Impact of Wireless Access on Traffic Management in ATM Networks

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ABSTRACT

Traffic management plays an important role in providing differentiated quality of service to the users and to support the integration of a variety of broadband services within a common ATM network. Wireless ATM access networks, which are currently under investigation in standards bodies as well as in first field trials, introduce new protocols that are able to cope with multiple access, error prone wireless channels and user mobility. The relation between mobile specific protocols and traffic management functions as well as their mutual impacts are discussed in this paper and possible solutions are outlined.

1. INTRODUCTION

Today we face two major trends in communications technology: multimedia and mobile communications. Thus there is a strong need for broadband wireless networks which support advanced multimedia applications. While for the fixed network new developments like ATM promise to provide differentiated Quality of Service (QoS), nowadays wireless cellular networks like GSM or IS-54 and wireless LANs like HIPERLAN1 (HIgh PErformance Radio Local Area Network) or IEEE 802.11 are mainly single service networks which are not able to meet all future demands.

Therefore, the wireless ATM working group of the ATM Forum started with the specification of various extensions to ATM protocols in order to cope with the mobility of users and wireless access [14]. Moreover, the recently formed ETSI BRAN (Broadband Radio Access Network) project (former ETSI RES10 working group) started to standardize ATM based wireless access networks as part of the HIPERLAN protocol family [2]. In parallel several companies like Olivetti [12] and NEC [15] among others as well as European R&D projects like the Magic WAND ACTS project [13] develop and investigate wireless ATM prototype systems.

In Figure 1 various application scenarios of wireless ATM are depicted. Whereas cellular wireless ATM networks may cover the area of a city or the center of it and allow the user to roam inside this relatively large area (or to another covered area) the possible user movement within wireless ATM LANs is restricted to e.g. a building or even only a floor. If wireless ATM is used for the wireless local loop configuration, the users are only allowed to connect to their corresponding access point. Hence, no specific mobility support functions like handover must be added to the ATM network.

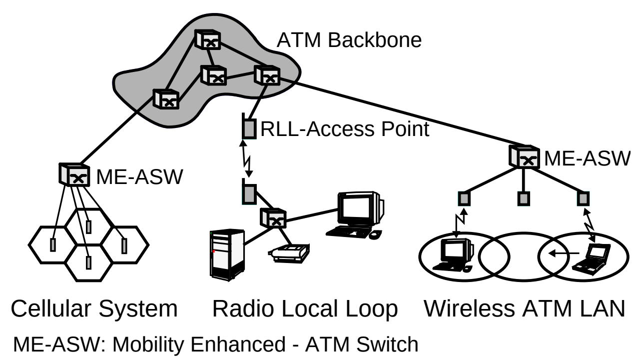

Figure 1: Wireless ATM application scenarios

In order to provide differentiated QoS, for fixed networks the ATM Forum has specified different ATM service categories (CBR, rtVBR, nrtVBR, ABR, UBR) and traffic management functions (e.g., UPC, CAC, traffic shaping, VP management) [1] which are able to guarantee the QoS objectives which are expressed through network performance parameter (see [5], e.g., cell loss ratio, cell transfer delay, and cell delay variation) negotiated upon connection set-up and are contained in the traffic contract. In order to allow the seamless attachment of wireless nodes to fixed ATM networks, both must support the same service categories. Hence, traffic management functions for both the wireless as well as the fixed network have to be designed such that they fulfil the specific control demands but also that they co-operate and thereby constitute a robust and efficient overall control framework.

The remainder of this paper is organized as follows. In Section 2 we describe traffic management in fixed ATM networks. Then Section 3 discusses in detail various problems that arise from wireless access to fixed ATM networks. In Section 4 we outline possible solutions to these problems and finally we conclude by giving an outline of future work.

2. TRAFFIC MANAGEMENT IN ATM FIXED NETWORKS

Traffic management in ATM fixed networks is based on the ATM service architecture which is discussed in the following.

2.1 ATM SERVICE ARCHITECTURE

The support and integration of different services (e.g. voice, video, data) in ATM networks requires specific protocols and service models at the ATM layer. In order to support typical broadband services while at the same time providing an efficient transmission resource usage, the ATM Forum defined several ATM service categories [1]. These can be distinguished by properties such as timing requirements, cell rate variability, QoS model, and resource allocation strategy (see Table 1).

