MASCARA, a MAC Protocol for Wireless ATM

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Abstract*:* *The Medium Access Control (MAC) protocol of a Wireless ATM (WATM) system is a critical component as it lies between the traditional ATM layer and the RF-based physical layer whose characteristics are far from those of fibber- or copper-based conventional ATM media. The constraints imposed on the MAC protocol of a WATM system lead to consider the design of a Half Duplex (HDX), point-to-multipoint, error prone communication channel while regular ATM Quality of Service (QoS) must be enforced. To take into account the former constraints, a novel MAC protocol has been designed by the Magic WAND project. It is a TDMA-based access scheme which combines both reservation and contention methods. This paper gives an overview of this protocol by describing its time frame structure and mode of operation, by introducing how ATM traffic is scheduled and by presenting the Data Link Control (DLC) and MAC Control means used to guarantee efficient and proper operations.*

Introduction

This paper presents a synthetic description of the Wireless ATM (WATM) Medium Access Control (MAC) protocol currently worked out by the WAND project. The reader is first invited to have a look at [1] for a general description of the main telecommunications elements defined within the WAND project. Considering a wireless ATM system, such as the one defined in the WAND project, the MAC layer is a key component as it lies between two fundamental layers (the ATM layer and the RF based physical layer), which significantly differ in terms of transmission characteristics. A standard ATM layer indeed follows the conventional ATM architecture which assumes that the transmission media is almost error free, full duplex and point-to-point. Unfortunately to this assumption, a wireless channel is characterised by a quite high bit error rate (BER), half-duplex transmissions and point-to-multipoint broadcast transmissions. Therefore the challenge of a WATM MAC protocol is to overcome the harsh reality of wireless transmissions to be in line with the classical assumptions on which the ATM architecture relies.
The paper first introduces the timing structure of the MAC protocol, then describes how ATM cells are transmitted over the air, introduces how ATM traffic is scheduled along the time scale and ends with some Wireless Data Link Control (WDLC) and MAC Control protocol considerations.

Time structure

The MASCARA protocol is built around the concept of MAC time frame (TF); a variable length timing structure during which ATM data traffic and/or MAC control information flows on the air. As the WATM architecture is unbalanced among the various wireless stations (see [1]), and as the Access Point (AP) is a central point for all wireless communications ending in Mobile Terminals (MT), it is advantageous to operate the MAC protocol also in a hierarchical mode, where the AP plays the role of a master station. This mastery is translated in the charge given to the AP to schedule all traffic flowing

on the air. According to the service class of supported ATM connections, some part of the traffic can be ‘anticipated’ by the AP, offering therefore the possibility to carry it in a reservation mode. It offers the great advantage of avoiding contention, and therefore collision, when accessing the wireless communication medium. A contention-based method must be considered to deal with the part of the traffic that cannot be forecast by the AP. As it suffers from limited channel efficiency (due to collision resolution schemes), the MASCARA protocol limits the use of the contention-based method to the strict minimum. For the traffic leaving the AP, contention can be avoided as the scheduling responsibility is tied to the AP; for the traffic leaving the MT, contention is only used to issue reservation requests in order to receive (in a subsequent TF) some reserved bandwidth, or to transmit control information. The name given to this MAC protocol, reflects the combination of both reservation-based and contention-based access to the wireless transmission medium: **M**obile **A**ccess **S**cheme based on **C**ontention **A**nd **R**eservation for **A**TM, or MASCARA.
We distinguish the downlink traffic (from AP to MT) from the uplink traffic (from MT to AP). For this purpose, the TF is split into a downlink period (reservation-based), an uplink period (reservation-based) and an uplink contention-based period, as outlined in the following figure.

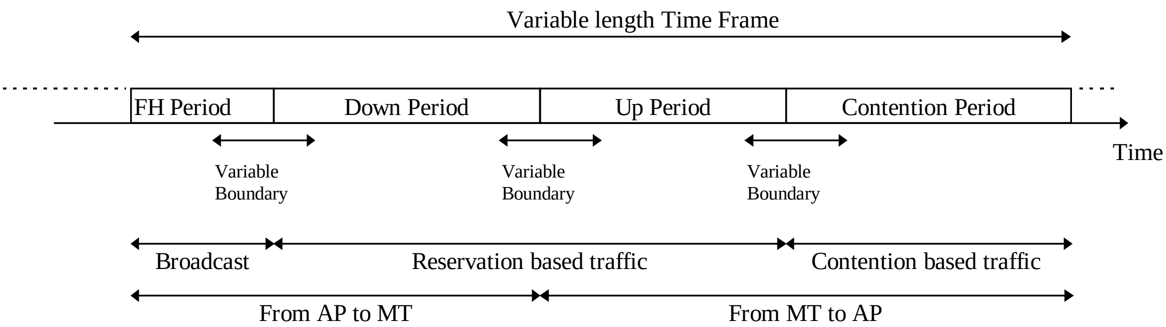

Figure 1: MAC Time Frame Structure

Each of the three periods has a variable length, depending on the instantaneous traffic to be carried on the wireless channel. For the two periods operating in reservation mode, it is possible that they collapse to empty periods when no reserved traffic is present. For the third period, a minimum size is kept to allow any new MT to signal its presence by sending a dedicated control packet. The TF is always beginning with a Frame Header (FH) period which is used to broadcast, from the AP to the MT, a descriptor of the current TF. As the size or the TF and of the periods can evolve from one TF to the next one, it is necessary that each MT can learn when each period begins and how long it lasts. Similar time frame structures have already been defined for Wireless Local Area Networking (WLAN) environments [2] and have proven their efficiency.
Each of the TF periods is further split into a variable number of time slots (TS) corresponding to the smallest time granularity on the air, as outlined in the next section.

