminals. This configuration can be interpreted as the implementation of a distributed, virtual ATM multiplexer with an internal radio link.**

**This situation is comparable to cable-based ATM access networks with a tree of fiber optical or coaxial cables. The main differences between wireless and cable-based ATM access networks are the behaviour of the physical medium and the possible mobility of wireless terminals.**

**In this paper the protocol stack for the air interface of wireless ATM systems is presented.**

## 1 Introduction

After the success of the *asynchronous transfer mode* (ATM) in the area of multimedia networks, a demand for the transparent integration of wireless ATM terminals into fixed ATM networks has become visible during the last years [2]. In 1995 ATM-Forum and ETSI have established special *wireless ATM groups* that are currently investigating requirements and architectures for a wireless extension of ATM networks.

Wireless ATM (WATM) systems are conceivable in a large variety of applications, cf. Figure 1, such as public or private access networks for substitution of cable-based infrastructure (Radio in the Local Loop), as indoor or outdoor broadband and multimedia cellular radio systems, wireless ATM-LANs or ad-hoc networks. This large range of applications leads to a variety of types of WATM systems differing in services and the terminal mobility, according to the specific scenario. Concerning the structure of the logical channels and the access protocols at the air interface, a scalable, standardized solution is desirable.

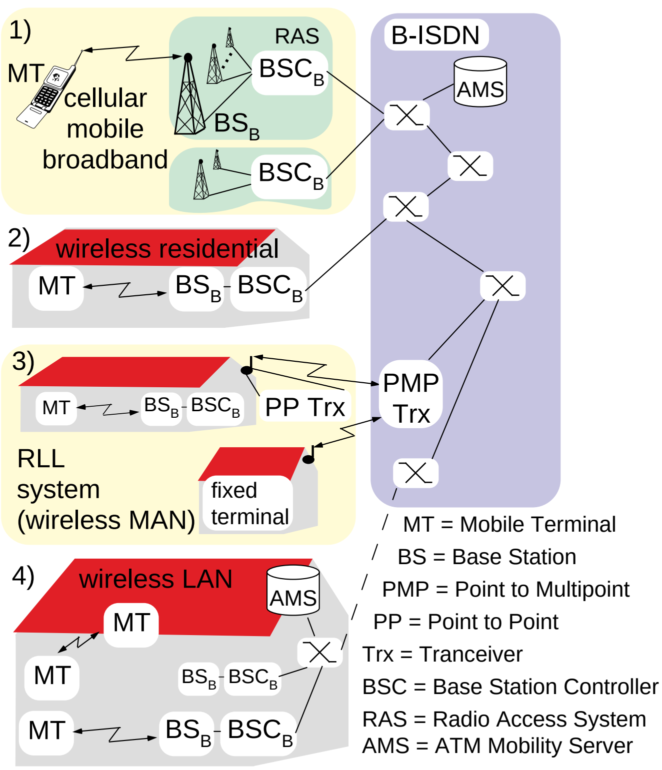


Figure 1: Different access environments for WATM systems

The unreliable behaviour of the radio link as well as the access to the shared radio resources lead to the requirement of additional functions at the ATM air interface, which are not necessary in a fixed ATM multiplexer. The functions are executed by the protocol stack at the air interface which is shown in Figure 5. It contains a wireless physical layer below the ATM layer and a data link layer consisting of a *medium access control* (MAC) and a *logical link control* (LLC) sublayer which belongs to the lower part of the ATM layer.

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# 2 Architecture of the ATM air interface

The structure of a cellular mobile telecommunication network for wireless ATM access [3, 4, 5] is shown in Figure 2. The base station (BS) is the access point to the fixed ATM network and consists of several receiver/transmitter units (TRX) and a central control unit (Base Station Controller, BSC). A TRX is controlled by the BSC and serves the mobile terminals inside its radio cell.