	CBR	rt-VBR	nrt-VBR	ABR	UBR
timing	real-time		non-real-time		
cell rate	constant	variable			
QoS model	guaranteed			flexible	best effort
resource allocation	preventive			reactive	none

Table 1: Classification of ATM service categories

In order to provide strict network performance guarantees to constant bit rate (CBR) connections, the required resources are allocated in advance for the connection lifetime. CBR connections have real-time constraints, i.e. the cell delay as well as the cell delay variation must be kept bounded.

Applications with time varying bit rates are supported by the variable bit rate (VBR) service categories. During the connection establishment phase the application must be able to provide information about the mean and peak cell rates of the connection. As the VBR services have a guaranteed QoS, preventive resource allocation must be applied. The variation of the cell rates of VBR connections can be taken into account when allocating resources which may result in a more efficient resource usage. Depending on the timing requirements, VBR is further divided into real-time (rt) and non-real-time (nrt) subcategories.

For applications without real-time constraints and the possibility to adapt to the currently free network resources the available bit rate (ABR) service category was defined. The ABR protocol allows fast access to spare resources. Moreover, during connection set-up a minimum guaranteed cell rate is specified. Therefore, the cell rate is composed of a guaranteed and a flexible part and is bounded by the peak cell rate.

The unspecified bit rate (UBR) service doesn't provide any guarantees to applications. UBR connections may use any spare resources which aren't in use by connections of other service categories. Usually no explicit allocation of resources is made for UBR connections. Hence, UBR connections have lowest priority for resource allocation.

Besides the ATM Forum the ITU-T has specified a similar service architecture based upon so-called ATM transfer capabilities (deterministic bit rate, DBR; statistical bit rate, SBR; ABR; ATM block transfer, ABT). For further information about the ITU-T concept it is referred to [6]. Moreover, in the reminder of the paper we will stay with the ATM Forum notation.

In order to provide diversified ATM services, various agreements must be made during connection set-up. This is done in the traffic contract (see Figure 2) which is usually negotiated between the user and the network at the standardized user network interface (UNI) and is composed of several components which are described in the following.

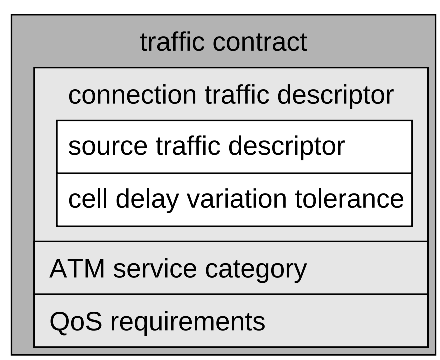

Figure 2: Elements of the traffic contract

The source traffic descriptor includes a list of all traffic parameter and describes the characteristics of the traffic profile. These parameter must be understandable by the network as well as the application and easily measurable. Currently peak cell rate (PCR), sustainable cell rate (SCR), maximum burst size (MBS), and minimum cell rate (MCR) are standardized [1, 6]. While the PCR parameter is part of all traffic contracts, SCR and MBS are used for VBR connections only. The MBS parameter specifies the maximum number of ATM cells which may be sent at PCR. The MCR parameter is used for ABR connections and specifies the guaranteed part of the ABR cell rate.

Besides the source traffic descriptor the cell delay variation tolerance (CDVT) parameter is part of the connection traffic descriptor. It describes how far and how long an application may exceed the PCR.

In addition to the connection traffic descriptor the used service category and the needed QoS must be specified in the traffic contract by means of ATM layer network performance parameter as standardized in [5]. Among others, these parameter are the cell loss ratio (CLR), cell transfer delay (CTD), and cell delay variation (CDV). The network performance objectives have to be guaranteed only for the part of the traffic which is conforming to the specified connection traffic descriptor. The treatment of non-conforming cells may be specified separately.

	CBR	rt-VBR	nrt-VBR	ABR	UBR
traffic parameter	PCR	PCR, SCR, MBS		MCR, PCR	(PCR)
network performance parameter	CLR, CTD, CDV		CLR	-	-

Table 2: Traffic and network performance parameter

The traffic and network performance parameter of all ATM service categories are summarized in Table 2.

2.2 TRAFFIC MANAGEMENT FUNCTIONS

Traffic management functions are mechanisms and protocols that directly or indirectly influence the flow of cells in an ATM network. Their task is to support the different ATM service categories (see Table 1) and to guarantee the negotiated network performance objectives with optimal network resource effort. The traffic management framework can be divided further into a traffic control and congestion control part. While traffic control functions try to avoid network overload situations, congestion control functions try to minimize the impact, intensity, duration, and spread of such situations. Overload situations are usually caused either by statistical multiplexing effects or incorrect network element operation.

