Support of ATM service classes in Wireless ATM Networks

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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 [1]. 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.

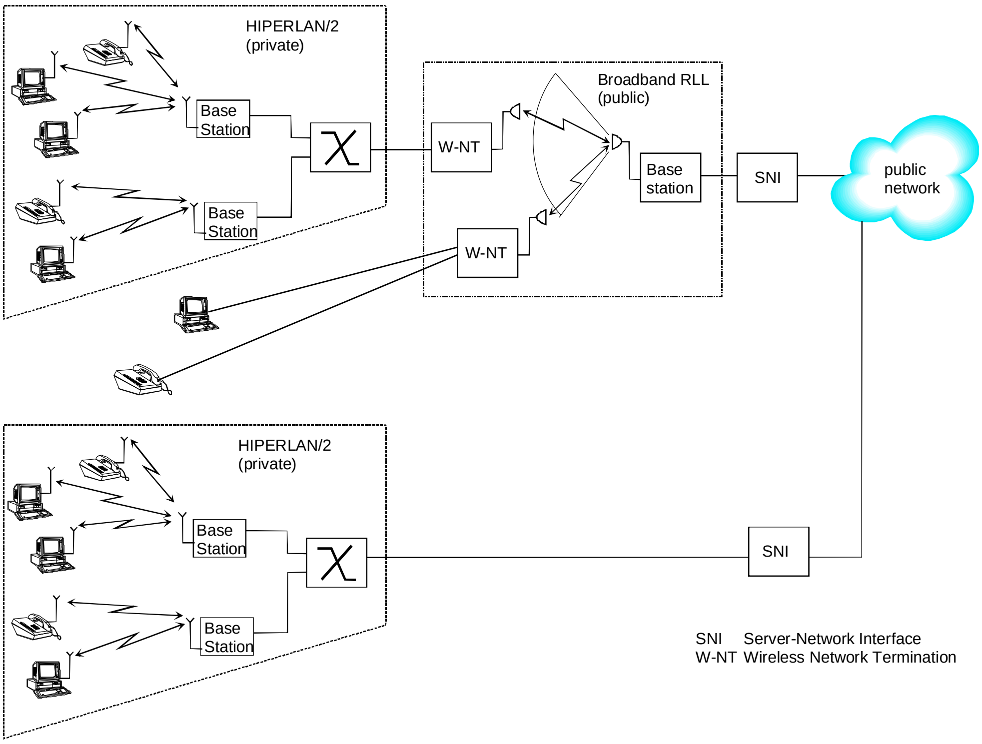

Fig. 1: Different applications for wireless ATM systems

Wireless ATM (W-ATM) systems are conceivable in different applications, cf. Fig. 1, e.g. *Radio-in-the-Local-Loop* (RLL) systems for substitution of cable-based infrastructure, indoor/outdoor broadband and multimedia cellular radio systems (HIPERLAN/2 [3]). The Bosch activities concerning W-ATM are carried out in several projects:

- **ACTS projects SAMBA, WAND, national project ATMmobil[1]):**
  investigation of HIPERLAN/2 and MBS type systems
- **Bosch internal project DMS (Digital Multipoint System):**
  investigation of wireless broadband access systems