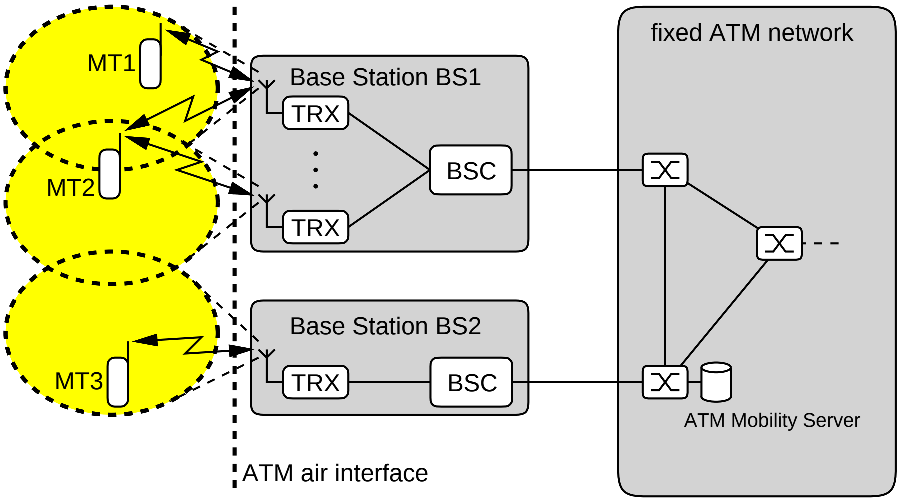


Figure 2: Architecture of a cellular ATM network

The structure of the WATM system leads to two different types of handover, cf. Figure 3:

**Radio-Handover:** A radio handover is performed between two transceiver connected to the same BSC. This means that the switching of the virtual channel is performed inside the BSC and does not effect the fixed ATM network.

**Network-Handover:** The network handover is carried out between transceiver of different BSC and requires a rerouting of virtual connection inside the fixed ATM network. This means that the certain mobility function has to be supported by the fixed ATM network.

The characteristic parameters of the considered ATM air interface are according to [5] and are summarized in Table 1.

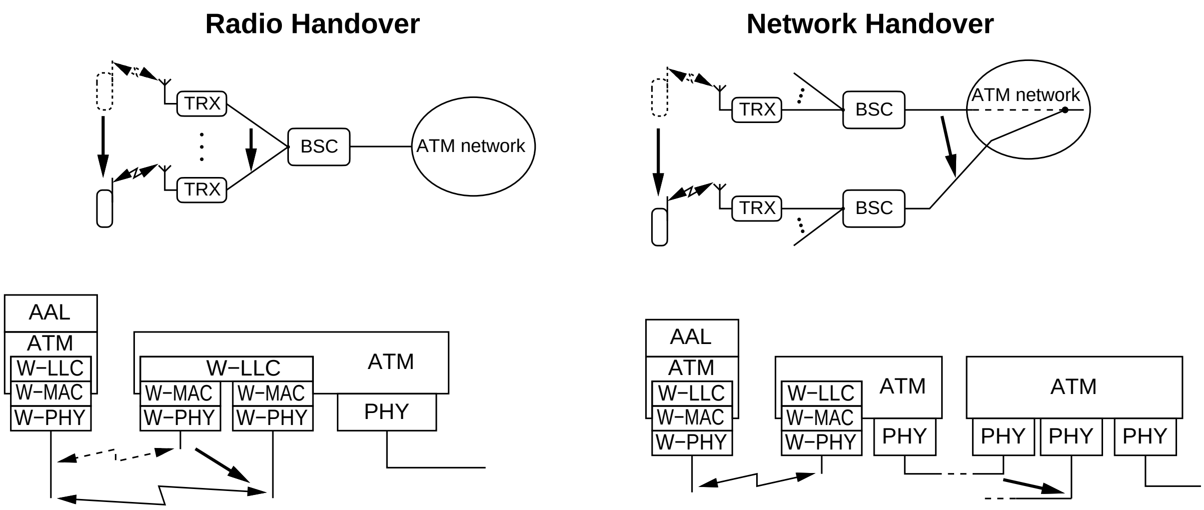


Figure 3: Comparision between Radio and Network Handover

| | |
|---|---|
| frequency band | 5.2 GHz |
| channelization | FDM |
| duplexing scheme | TDD |
| bandwidth p. carrier | 23.5 MHz |
| gross data rate p. carrier | 50.000 ATM cells/s ($\approx 20$ Mbit/s) |

Table 1: Characteristic parameters of the considered ATM air interface

# 3 Radio cell as a distributed ATM multiplexer

Users of wireless ATM terminals usually request the same functionality (beside the fact of restricted operating time and limited data rate) and *Quality of Service* (QoS) as the users of wired terminals. Especially all ATM based applications have to be supported.

