

MAC Protocol for a wireless Point to Multi-Point ATM Access System

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ABSTRACT

This paper deals with the Medium Access Control (MAC) functions applied to a Broadband Wireless Point-to-MultiPoint (PMP) Radio Access System. The communication between the master station and the peripheral stations is based on a TDM/TDMA scheme in downlink/uplink direction: both the downlink and uplink data streams are a sequence of Bursts, each one allocated in a Time Slot of the multiplexing scheme. The suitable TDMA slot assignment in the uplink direction will be assured by the MAC processor located in the master station according to the state of connections being configured in each peripheral station; this status information is reported to the master station by means of uplink MAC signaling information. The protocol assures the fulfillment of QoS parameters of each connection belonging to different classes of traffic defined in international bodies. In this paper the MAC algorithms and the related information streams are further dealt with.

1 INTRODUCTION

This paper deals with the Medium Access Control (MAC) functions applied to a Broadband Wireless Point-to-MultiPoint (PMP) Radio Access System.

The system uses fixed bi-directional radio connections (line of sight) between a master station and a number of peripheral stations, in order to convey broadband services between a broadband core network and users' premises.

It is based on an ATM core transport platform, capable of delivering both variable bit rate and constant bit rate service classes (e.g. IP, native ATM, Frame Relay, n x E1/T1, fractional E1/T1) and providing users with a peak information rate of up to 25 Mbit/s.

The use of ATM transport technology makes it easier to provide dynamic bandwidth assignment and statistical multiplexing, allowing sharing of the radio medium among several hundreds of users, with substantial economic benefits for the access operators.

The communication between the master station and the peripheral stations is based on a TDM/TDMA scheme in downlink/uplink direction: both the downlink and uplink data streams are a sequence of Bursts, each one allocated in a Time Slot of the multiplexing scheme. While the downlink data stream will be a continuous sequence of bursts broadcasted to all peripheral stations, the uplink will be a discontinuous single-burst point-to-point transmission from each peripheral station to the master station.

The suitable TDMA slot assignment in the uplink direction will be assured by the MAC processor located

in the master station according to the state of connections being configured in each peripheral station; this status information is reported to the master station by means of uplink MAC signaling information.

The protocol assures the fulfillment of QoS parameters of each connection belonging to different classes of traffic defined in international bodies (e.g. ATM Forum traffic management specification 4.0).

In this paper the MAC algorithms and the related information streams are further dealt with.

2 SYSTEM DESCRIPTION AND NETWORK ARCHITECTURE

The access networks in today and tomorrow telecommunication market have to efficiently handle every traffic type, spreading from legacy services (such as POTS and ISDN) to new multimedia (Internet, VOD, etc.) and distributive services.

One technique that has the potential to fulfill these requirements comes out from the combination of two concepts: "wireless PMP" and ATM, into a single system: the broadband wireless PMP ATM access system.

In the following the basic architecture of such a system is dealt with.

The Broadband Access PMP System provides wireless broadband access to the operator service nodes (POPs) from remote customer locations.

As shown in Figure 1, each remote location is served by a peripheral station that is able to offer a variety of service interfaces to end users. The peripheral station has a two-way full duplex radio link to the master station, which is connected to the Core Network with different types of trunk interfaces.

Subscribers can have access to the full range of services by means of various standardized user-network interfaces.

The master station provides also standard Core Network interfaces, to transparently connect subscribers to the appropriate service node. The system allows services to be provided to a number of subscribers, ranging from a few tens to many hundreds of users in the same area, and over a wide range of distances (depending on the RF frequency used).

The system will allow a multi-cellular topology to cover a wide highly populated metropolitan area collecting various kind of services.

Moreover, with the cellular topology each cell, served by a central master station, can be split into a variable number of sectors, thus allowing efficient reuse of allocated spectrum and increasing system capacity.

The master station radiates radio carriers from 30°, 60° or 90° sectored antennas. A number of traffic channels

are multiplexed on each (downlink) carrier, in addition to signaling information to control the allocation of upstream traffic channels.

Each peripheral station is equipped with a high gain directional antenna in line of sight with the master station. It receives the multiplexed traffic channels and de-multiplexes the information directed to the user served by the peripheral station. In its turn it transmits back to the master station, on a separate frequency (uplink), traffic and signaling information. Uplink transmission is slot based TDMA that is each peripheral station is assigned a time slot to transmit.

One master station can support up to 150 Mbit/s of traffic payload per direction per sector.