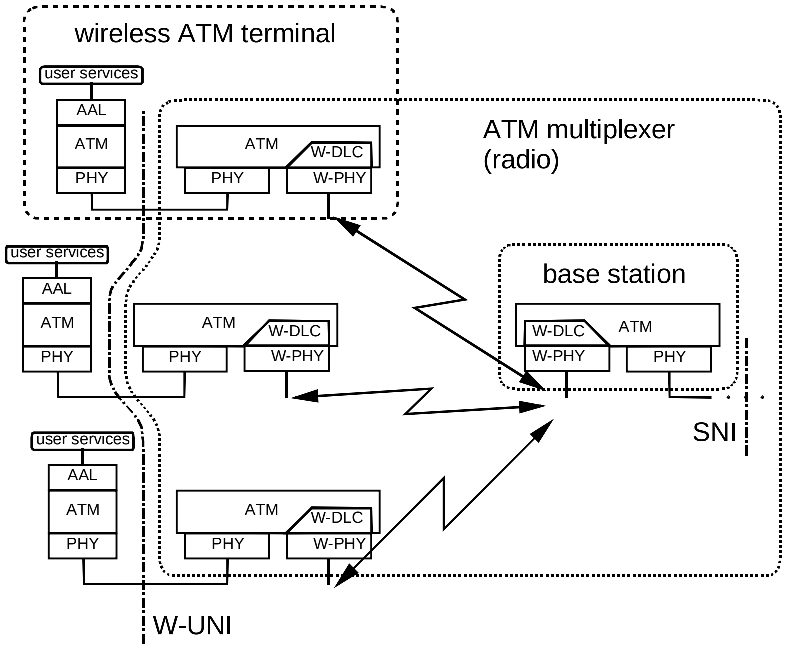

Fig. 2: Configuration of a radio cell of W-ATM systems

The typical configuration of a radio cell of W-ATM systems is shown in Fig. 2. At the air interface an additional protocol stack is necessary. It contains a wireless physical layer below the ATM layer and a *data link layer* (DLC) consisting of a *medium access control* (MAC) and a *logical link control* (LLC) sublayer which belongs to the lower part of the ATM layer. The MAC protocol is necessary in both RLL and HIPERLAN/2 systems to co-ordinate the access to the shared radio resources. The LLC protocol executing an additional error control scheme is only required in HIPERLAN/2 due to the terminal mobility which causes a far more unreliable behaviour of the radio channel than in RLL systems.

Radio cell as a distributed ATM multiplexer

In general, the users of W-ATM terminals request the same functionality and Quality of Service (QoS) as users of wired terminals. These user requirements can be transformed into the demand for building a (virtual) ATM multiplexer around the air interface which is characterized by a radio channel inside, cf. Fig. 2 [2]. The negotiated QoS for each virtual channel (especially of real-time oriented CBR and VBR services) is only possible, if the transmission order of ATM cells is controlled by the multiplexing function of the ATM layer. Usually fixed ATM multiplexers are employing an ATM cell scheduler executing an appropriate service strategy that focuses on two key targets [5]: avoiding overflow of buffers and controlling delays of ATM cells. While a fast transfer rate like 100 Mbit/s and more in wired ATM networks causes buffer overflows to be the more critical aspect, in W-ATM applications with slow transfer rates (e.g. 50.000 cells/s per carrier ~20 Mbit/s [3]) cell delay guarantees become more difficult to fulfil and the service strategy plays a major role in providing QoS.

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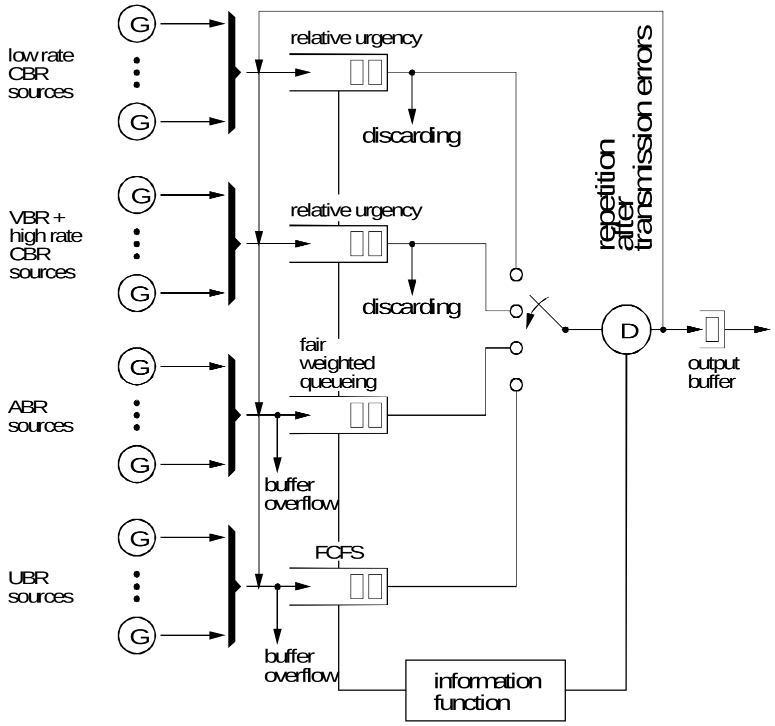