The dynamics of ATM traffic flows range from cell level (microseconds) to hourly or even seasonally fluctuations. Hence, different traffic management functions operating at different time scales exist. All functions together constitute a hierarchical traffic management framework where long-term control functions are based on short-term control functions (see Figure 3). Most of the depicted functions are specified in a generic form, leaving the implementation of algorithms and protocols open. Only the algorithms for the usage parameter control (UPC) and the protocols for ABR are standardized. Moreover, only the UPC function and connection admission control (CAC) function are mandatory, all others are optional.

The CAC is a central part of the traffic management framework. Based on the traffic parameter, the selected service category and QoS it decides whether a new connection may be set up or not. A very simple version of the CAC is based on the peak cell rate allocation which is used for CBR connections. Obviously this strategy is very inefficient for VBR connections as the potential statistical multiplexing

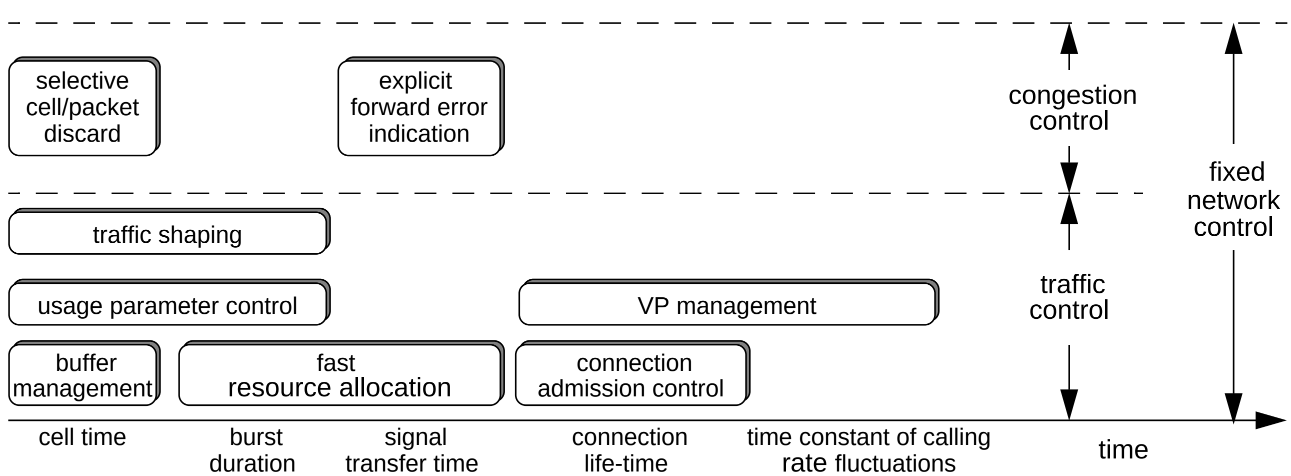

Figure 3: Classification of traffic management functions [9]

gain cannot be exploited. Especially for very bursty traffic this causes a waste of valuable network resources. Therefore, an equivalent cell rate [4] can be calculated which is bounded by the SCR and PCR parameter. This must take into account the traffic and network performance parameter of all existing as well as the new connection. Obviously there exists a trade off between a high statistical multiplexing gain and a low cell loss ratio. For ABR connections only resources for the MCR must be allocated while for UBR no resources have to be reserved.

If an application sends traffic which is not conforming to the connection traffic description, the network may not be able to provide the QoS guarantees of other conforming traffic multiplexed within the same network. Hence, the traffic parameter of all connections must be monitored which is done by the generic cell rate algorithm (GCRA) [1,6]. The GCRA is based on the leaky bucket mechanism which allows to monitor a rate parameter together with its tolerance value. By this means PCR and CDVT as well as SCR and MBS parameter are monitored together by one GCRA respectively. Non-conforming cells may either be discarded or given a lower priority. The traffic parameter are monitored at the UNI or network node interface (NNI). The corresponding functions are therefore denoted usage parameter control (UPC) and network parameter control (NPC) respectively.

Traffic shaping can be used at the UNI or NNI interface to change the profile of the cell flow. A subscriber may not know in advance the exact traffic parameter of the cell flow generated by his applications. As he doesn't want to waste money by reserving too much bandwidth he may ask for a SCR which is too small for some periods of time during the connection. Traffic shaping may be used to delay non-conforming cells until they become conforming to the traffic contract. This function can be located at the user or network side of the UNI. Inside the network traffic shaping may be used to eliminate changes of the traffic profile caused by asynchronous multiplexing.