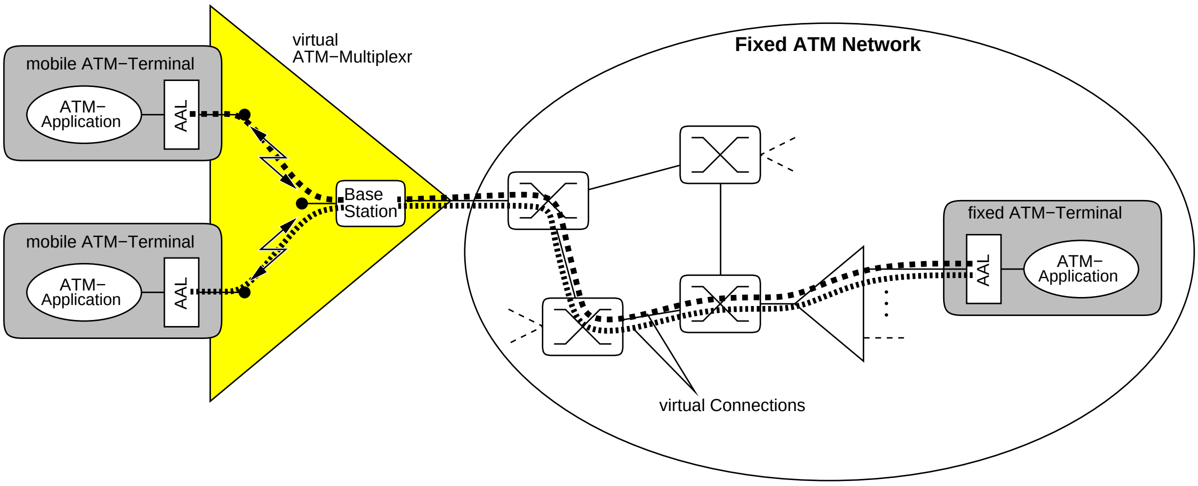


Figure 4: Integration of a cellulare ATM network into a fixed ATM network

In Figure 4 it is illustrated that the AAL protocols are transport protocols with an end-to-end relation, with the protocol instances located in the terminals. The transmission of ATM cells over the air interface takes place inside the ATM layer base on single cells. In this way, the influence of the air interface is hidden from the AAL layer. From the users point of view, the terminals of a radio cell, which are connected to the fixed network by a BSC, behave like wired terminals, cf. Figure 5.

A radio cell with its central BSC and its wireless terminals can be seen as a distributed, virtual ATM multiplexer with an air interface inside, cf. Figure 5. To consider the individual QoS requirements of all virtual connections, the MAC layer also executes functions of the ATM layer.

On the terminal side of the virtual multiplexer a modified UNI interface is used, called W-UNI. To ensure transparency, only the control and management plane of the ATM reference model [6] are modified to handle the mobility of terminals. The user plane remains unchanged to guarantee the transparent transmission of ATM cells.

Between the virtual multiplexer and the fixed ATM network a modified NNI interface is required (M-NNI) with additional functions to execution of handovers and for radio resource management.

Usually the W-UNI interface is an internal interface inside the terminal. To reduce the implementation effort, the AAL layer can be set up directly on top of the ATM layer of the ATM air interface, cf. Figure 5.

The virtual ATM multiplexer represents a distributed queuing system with queues inside the terminals (for uplink cells) and the base station (for downlink cells). The base station also contains the scheduler which determines the transmission order of the ATM cells.

Like in fixed ATM networks with a relatively low data rate (e.g. 20 Mbit/s [5]) the QoS requirements of real-time oriented services can only be supported if the transmission order of ATM cells is based on the waiting time inside the queues.