Fig. 3: Modelling the virtual ATM multiplexer as a distributed queueing system

A service policy has to differentiate between the real-time oriented CBR/VBR services and non-real-time ABR/UBR services. Considering their special characteristics, static priorities are introduced between the service classes (CBR > VBR > ABR > UBR), cf. Fig. 3. CBR connections can be easily handled due to their deterministic traffic characteristic. For ABR services the algorithms applied for fixed ATM multiplexers are used [5], while the UBR service class does not need specific handling. Within the CBR and VBR classes the Relative Urgency (RU) discipline [4] is considered, where the priorities of ATM cells depend on their waiting time and their connection specific QoS requirements. Under this strategy the probability for cells being late (exceeding their due-dates) is minimized. ATM cells which exceed their maximum delay will usually be discarded by the receiving application. Thus, discarding old 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.

Realizing the ATM cell scheduler at the air interface

The main difference between the virtual ATM multiplexer and a fixed ATM multiplexer is the distribution of the multiplexing function between wireless terminals and the base station. This requires a frequent notification of the scheduler in the base station about the status of the incoming buffers inside the wireless terminals, which is performed by transmitting capacity request messages. The scheduler is separated into two parts, cf. Fig. 4. The lower part is located in the MAC layer and selects the terminal which will receive a slot or is allowed to send. In the upper part, belonging to 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.