Buffer management plays an important role in supporting and integrating different service categories. It includes all functions to partition and reserve buffer space and to handle the cells inside the buffer queues. Different strategies based on weighted fair queueing are discussed in the ATM community as possible approaches for the integration of ATM service categories [16]. During connection set-up, each connection is assigned to a FIFO (first in first out) queue with a specified service rate. Depending on the separation of different connections, a group of connections (e.g. a complete service category) or a single connection may be assigned to one queue. The sequence how different queues are served is controlled by a flexible scheduling strategy. In order to avoid overload, cell buffers may set a bit in the ATM cell header and thereby indicate that the applications should lower their rates (explicit forward error indication). Moreover, special cell and packet discard schemes can be used in order to improve network throughput.

Data traffic is usually characterized by very high cell rate variations and hence very bursty traffic. Besides it tolerates higher transfer delay and delay variation but demands very low error rates, because errors lead to retransmissions of data packets. Therefore, it is not feasible to use the same service categories as for guaranteed services. In order to support the specific needs of data traffic different protocols for fast resource management (FRM) were developed. The basic idea is to reserve resources for a connection only when it really needs them and to give them back to other connections when it doesn't need them. During connection set-up only the route through the network is determined. By sending special resource management (RM) cells the sender reserves buffer space and/or bandwidth in the network nodes along the selected route. Depending on the used protocol the reservation may change during connection lifetime. An adaptive mechanism that allows a fast and continuous adaptation of the sending rate is the ABR protocol specified by the ATM Forum. In this protocol the sender periodically inserts RM cells with the allowed cell rate (ACR). In a control loop all nodes on the way to the receiver may lower this rate and send the RM cell back to the sender. Another FRM protocol is ABT which has been standardized by the ITU-T [6].

The concept of virtual paths (VP) allows the logical separation of different service categories and can simplify CAC. The major drawback is the lower achievable multiplexing gain, e.g. one VP is fully loaded and therefore new connection requests on this VP must be rejected although there is spare capacity on the link the VP belongs to. In order to avoid such situations and increase the overall throughput, VP management tries to optimize the capacity assigned to each VP and to adapt the VP network configuration according to the current traffic load.

3. IMPACT OF WIRELESS ACCESS

Most of the existing proposals for wireless ATM access (cf., [7],[8],[11],[12],[13], and [15]) introduce a wireless data link control (DLC) layer below the ATM layer that uses a centralized access protocol in which the base station acts as an ATM multiplexer with distributed input queues located inside the mobile stations. The protocol reference model for a wireless ATM access network is depicted in Figure 4. As shown there, the radio resource management on the wireless channel cooperates with the resource management in the mobility enhanced ATM switch and the wireless DLC layer. In cellular networks besides special wireless DLC protocols specific support of terminal and

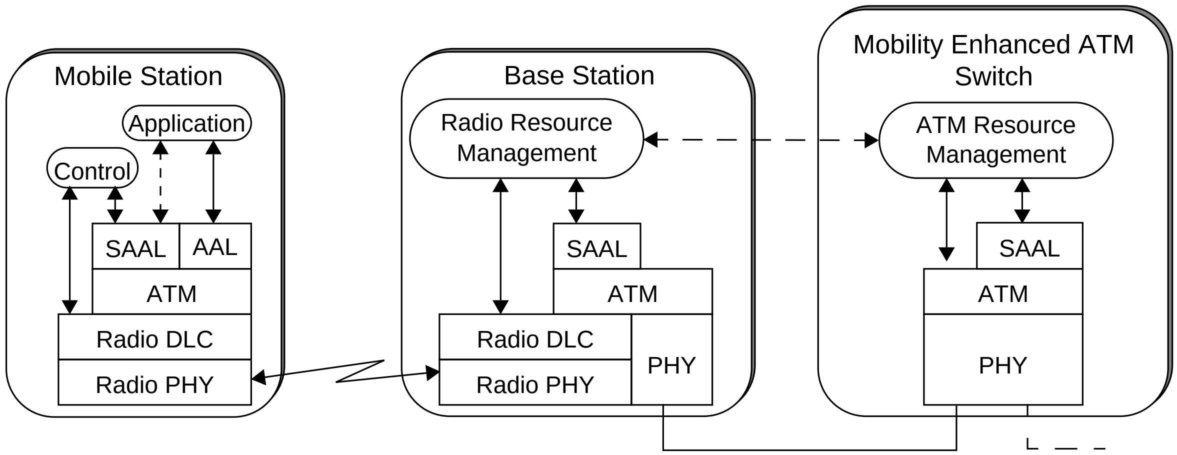

Figure 4: Wireless ATM reference model

personal mobility must be added to the wireless ATM access network. If a user moves from one radio cell to another while connections are established, a handover protocol takes care of the continuation of the connections.