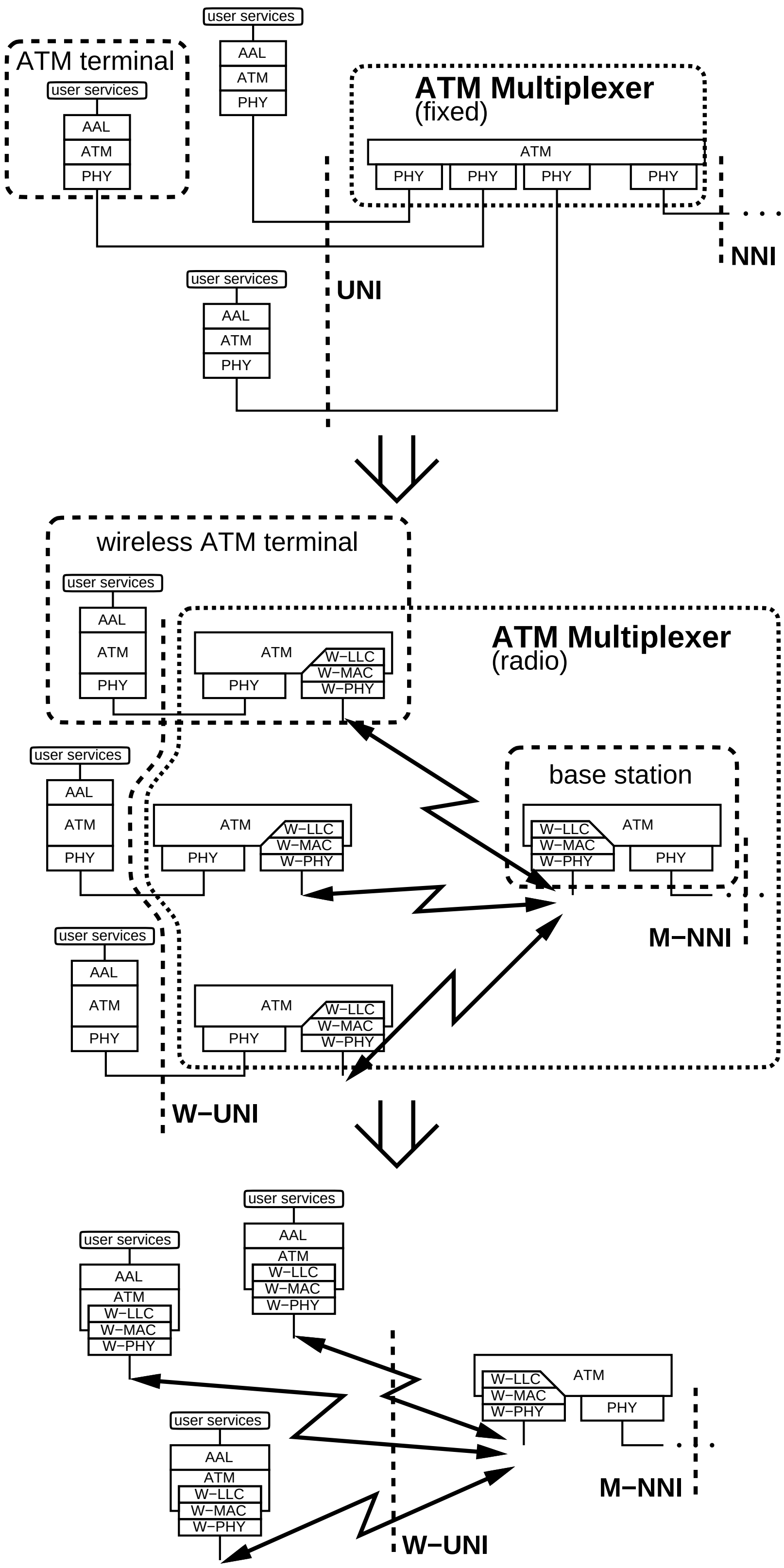


Figure 5: Implementation of a distributed virtual ATM Multiplexer at the ATM air interface

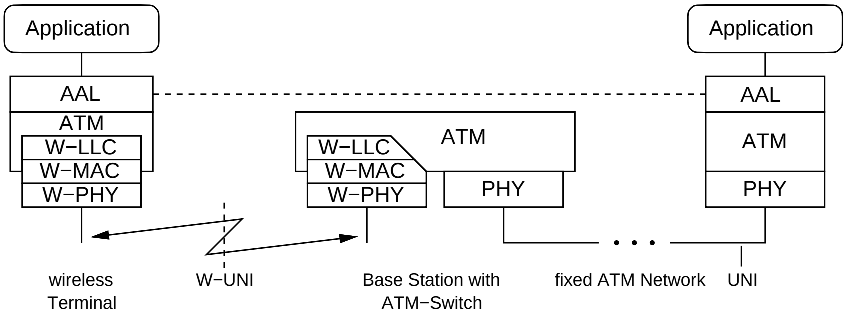


Figure 6: Protocol Stack at the ATM air interface

# 4 Protocol stack for the ATM air interface

The radio link leads to two tasks which has to be fulfilled by the protocol stack of the ATM air interface:

**Medium Access:** Controlling the access of terminals to the shared radio link according to the transmission order determined by the scheduler

**Error protection:** The unreliable behaviour of the radio link requires a service specific error correction scheme.

These functions are performed by the layers of the protocol stack of the wireless air interface, shown in Figure 6. It consists of a *Wireless Physical Layer* (W-PHY) and a *Data Link Control* (DLC) layer which contains a *Medium Access Control* (MAC) sublayer and a *Logical Link Control* (LLC) sublayer.