Data transmission

It is well known that efficient wireless data transmission can be achieved if the amount of transmitted data is not too small, as the overhead induced by the physical layer is commonly much more large than for wired media. On the other end, the poor BER figures characterising the wireless transmission media ask for not-too-large data packets to keep the block error rate below acceptable values. In the ATM world, the information granularity corresponds to the ATM cell which is 53 byte long. This piece of data is quite short when compared for instance with conventional MAC frames (such as 802.3 or 802.5), so that it would be quite inefficient to send each individual ATM cell on the air as a single MAC Protocol Data Unit (MPDU). Therefore the MASCARA protocol defines the concept of ‘cell train’ which is a sequence of ATM cells sent as the payload of a MPDU. More precisely, each MPDU is constituted by a MPDU header, followed by a MPDU body. In term of duration, the time required by the physical layer to initiate a MPDU transmission (referred to as the PHY header) plus the time needed to send the MPDU header is equal to the transmission time of a single ATM cell. This

PHY+MPDU header duration allows to define a time slot (TS) size which guarantees high protocol efficiency, whatever the size of a MPDU is.
The size of the time slot has been chosen equal to the time required to transmit a single ATM cell: it is therefore possible to follow the TS based timing structure, whatever the number of transmitted cells contained in a MPDU. This is illustrated in the following figure.

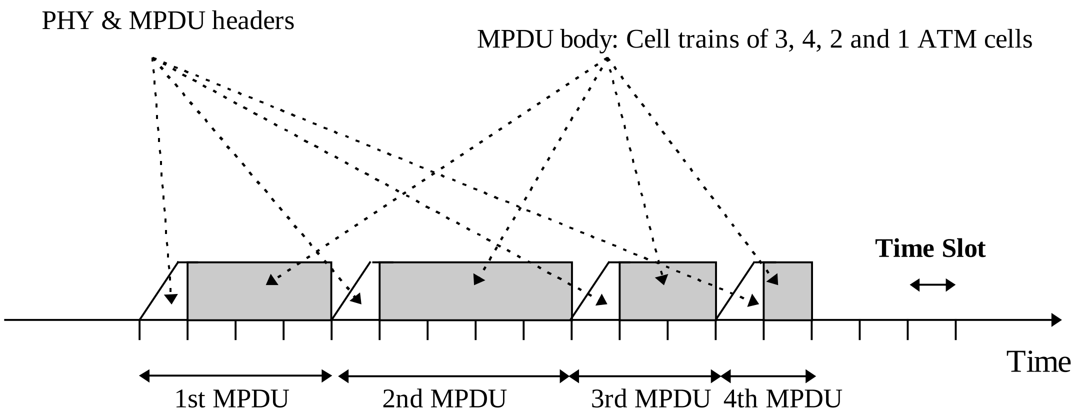

Figure 2: MPDU structure along the time slot scale

Traffic Scheduling

The traffic scheduling is performed at each new TF by a *Master Scheduler* entity running in the AP. This scheduler compiles various information, such as the service class and the QoS parameters of current ATM connections, the amount of outstanding traffic and reservation requests to determine the nature and volume of traffic that will be exchanged during the TF. This latter is described by a slot map which specifies the relative size of the three periods, as well as the assignment of all the time slots building up the entire TF. This slot map information is shared with all MTs as it is broadcast within the Frame Header (FH) control MPDU issued at the beginning of each TF. By recording which time slots are allocated to them, each MT can determine when it is allowed either to receive or transmit MPDUs during the TF. This approach enables also some power saving capabilities as each MT can enter some 'sleeping' mode when no traffic is scheduled for it.
As the Master Scheduler running in the AP specifies MTs how the various TS are allocated to MTs, it allows the MT to further identify which part of its outstanding traffic will be sent during the uplink period; this process is performed by a *Slave Scheduler* entity, which can therefore further optimise the protocol efficiency by sending, within the TS allocated for him by the master scheduler the part of its traffic that must be server first. Let us take a simple example to illustrate this behaviour. Let us assume that a given MT has two ATM real time Variable Bit Rate (rt-VBR) connections whose traffic parameters ask for the transmission of two uplink ATM cells in the next TF. The master scheduler, aware of these traffic parameters, specifies in the slot map carried in the FH control packet a total of 5 TS for this MT, corresponding to a single MPDU whose body carries a cell train consisting of 4 ATM cells, with 2 ATM cells for each rt-VBR connection. If it turns out that the transmission queue for the MT contains a single ATM cell for the first rt-VBR connection, and three ATM cells for the second one, then the slave scheduler of the MT may decide on its own to modify, within the constraints of allocated TS, the slot map built by the master scheduler by transmitting the four ATM cells present in its queue. This optimisation raises some technical difficulty as the AP must be able to receive information that differs from the expected one. The various possible traffic scheduling strategies are further detailed in [3].