Like the traffic management functions these wireless control functions operate at different time scales (see Figure 5). While the wireless medium access control (MAC) as well as the wireless logical link control (LLC) protocols operate on the cell and burst level, handover becomes effective on longer time scales up to the connection life-time. Therefore, different ATM traffic management functions are influenced by wireless DLC (MAC and LLC) and handover protocols which is discussed in the following two subsections.

3.1 SHORT-TERM EFFECTS

As mentioned above the wireless MAC protocol layer works like a distributed ATM multiplexer with a scheduler inside the base station and input queues in the mobile station. Additional input queues are located at the base station if time division duplex (TDD) is used, i.e. uplink and downlink share the same frequency band and are separated by different time slots. In most of the existing proposals for wireless ATM MAC protocols only input queues with queue length greater zero are served in order to allow a work conserving scheduling and to fully exploit the available bandwidth. Therefore, the scheduler inside the base station needs accurate information for fair and efficient operation. Obviously this is not a problem concerning queues located in the base station but for the queues within the mobile terminals an additional mechanism is needed to update state information. This can be done with special request packets (usually shorter as data packets) sent either piggy-backed to a data packet or in special time slots. The access policy on the uplink time slots used to sent request packets may be based on polling, random access, or a combination of both. Depending on the used mechanism and the content of the request packets the queue state informations available at the base station scheduler may be inaccurate and partially outdated. As the information updates consume transmission capacity which could otherwise be used for sending data packets, there obviously exists a trade-off between the update frequency and the accuracy of the state information at the base station. This mechanisms and the scheduling algorithm therefore heavily influence the ATM

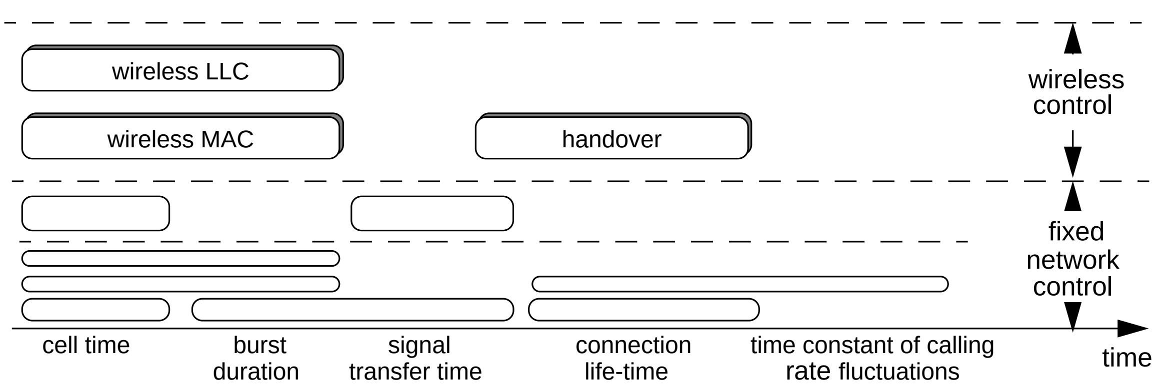

Figure 5: Relation between traffic management functions and wireless control functions

cell transfer delay and change the profile of the incoming source traffic (e.g., enlarged cell delay variation). Hence, traffic which is conforming to the traffic contract at the terminal side may be altered to non-conforming traffic through the wireless MAC protocol. Inside the ATM network (e.g., at the first ATM switch) UPC and/or NPC functions may therefore discard ATM cells if no special precautions are foreseen. A similar problem can be found in MAC protocols for passive optical networks [10] and other access network technologies.