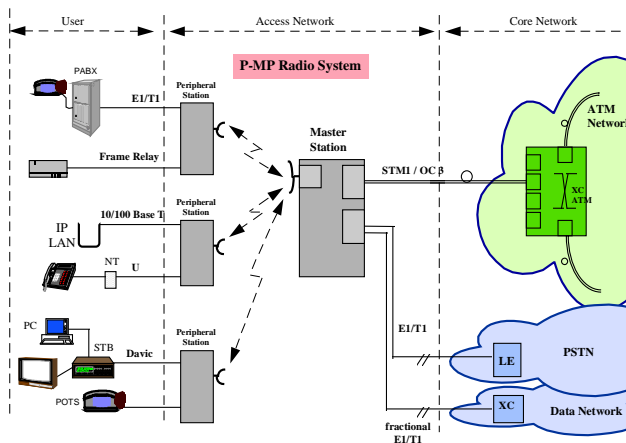


Figure 1: System Overview

3 MAC FUNCTIONALITY

Medium Access Control protocol is a central feature of a PMP system. It is responsible for assignment of upstream transmission bandwidth to peripheral stations allowing statistical multiplexing of traffic from different peripheral stations over the single upstream TDMA channel.

Each time slot is reserved to transmission from a single peripheral station that is activated in that particular slot by a message, called Grant, sent by the master station on the downstream channel.

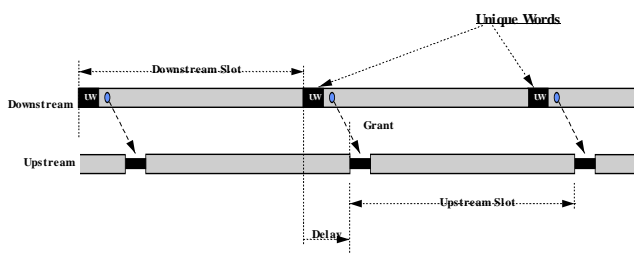


Figure 2 – FDD Uplink and Downlink channels

MAC functionality, located in the master station, is in charge of generating these 'grant' messages in order to satisfy bandwidth requirements of peripheral stations. In an ATM system, moreover, MAC functionality has to be able to guarantee that bandwidth assigned to each peripheral station allows the fulfillment of QoS parameters of each connection belonging to one of the

different classes of traffic defined in the international specifications.

Present MAC protocol is capable of not only serving connections related to narrowband and broadband services with required efficiency, but also to satisfy traffic parameters of broadband services, differentiating thus, within broadband services, treatment of connections belonging to different traffic classes. In the meantime it guarantees efficient use of all available transmission capacity of the upstream channel.

According to present MAC technique, upstream transmission is assigned by the master station to peripheral stations, following two different modalities:

- static allocation
- dynamic allocation

Static allocation is the periodic assignment of transmission slots to peripheral stations with a fixed rate.

This kind of assignment is used for serving constant bit rate services (CBR) complying with strict delay and delay variation requirements.

Dynamic allocation is made according to two different mechanisms:

- One mechanism called 'Dynamic guaranteed bandwidth' allocation guarantees that a peripheral station has always the possibility to be assigned, for certain connections, a certain amount of "minimum guaranteed bandwidth" defined during connection setup phase. The peripheral station can momentarily free a part of or all this "minimum guaranteed bandwidth", according to its instantaneous bandwidth requirements;
- A dynamic mechanism to partition bandwidth that remains available distributes "available bandwidth" in equal parts among all peripheral stations that have traffic to be transmitted, thus implementing a fairness model perfectly attending criteria specified by standardization bodies.

The combination of these two dynamic bandwidth assignment mechanisms are powerful for serving VBR, ABR and GFR connections, that is all the service classes that have minimum bandwidth requirements but can be statistically multiplexed.

It has been previously mentioned that a peripheral station can momentarily free guaranteed dynamical bandwidth: it can modulate assigned bandwidth according to two modalities:

- First modality which is on/off, is based on the sending by the peripheral station of an aggregated information about queue status related to those queues which rely on the dynamical bandwidth allocation; this information, indicating whether traffic to be transmitted is present or not can be used by the centralized unit to momentarily inhibit bandwidth assignment to the peripheral stations that don't have traffic waiting to be transmitted in connections with dynamical bandwidth allocation.
- Second modality is, instead, based on the sending by the peripheral station of a more detailed information about real bandwidth

requirements for guaranteed bandwidth connections and allows centralized unit, on the basis of received information, to change instantaneous bandwidth assignments.

The described protocol is able to treat in an optimal fashion bandwidth allocation for ATM classes like CBR and UBR and for different variable bandwidth traffic types with guaranteed minimum (like UBR+, VBR non real time, ABR, GFR, etc.).