Wireless DLC

As the quality of the wireless channel is significantly worse than conventional wired media (Bit Error Rate can reach values as bad as 10^{-3}), it is required to introduce some means to recover (even partly) from this situation. For this purpose a Wireless Data Link Control (WDLC) sublayer is introduced

within the MAC layer which controls errors through conventional techniques. The selection of the WDLC technique depends on the constraints imposed on each ATM connection, such as delay constraints or lossless transfer constraints. Candidate techniques may be for instance Forward Error Correction (FEC) schemes, Selective Repeat strategies, Go-back-N strategies or any other Automatic Repeat reQuest (ARQ) schemes. The selection of such a scheme is still a work item within the WAND project, but whatever technique used, the current MASCARA design point assumes that it results in some WDLC overhead added to each individual ATM cell transmitted on the air. It means that the cells which are found within the MPDU body are not really ATM cells, but rather 'DLC-ed cells' consisting of a WDLC header, followed by an ATM cell. Therefore the size of the TS, as introduced previously, corresponds in fact to the duration required to transmit a DLC-ed cell.
From the previous discussions, we can now outline the MASCARA architecture for the data path, which is identical, either in AP or in MT, as described in the next figure.

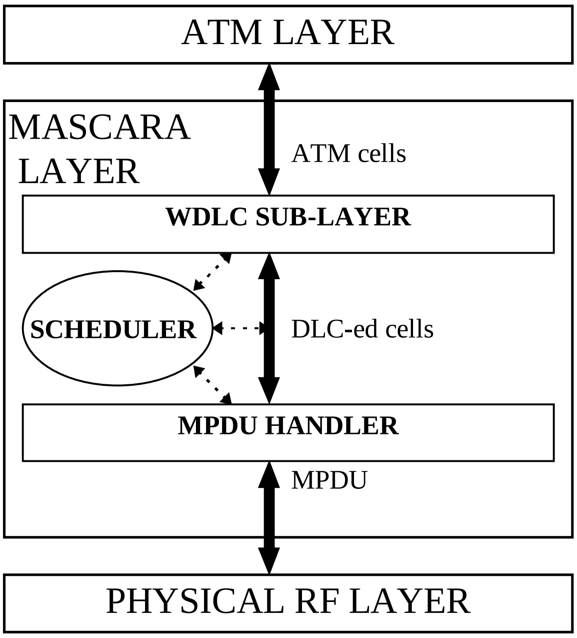

Figure 3: MASCARA architecture for the data path

MASCARA Control Protocol

Up to now, we have discussed how the MASCARA protocol handles the transmission and reception of ATM traffic on the RF physical channel. Besides these aspects, the MASCARA protocol includes also some MAC control features needed to establish, maintain and release wireless connections between an AP and a MT. The association phase establishes a 'communication pipe' between an AP and a MT, either after MT power-on, or after a hand-over (a MT moving from one 'old' AP to a 'new' one). The association phase can be seen as the sequence of the following steps. First, the MT must determine the presence of neighbouring APs pertaining to its WATM system. For this purpose, the MT listens to dedicated Beacon control MPDUs regularly issued by the AP and which carry information like their current load and the frequency channels at which other neighbour APs are operating. In a second step, the MT provides the list of heard APs, with their characteristics to the Mobility Management Control (MMC) entity (as described in [4]). In return, the MMC asks the MASCARA layer to establish an association with the best AP, according to criteria not described here. Then the MT moves to the corresponding frequency channel, synchronises itself to the AP slot time clock (thanks to the reception of FH control packets) and finally exchange a dedicated control MPDU to ask the AP to accept him as an associated MT. This last step relies on the exchange of several control packets between the AP and the MT, during which the AP allocates a local short identifier to the MT (it would be quite inefficient to rely on the 20-byte long ATM addresses to identify the source and destination of a MPDU). Finally the higher layers entities both in the AP and in the MT are informed of the association completion so that, for instance, location update procedures may be initiated.

Once an MT has been associated, the AP must continuously know if the association is still established. This could be easily detected by the presence of traffic generated by the WDLC sub-layer, but some specific control means must be introduced in absence of traffic; upon AP request, a control MPDU called ‘I_am_alive’ is issued by the MT to signal its presence. A de-association procedure allows the release of an established association.

Conclusion

We have presented a WATM MAC protocol which is characterised by its capability to adapt itself to instantaneous traffic conditions, while taking into account the specificity’s of ATM traffic, as recorded in the traffic and QoS parameters. The combination of reservation-based and contention-based access methods in a TDMA structure is the key factor offering both dynamicity to traffic changes and respect to QoS. Some means have also been introduced to recover from the poor quality of the transmission medium, allowing thus to respect the ATM traffic contract established at connection set-up. Finally some MAC control procedures allow to establish, maintain and release wireless connections between the mobile terminals and the access points.

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