Another problem induced by the wireless channel is the relatively high bit error probability. In order to guarantee fixed ATM like cell loss and cell error probabilities, forward error correction (FEC), automatic repeat request (ARQ), or hybrid schemes are used at the LLC and physical layers. Due to the asynchronous nature of transmission interleaving over several data packets cannot be adopted in combination with FEC. Hence, the ATM cell transmission is vulnerable by burst errors which are common in wireless communications. If the LLC layer recognizes an error by means of an error detection code the ATM cell must be retransmitted. In order to guarantee the cell sequence integrity all other ATM cells of the same ATM connection, which are correctly received later, must be delayed until the correct reception of this cell leading to an additional delay and delay variation. Cells may even be sent back to back. Depending on the ARQ protocol positive or negative acknowledgments for single or several ATM cells of each connection or mobile terminal must be exchanged between mobile station and base station. Again the uplink direction is the more critical part. Like request packets ARQ information may be piggybacked or sent separately. While FEC (adopted to a single data packet) doesn't introduce additional cell transfer delay or delay variation ARQ schemes even further change the traffic profile. Moreover transmission capacity needed for retransmissions is not available for other data transmission which causes a reduction of the effectively available bandwidth. During high error probability phases retransmissions in one connection sent at high priority may even reduce the QoS of other connections.

3.2 LONG-TERM EFFECTS

Besides these short-term effects introduced by wireless DLC protocols long-term effects caused by the movement of terminals must be considered during the development of wireless ATM networks. Changes of the radio cell while connections are established must be handled by new handover protocols. In order to allow a seamless transition into the new cell the handover protocol must be able to guarantee the cell sequence integrity and a low cell loss probability during handover. Moreover, a mandatory prerequisite for an successful handover is the availability of enough resources at the air interface of the new radio cell as well as within the fixed part of the access network. In contrast to nowadays cellular networks a single user in future wireless ATM networks will be able to claim a significant portion of the overall available bandwidth. Therefore, simple concepts that reserve channels for handover purposes without taking into account the current situation of the network (e.g., active connections and the location of the active terminals) will fail.

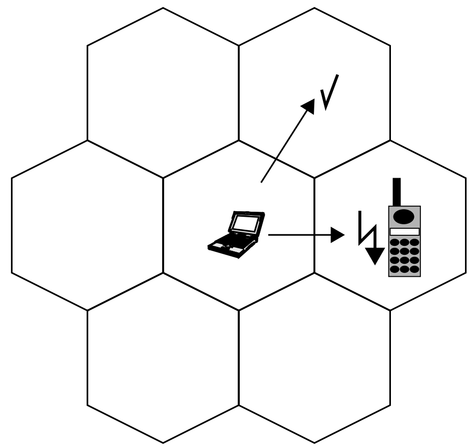

Figure 6: Example for successful and unsuccessful handover

In Figure 6 a handover example is given. While a successful handover of the notebook terminal to the radio cell on the upper right is possible, a transition to the right will lead to dropping its connections because most resources are already allocated to other terminals. In order to guarantee (at least to a certain extent) the continuation of connections after handover the connection admission control (CAC) of the fixed network should consider the movement of the users.

In order to provide low connection blocking probabilities enough capacity to set up new connections must be made available. The amount of needed resources is very much dependent on the spatial user density which may change with time. While people stay at work during the day they tend to stay at home during the night. Furthermore, there are hot spots with varying user density in space and time dimension. These occasions may occur periodically (e.g. once a week) or even just once. This variability must be taken into account for resource reservation at the air interface and in the fixed network.

4. INTEGRATED TRAFFIC MANAGEMENT

As described in Section 3 and depicted in Figure 5 several relations exist between the wireless control protocols and traffic management functions defined for fixed ATM networks. In order to constitute a robust and efficient overall traffic management framework for wireless ATM networks, the interactions between the different protocols has to be taken into account during the system design. Moreover, new protocols should be designed to co-operate with already existing mechanisms. In this section we propose and discuss approaches for traffic integration, enforcement of UPC conformance and handover support.

4.1 TRAFFIC INTEGRATION

In order to support differentiated QoS in an efficient way, wireless ATM DLC protocols must allow the isolation and integration of the different service categories, i.e. traffic from all service categories should be multiplexed in one network while at the same time the QoS of guaranteed services must not be violated. As mentioned in Section 2.2, buffer management strategies based on weighted fair queueing are able to provide these properties. Therefore we propose the use of self-clocked fair queueing (SCFQ) [3] within the wireless ATM MAC protocol. The adoption of SCFQ to MAC protocols is discussed in the following.

The ETSI BRAN project group is currently investigating MAC protocols which are based on time division multiple access / time division duplex (TDMA/TDD), i.e. different connections as well as both directions (uplink and downlink) are distinguished by different time slots. Several time slots are bundled to frames of fixed or variable length. A simplified model for wireless ATM MAC operation using TDMA/TDD access is depicted in Figure 7.