The proposed MAC protocol offers instruments that allow master station to assign to each peripheral station a bandwidth which is evaluated on a instant by instant basis according to state information received by peripheral stations, always guaranteeing respect of traffic parameters and, in particular, of a minimum guaranteed bandwidth.

ATM layer is left the responsibility to guarantee other service parameters, like cell loss probability and delay constraints.

To satisfy QoS (Quality of Service) requirements of CBR traffic, static assignment is used; for other types of traffic, dynamic assignment is preferred.

MAC functionality must, thus, be able to operate, even simultaneously, in both ways.

4 MAC MESSAGES

In the following, MAC messages, an essential part of the protocol are defined.

In downstream direction the MAC master processor must send messages to assign the use of each upstream slot. The message that carries assignment information is called "Grant".

Grants carry the following information fields:

1. Type of slot to be transmitted (user traffic, operation and maintenance, etc.);
2. Identification number of the peripheral station to which the slot is assigned (Connection ID or type of traffic is NOT carried).

Grant is protected with an error correcting code, because a grant which isn't received or is erroneously received can cause collisions or wasted slots with the effects of bandwidth waste and potentially an excessive Cell Delay Variation (CDV) for CBR traffic.

In the upstream direction, each peripheral station sends to the master station indications about (instantaneous) queue status and instantaneous bandwidth needed for dynamic bandwidth allocation. This message is called "Request".

Information fields are:

1. Aggregated queue status: the field carries information about queue status in the peripheral station without distinguishing among connections but cumulating information of all ATM connections that use dynamic bandwidth allocation. Static allocation connections are excluded.
2. Requested dynamic bandwidth, always less than minimum guaranteed bandwidth defined during connection setup phase, expressed as instantaneous required minimum cell rate or minimum requested bandwidth of the peripheral unit. This second information is

optional and is computed by the peripheral station on the basis of internal status (number of active connections and related instantaneous traffic).

This information reaches MAC master processor with a certain minimum periodicity, determined by a proper programming, as to guarantee fulfillment of all traffic parameters of active connections.

Request transport can take place with two different and coexistent modalities:

1. piggy-back in traffic slot: in the upstream slot transmission, the peripheral station to which the slot is assigned, transmits a Request as well as user traffic;
2. mini-slot: in special upstream slots of shorter duration, called mini-slots and assigned through particular Grants, a peripheral station transmits only a Request (plus physical layer preamble).

5 MAC PROCESSOR

As already stated the master station hosts the MAC master processor.

The MAC master processor, through proper Grant generation, performs bandwidth allocation in order to guarantee:

- Static bandwidth assignment (meaning by static that it can be modified by commands sent to MAC master processor, but non according to peripheral station queue status) of a certain amount of bandwidth to each peripheral station.
- Dynamic assignment of bandwidth to priority connections. This allocation scheme can be influenced by peripheral station queue status.
- Ex-equo assignment of bandwidth not assigned with previous mechanisms to all the peripheral stations that have traffic in the queue.

Static allocation corresponds to the assignment of a fixed capacity, equal to a constant grant rate, to a certain station, that is to a certain group of ATM connections with constant traffic profile.

Configuration information for static bandwidth allocation transits through proper maintenance and control interfaces and reaches MAC master processor control interface in the MS.

MAC master processor is not influenced by the status of the queue related to static allocation connections: for these connections no Request information is transmitted.

Static allocation is usually applied to CBR traffic, but it can be used also for VBR real-time and, in principle, it can be applied to UBR traffic with clear inefficiencies.

Static modality must guarantee a continuous Grant generation stream, correspondent to a certain predetermined capacity to each requesting station.

Grants needed to statically assign a certain constant capacity to a certain station are inserted in a table in proper positions; the table is shown as a circular stripe in Figure 3 to indicate that the table is cyclically scanned.

The position inside the table is decided by an algorithm whose task is to resolve conflicts if more than one station have contemporary right to a certain slot assignment; the algorithm assigns subsequent and

adjacent slots to the various stations thus introducing a Cell Delay Variation which is acceptable because equivalent to that introduced by an ATM multiplexer.

Grants extracted from the table during cyclical scanning are transmitted to the peripheral stations.

Table dimension must be such as to obtain granularity and minimum allocation as requested by system specification.

Each position in the table corresponds to a slot and can contain:

- A static allocation user traffic Grant for a particular station
- An Operation and Maintenance Grant for a particular station
- A Grant for a group of minislots thus addressed to a group of stations
- An available grant for dynamic allocation (free position)

Dynamic allocation is mainly used for traffic with variable traffic profile.

In Figure 3 MAC master processor functional scheme that implements static/dynamic Grant generation is shown.