The MAC layer offers services to the scheduler which are required to control the transmission order of the ATM cell. It performs a signalling protocol for informing the terminals about slots in which they are allowed to send (uplink) or receive (downlink) cells. Furthermore, the MAC layer takes care of the transmission of capacity requests form terminals to the base station, which is required to inform the scheduler about the states of the queues inside the terminals.

The LLC sublayer performs a service class specific error correction scheme. It consist of a combination of forward error correction (FEC) and an automatic repeat request (ARQ) protocol. The FEC is combined with a suitable channel coding scheme and executed by the physical layer. In the LLC sublayer a service class specific ARQ protocol retransmits lost cells according to the individual requirements of the different virtual channels.

## Medium Access Control Layer

The demands for transparent transmission of ATM cells over the air interface between several mobile terminals and a central base station leads to a MAC scheme which expands the statistical multiplexing of ATM multiplexers to the specific scenario which is characterized by the competition of mobile terminals which are hard to co-ordinate. Statistical multiplexing on a TDMA channel is used with a slot length able to carry one ATM cell together with the necessary overhead for training sequence, synchronization, FEC and guard time.

A fair (and efficient) medium access control based on single ATM cells is possible only, if the allocation of slots is controlled by a central instance [7].

The used protocol is called *Dynamic Slot Assignment* (DSA) protocol. Its functionality can be described as follows [8]:

- Signalling of capacity (slot) assignments/reservations on the downlink by the base station controller
- Transmission of capacity reservation requests on the uplink (by inband signalling, random access or polling) by the mobile terminal
- Service strategy of the scheduler in the base station to determine the transmission order of ATM cells on uplink and downlink

The scheduler is separated into two parts, cf. Figure 7. The lower part in the MAC layer selects the terminal which will receive a slot or is allowed to send. In the upper part of the LLC sublayer the virtual channel of a terminal is selected. The function of the scheduler is furthermore divided into two phases: a planing phase and a transmission phase.

During the planing phase the DSA++ protocol groups the reservations for several consecutive slots (signalling period) and groups the corresponding signalling messages to a *downlink signalling burst* starting a signalling period of a specific length, cf. Figure 8. Because only this downlink signalling burst is send in broadcast mode, power control can be used for all other bursts. A downlink signalling burst contains the following messages:

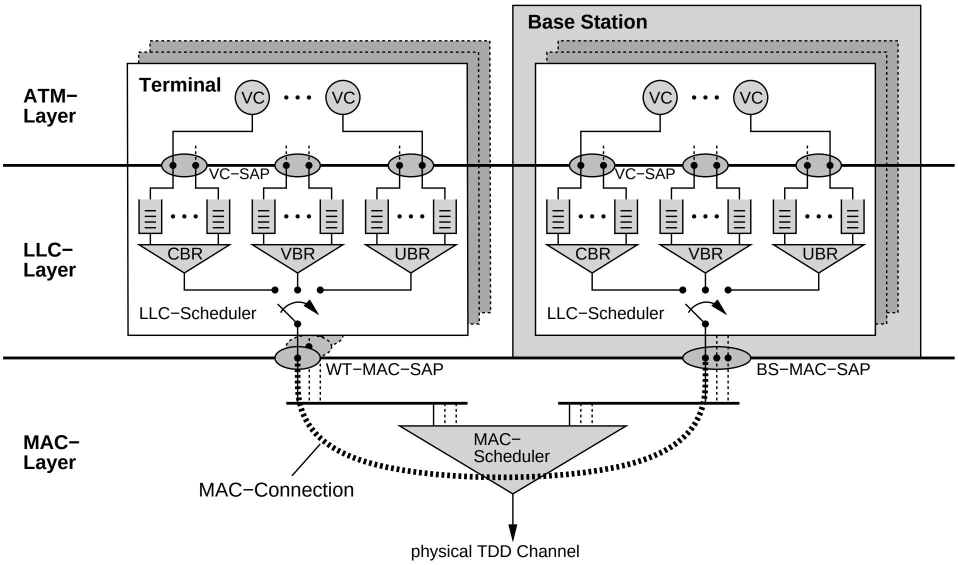


Figure 7: Dividing the Scheduler into an LLC and MAC part

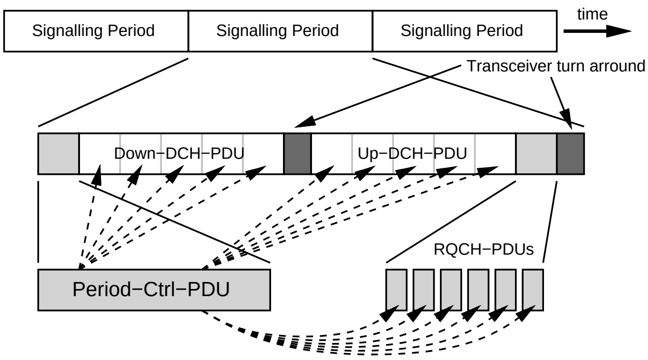


Figure 8: Downlink signalling scheme of DSA++ protocol

- a reservation message for each uplink slot of the signalling period
- an announcement message for each downlink slot of the signalling period
- a feedback message for each slot that has been used for random access in the previous signalling period
- a field for other system signalling messages (acknowledgements, paging channel, info channel, etc.)

The number of messages within a downlink signalling burst and therefore the length of a signalling period depends on the available number of bits in a burst. Realistic period lengths are in the range from 20 to 30 slots. Transmission of announcement messages permits mobile terminals to leave a physical channel for short time intervals (e.g. to scan other channels or switch to power save mode) without loosing synchronism or missing a message. The feedback messages are used to enable fast collision resolution for capacity requests transmitted in contention slots. Random access is always performed in subslots by using specific algorithms for fast collision resolution like probing algorithms [9, 10].

## Logical Link Control

The ATM concept has been developed assuming a guaranteed high transmission quality, which is certainly true for the present fiber-optic based technology. However, the transmission over a radio link is far more unreliable and strongly depends on the environment. It has been shown [11] that the end–to–end error control scheme and header error control performed by the AAL protocols are not able to achieve the required error performance when one or several fiber-optic links are replaced by radio links. Instead, an additional error correction scheme adapted to the characteristics of the air interface is required. Because of the AAL protocol's demand on transparency, this additional error control scheme has to be performed at the air interface.

An ARQ protocol is able to reduce the cell loss ratio (CLR) but increases the cell delay by retransmissions. In the application considered, it might be not useful or even not possible to achieve a CLR on the radio link comparable to that of coaxial or fiber optic cables. Instead, the effort devoted to error correction has to be correlated to the QoS requirements of the ATM service class and can additionally be adapted for each VC. The QoS parameters to be considered are the *maximum cell delay* and the CLR.

For VBR services we developed the Selective-Repeatt-with-Discarding (SR/D) ARQ protocol [12] that is based on conventional selective reject ARQ protocols [13] but retransmits ATM cells as long as a service specific maximum delay is not exceeded. When exceeding its due-date, an ATM cell may be discarded. A good bit error detection capability for detecting faulty ARQ frames is combined with forward error correction to reduce the bit error ratio of the physical channel.

The actual number of retransmissions of an ATM cell results from its priority assigned by the ATM cell scheduler as well as the current channel load. The scheduling algorithm favours retransmissions, since a priority is determined considering the due-date of each ATM cell. Therefore, the increased cell delays are less resulting from multiple retransmissions of single cells, but more from the additional load caused by unsuccessful transmitted frames.

Especially for VBR services, discarding old ATM cells contributes to avoid and resolve congestion events, since the delay of the following cells can be shortened and the probability to exceed further due-dates is reduced. With conventional ARQ protocols, after the assignment of a sequence number to an ATM cell, discarding the ATM cell will result in a protocol failure. The SR/D-ARQ protocol has been extended to be stable even with discarding of ATM cells. Three different procedures can be applied:

1. An ATM cell may be discarded, before sending it the first time (assigning a sequence number to it).
2. An ATM cell being assigned a sequence number may be discarded if the receiver is informed by an explicit discard acknowledgement.
3. The buffering of successfully transmitted ATM cells in the resequencing buffer at the receiver waiting for retransmission of lost cells with lower sequence numbers can prematurely be ended to deliver the correctly received ATM cells just in time. When the delayed cell is received correctly later, it has to be discarded. To be able to prematurely end the buffering of received cells, the knowledge of the due-date (or ages) of the buffered ATM cells is required which has to be transmitted together with the cells.