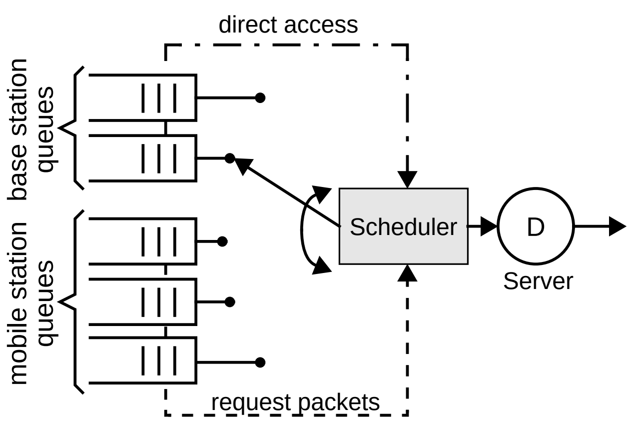

Figure 7: Model of wireless MAC using TDMA/TDD

The scheduler inside the base station decides about the allocation of time slots based on the available queue state information and informs the mobile stations through a frame control packet (FCP) about the allocation. In turn they send a data packet in the allocated time slot. As shown in Figure 7, the scheduler receives queue state information from the base station queues via direct access and from the mobile stations via request packets. The server (D) models the constant service time of an ATM cell on the radio link.

If SCFQ is used for the MAC protocol the scheduler needs information about the number of cells waiting in the queues, i.e. the mobile stations send the queue length together with the corresponding queue indicator to the base station which saves it in the corresponding queue length counter. Virtual time stamps are assigned to the first cells of all active queues according to the SCFQ algorithm. The cell with the lowest time stamp value is scheduled for transmission and the queue length counter for this queue is decreased by one. If it is still greater than zero, a new time stamp is calculated for the next cell of this queue. This is repeated until all slots of a frame are assigned or all queue length counters are zero. The complete scheduling information of the next frame is then inserted into the FCP and broadcasted within the radio cell. The mobile stations send their data packets in the assigned slots together with the request packet including the current queue length. If a queue in a mobile station is empty and a new ATM cell arrives, a request packet is sent in the random access channel to the base station and a virtual time stamp is calculated for the first cell in the queue.

Our approach outlined above is quite simple and has several advantages. If the queue length is greater than zero, time stamp values of the ATM cells can be directly derived from the time stamp value of the preceding cell in the queue. Hence, there is no need to transmit other queue state information in addition to the queue length. Moreover, as request packets are piggy-backed to data packets, mobile stations only have to send a request packet via random access, if new cells arrive at a previously empty queue. The size of the queue length information field can be limited to the maximum number of slots in a frame which is the absolute maximum number of cells which can be served within one frame. It can be shown that SCFQ is able to guarantee the QoS of traffic that is conforming to the GCRA, independent of other connections even if another terminal tries to send more than it is allowed to. Spare capacity is fairly shared among all active connections according to their corresponding rates. The service rates for CBR and VBR connections are directly derived from the CAC parameter, for ABR connections these are calculated from RM cell informations. In order to provide at least a minimum QoS to UBR connections, a provider may also decide to reserve some bandwidth for them and to assign a small service rate to these connections. To improve the performance of UBR service, cell and packet discard schemes could additionally be included in the MAC protocol.

If the radio channel between the base station and one mobile station currently has a high error rate and therefore causes lots of (high priority) retransmissions, additional bandwidth is needed which cannot be used for other connections. With our approach a service rate is also assigned for retransmission purposes. It is used by connections suffering from bad radio channel conditions. If all mobile stations experience good channel conditions this capacity is again fairly shared among the active connections. By reserving bandwidth for retransmissions the QoS of all connections with good channel conditions can still be maintained.

4.2 UPC CONFORMANCE

As described in Section 3.1, wireless ATM DLC protocols change the profile of the traffic. Hence, traffic conforming to the traffic contract at the mobile station may be altered to non-conforming traffic which may therefore cause cell discards by the UPC. One way to deal with this problem is to adapt the MAC algorithm to the conformance definition of the UPC function, i.e. GCRA. With this approach the conformance of the resulting traffic can be enforced but it still cannot remove the changes of the traffic profile caused by ARQ protocols. Hence clumping of ATM cells may still occur.