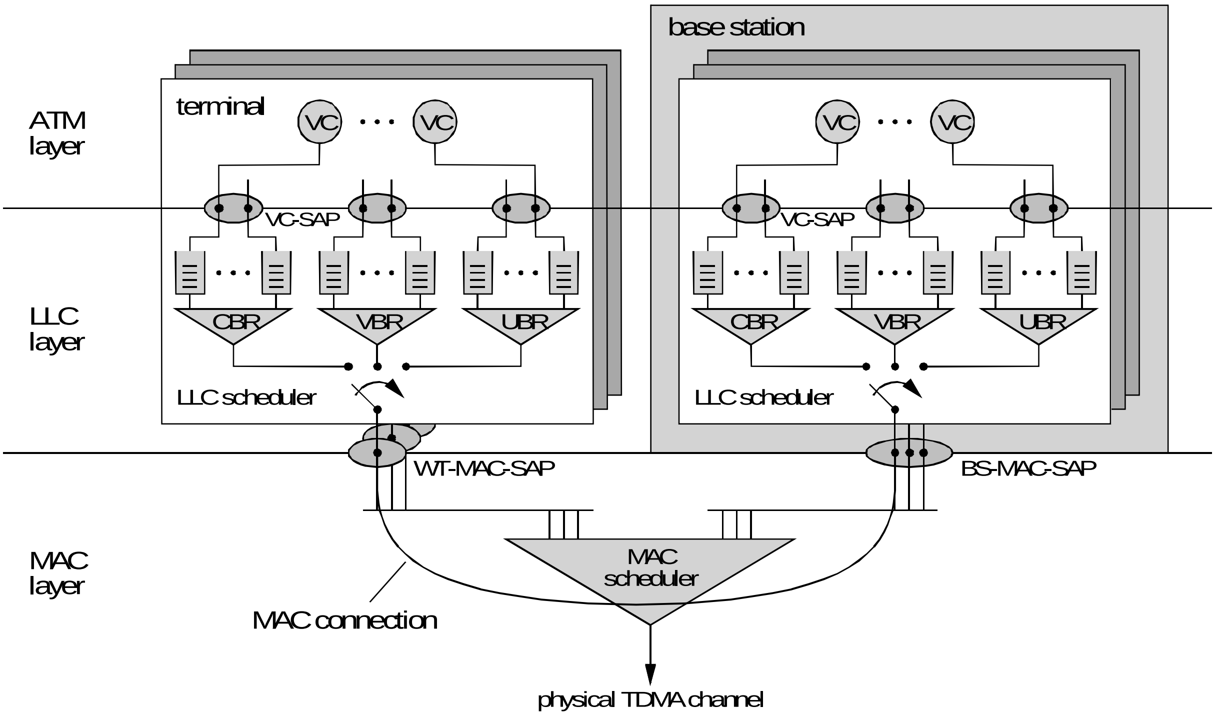

Fig. 4: Dividing the Scheduler into an LLC and MAC part

The MAC protocol realizes statistical multiplexing of ATM cells on a TDMA channel with a slot length able to carry one ATM cell together with the necessary overhead of the physical layer. The used *Dynamic Slot Assignment* (DSA++) protocol has been described in [6].

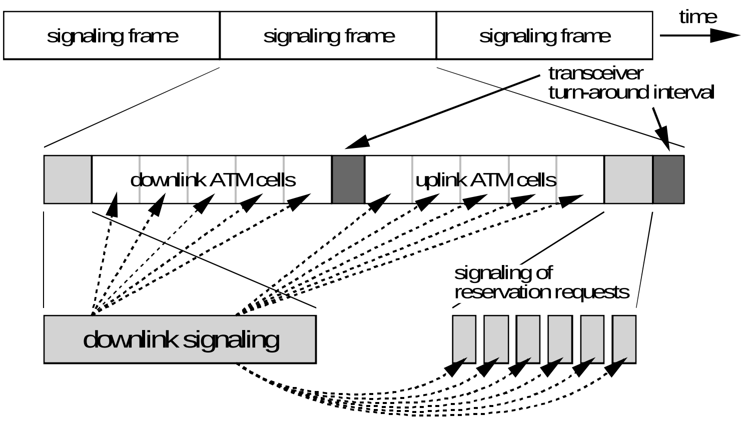

Fig. 5: Downlink signalling scheme of DSA++ protocol

During the planing phase the DSA++ protocol determines 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. Fig. 5.

Short slots of the Request Channel (RQCH)

The short time slots of the Request Channel (RQCH) in the uplink have a major influence on the performance of the whole system. They are applied for transmission of capacity request messages and in HIPERLAN/2 furthermore for transmitting acknowledgements of the error control protocol in the LLC.

The number of short slots in a period can be chosen from 0 to n with realistic n<50. The access protocol on the RQCH is called *probing algorithm* and can be considered as an unblocking adaptive identifier splitting algorithm [7]. It combines the advantages of random access and polling. Registered terminals are assigned a temporary identification number from a limited identifier space [0..*N*]. At the beginning of each period the probing algorithm divides the identifier space in a variable number t of consecutive intervals and assigns one RQCH slot to each interval. The l^{th} interval is starting with terminal i_l and ending with terminal i_{l+1}-*1*, with i_1=0 and i_t=*N*. An algorithm for finding the optimal interval borders has been analysed in [8][10]. The probing algorithm is able to limit access delays below a predefined terminal specific limit, as it is required for the support of realtime oriented multimedia services in ATM networks.

The length of a short slot $\tau_{short\_slot} = \tau_{slot}/r_{short\_slot}$ has a considerably influence on system performance. This has been evaluated by a simulation model according to [9]. It uses realistic source models of a multimedia application with symmetric load summarized in Table 1.

Table 1: Parameters of multimedia scenario

service	ATM class	λ per VC	#WT	Σ load	$\tau_{d\ max}$	$\tau_{d\ max}/\tau_{slot}$
voice	CBR	64 kbps	4	3%	2 ms	100
video	VBR	1 Mbps	2	22%	20 ms	1000
data	ABR	460 kbps	10	50%	undef.	undef.

In Fig. 6 (left) the mean delay of ATM cells from different service classes is shown for the probing algorithm when varying r_{short_slot}. It can be seen, that increasing r_{short_slot} leads to shorter delays, but only a slightly further improvement can be expected for $r_{short\_slot} > 6$. Fig. 6 (right) shows the complementary distribution functions of delays of ATM cells from all service classes for $r_{short\_slot} = 4$. It can be seen, that due to guaranteed maximum delays during collision resolutions with the probing algorithm, no CBR uplink cells (service with shorted delay requirements and most random accesses) are too late.