Functional blocks in Figure 3 are:

- A Priority Scheduler, that selects the right FIFO from which Grant must be extracted in each slot choosing on the basis of FIFO status and priority. Static traffic is the highest priority.
- As many Grant Managers as the number of handled priorities. Slots that aren't assigned statically are dynamically assigned to other traffic types. In the figure three priorities are shown. Grant Manager function is repeated for each priority; only one priority will be therefore described in the following.
- Request Processor & Queue Status Mirror elaborates Requests sent by peripheral stations for that traffic priority, rebuilding in dedicated registers the mirrored queue status related to each station.

When the mirrored status indicates the queue of a station is not empty, a 'Pending request' information related to that station is active inside the MAC master processor.

'Pending request' can't be served until a down-counter associated to that priority of that station has expired.

This constraint realizes an automatic flux control on the upstream traffic in the system.

The starting value of the down-counter is such as to generate a grant rate equal to the dynamic guaranteed bandwidth of the peripheral station (within that priority).

The starting value of the counters is chosen at connection setup and can be modified during normal operation by the information carried by the Request.

All the counters in the master station are decremented at each upstream slot time. When a counter after downcounting from starting point to zero, expires, it is reset to starting point and a binary information called 'Expired Counter' associated to related peripheral station is set to 1.

Activation of both 'Expired Counter' and 'Pending Request' at the same time for a particular station corresponds to the activation of a 'Pending Grant' information associated to that station.

Another process scans all the Pending Grants at each slot time and inserts in the Grant FIFO a Grant of user traffic type with the identification number of the related peripheral station for each station that has an active Pending Grant. At the same time the process sets to 0 the 'Expired Counter' information.

One Grant is extracted from the FIFO at each slot that is not reserved to higher priority traffics.

If the counter expires when 'Pending Request' is not active, the counter is re-set to starting value and then it resumes counting, while 'Expired Counter' is set and stays at 1, so that eventual later activation of Pending Request will immediately cause Pending Grant activation.

Bandwidth not assigned according to previously described mechanisms (that is when, on Grant generation time, no Pending Grant is active and no static assignment is preallocated) is distributed in equal shares to all the peripheral stations that have at least one cell in queue in any connection which is handled by the dynamic modality (statically handled connections are therefore excluded) and related Grants are assigned cyclically to all the peripheral stations that have an active 'Pending Request'.

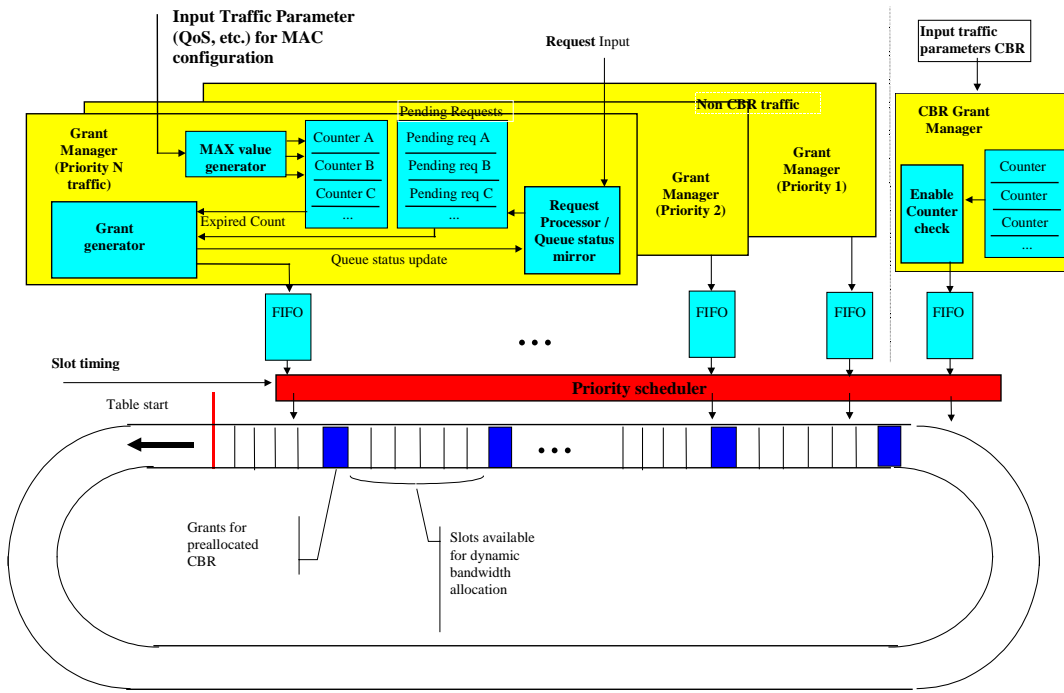


Figure 3 – MAC Processor