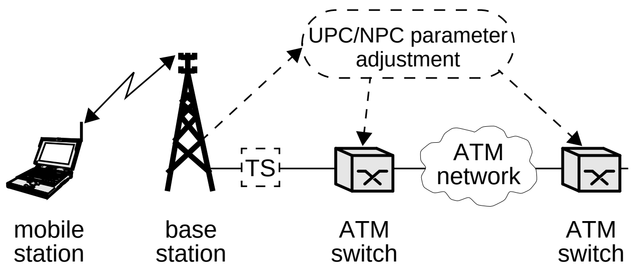

Figure 8: UPC conformance support

Two other approaches to support the conformance of traffic to the UPC/NPC functions are depicted in Figure 8. In the first approach, a traffic shaper (TS) at the output of the base stations or at the input of the ATM access switch may be used to enforce conformance. The major drawback of this approach is the additional delay introduced by shaping. A different approach to deal with changes in the traffic profile is to negotiate during connection set-up more tolerant UPC/NPC parameter, especially a higher CDVT value. While this method can easily be applied it also reduces the achievable multiplexing gain and therefore results in higher connection costs and less efficient use of resources. Moreover, it cannot guarantee UPC conformance but only lower the possibility of cell discards by the UPC. In order to improve this approach, also temporal changes of the UPC/NPC parameter for wireless ATM access networks could be envisaged, i.e. depending on the current radio link quality and load the parameter of all UPCs are continuously adjusted. This may be very costly, especially, if the service is provided by more than one network provider.

4.3 HANDOVER SUPPORT

In order to guarantee the continuation of connections during handover, resources must be reserved in neighboring radio cells and the access network in advance. These resources cannot be used for other guaranteed services in the neighboring radio cells. Therefore additional resources should be allocated sparsely. In order to support an efficient operation of this mechanism a new element describing the movement class (static, slow, fast) should be added to the traffic contract. Of course each movement class would be charged differently by a public provider as there are big differences in the required resources. Furthermore, through mobile station tracking the direction of the movement could be predicted and the amount of allocated resources can be adapted accordingly. If not enough resources are available in the new radio cell and therefore the QoS cannot be guaranteed, the connection may be renegotiated again and new traffic parameter may be chosen. Therefore, additional parameter like renegotiation properties may be added to the traffic contract.

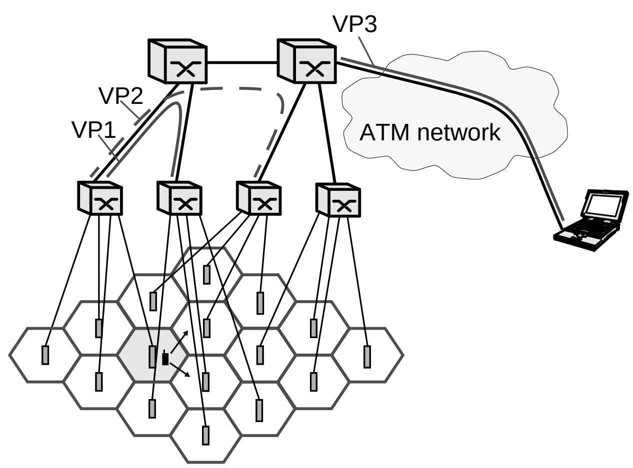

Figure 9: VP management operations for handover support

Additional bandwidth must be allocated inside the fixed network. In Figure 9 an access network for wireless ATM is depicted. In this example the mobile terminal in the shaded cell will move to one of the cells to its right which are connected to different access switches. For simple and fast handover the route of the mobile terminals' connections can be extended to the next access switch using the old one as anchor point. This handover mechanism can very much benefit from the concept of VPs. In order to prepare handover, VPs between access switches of neighboring cells may be set up in advance (VP1, VP2). Through these VPs the access switches are logically directly connected even if the VP traverses several switches (VP2). Hence, switching over of connections during handover is handled by the access switches and doesn't affect switches on the next higher network hierarchy level. The assignment of connections to VPs in other parts of the network (VP3) are not be affected at all by the movement.

Through the introduction of appropriate VP management functions which allow for a fast and flexible capacity reservation on VP level, successful handover procedures can be combined with efficient resource utilization.

5. CONCLUSIONS

Wireless ATM networks will have to support the same ATM service categories as defined for fixed networks. Problems that arise through wireless access and the mobility of users were discussed and approaches for the integration of wireless ATM protocols and traffic management functions of the fixed network were outlined. Currently we are investigating the performance of the proposed MAC mechanism. An important question for the implementation of this protocol is whether each single connection must be treated separately or all connections of a mobile station may be served together. In the latter case an additional multiplexer inside the mobile station decides which connection will be served next. While scheduling on connection basis is more accurate it also needs more bandwidth to update the queue state information. First results achieved by computer simulations can be found in [17].

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