The usage of a deadline oriented service strategy in the scheduler requires the generation of one ARQ instance per VC or virtual path (VP). This enables those ATM cells not belonging to the same VC to pass each other, so that it is possible to handle VCs with different priorities. An ARQ instance contains the sending and resequencing buffers.

Although virtual connections are bidirectional most of them will have unidirectional traffic flow only. In these cases there is no ATM traffic in the backward direction to carry piggybacked acknowledgements. On the other hand most of the time wireless terminals have parallel VCs and therefore parallel ARQ instances. With these parallel instances it may happen that the instance with the most urgent ATM cell does not also have to transmit the acknowledgement with the highest urgency. Hence, the information and acknowledgement fields of an ARQ frame can be occupied by different instances as long as both instances belong to the same wireless terminal. The two instances allowed to deliver the contents of an ARQ frame are determined by the ATM cell scheduler of the MAC layer. This requires two addresses inside the ARQ frame which is different from conventional ARQ protocols.

# 5 Conclusions

The protocols of the air interface of wireless ATM system which has been presented in this paper co-ordinates the access of different mobile terminals on the shared radio link. The base station as central instance assigns slots to the terminals according to their capacity requirements.

This situation is comparative with cable-based ATM access networks, since the a common medium has also to be shared among different terminals. The main differences between is the behaviour of the physical medium the the possible mobility of wireless terminals. Therefore the signalling concept of wireless ATM networks can be reused. The access on the shared physical medimum in a access network with a tree of fiber optical of coaxial caples can be easily controlled by using a central instance like in wireless ATM networks. Due the different behaviour of the physical medium only some characteristics (like period length, error correction) have to be adapted.

# 6 References


[1] D. Petras, A. Hettich, and A. Krämling, "Performance Evaluation of a Logical Link Control Protocol for an ATM air interface," in *PIMRC'96*, (Taipei, Taiwan), Oct. 1996.

[2] B. Walke, D. Petras, and D. Plassmann, "Wireless ATM: Air Interface and Network Protocols of the Mobile Broadband System," *IEEE Personal Communications Magazine*, vol. 3, pp. 50–56, Aug. 1996.

[3] C.-H. Rokitansky and Scheibenbogen, "Mobile Broadband System: System Description Document," tech. rep., RACE, R2067/UA/WP215/DS/P/68.b1, 1995.

[4] Members of Project: cellular ATM, "ATMmobil: Broadband Cellular ATM Access, specification," tech. rep., BMBF, 1997.

[5] ETSI RES10, "HIgh PErformance Radio Local Area Network (HIPERLAN), Requirements and Architectures," Draft ITR, Sophia Antipolis, France, 1997.

[6] R. Händel, M.-N. Huber, and S. Schröder, *ATM Networks: Concepts, Protocols, Applications*. Addison–Wesley, 1994.

[7] A. Wolisz, M. Schlaeger, J. Weinmiller, and H. Woesner, "Wireless access to high speed networks," in *High-Speed Networking for Multimedia Applications*, Kluwer Academic Publishers, Boston/Dordrecht/London, 1996.

[8] D. Petras, A. Hettich, and A. Krämling, "Design Principles for a MAC Protocol of an ATM Air Interface," in *ACTS Mobile Summit 1996*, (Granada, Spain), Nov. 1996.

[9] D. Petras and A. Krämling, "Fast Collision Resolution in Wireless ATM Networks," in *2nd MATHMOD*, (Vienna, Austria), Feb. 1997.

[10] D. Petras and A. Krämling, "MAC protocol for Wireless ATM: contention free versus contention based transmission of reservation requests," *Int. J. of Wireless Information Networks*, 1997. submitted for publication.

[11] D. Petras, *Development and Evaluation of a ATM airinterface*. PhD thesis, 97.

[12] D. Petras and A. Hettich, "Performance Evaluation of a Logical Link Control Protocol for an ATM air interface," *Int. J. of Wireless Information Networks*, 1997. submitted for publication.

[13] D. Bertsekas and R. Gallager, *Data Networks*. Englewood Cliffs, NJ: Prentice-Hall, 1987.