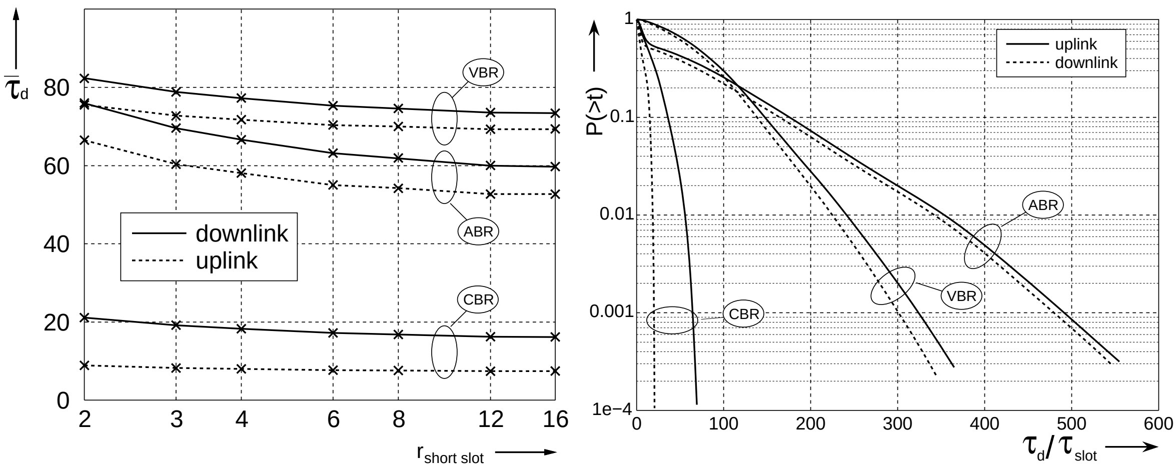

Fig. 6: Simulation of multimedia scenario:
left diagram: mean delay τ_d of ATM cells for probing algorithm with different lengths of short slots $\tau_{short\_slot} = \tau_{slot}/r_{short\_slot}$
right diagram: complementary distribution functions of delays for $r_{short\_slot} = 4$

References

[1] B. Walke, D. Petras, D. Plaßmann, „Wireless ATM: Air Interface and Network Protocols of a Mobile Broadband System". In IEEE Personal Communications, Vol.3, No.4, Aug. 1996

[2] D. Petras, A. Hettich, A. Krämling, „Performance Evaluation of a Logical Link Control Protocol for an ATM air interface". In PIMRC´96, Taipei, Taiwan, Oct. 1996

[3] ETSI RES10, „HIgh PErformance Radio Local Area Networks (HIPERLANs), Requirements and Architectures for Wireless ATM Access and Interconnection“. TR101031, Sophia Antipolis, France,1997

[4] H. Kist, D. Petras, „Service Strategy for VBR Services at an ATM Air Interface“. In EPMCC´97, Bonn, Germany, Oct. 1997

[5] COST 242 Management Committee, „Methods for the performance evaluation and design of broadband multiservice networks, Part I Traffic control“. Jun 1996

[6] D. Petras, A, Hettich, A. Krämling, „Design Principles for a MAC Protocol of an ATM Air Interface“. In ACTS Mobile Summit 1996, Granada, Spain, Nov 1996

[7] D. Bertsekas and R. Gallager, „Data Networks“. Englewood Cliffs, NJ: Prentice-Hall, 1987.

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

[9] D. Petras and A. Krämling, „MAC protocol with polling and fast collision resolution for an ATM air interface“, in IEEE ATM Workshop, (San Francisco, CA), Aug. 1996.

[10] D. Petras, A. Krämling, and A. Hettich, „MAC protocol for Wireless ATM: contention free versus contention based transmission of reservation requests“, in PIMRC´96, (Taipei, Taiwan), Oct. 1996.