A MEDIUM ACCESS CONTROL SCHEME WITH SERVICE CLASS DISTINCTION FOR WIRELESS ATM (WATM)

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Abstract – **In this paper, a proposal of a medium access scheme with distinction of service classes for Wireless ATM is presented. The proposed protocol uses an efficient scheme of reservation for uplink channels and it allows facility to satisfy the QoS of each service class. The structures of uplink and downlink frames are explained in details. A delay analysis for the contention field of the uplink channel is carried out. An example of network project is made showing the number of average terminal in backlog and the transfer delay time spent to transmit the request packet**

keywords: MAC, WATM and QoS.

I - INTRODUCTION

Since ATM (Asynchronous Transfer Mode) was adopted by ITU-T (International Telecommunications Union - Telecommunication Standardization Sector) as the transfer mode technique for B-ISDN (Broadband Integrated Service Digital Network), many researches have been carried out to implement all aspects of the ATM network. So, the evolutions in high speed switching, in connection control, in traffic control, as well as in transmission techniques applicable to ATM, have been remarkable. Now ATM is a nature technology and is widely adopted in backbone applications.

An aspect that is still object of research is related to the wireless application denoted WATM (Wireless ATM).

A WATM distinguishes from a cellular telephony network or from wireless LAN (local area network) in the following aspects: the need of a flexible bandwidth allocation to handle different kind of services and the way to guarantee the QoS of each service.

These two aspects lead to important fields of research in the designing of a WATM network. For instance, since the radio channel is very noisy and ATM is not designed to support a high bit error rate, an error control scheme must be provided at some part of the network.

An another important aspect to study is how to provide an efficient radio channel access scheme. There are two common ways of reservation requests: contention free and contention based [6]. In the first, the parameters are always transmitted by polling and there are no collisions, but the maximum number of terminals is fixed. In the second, the MTs (mobile terminals) initiate the transmission of their dynamic parameters by themselves and it may have collisions.

The contention based doesn't limit the number of terminals but, depending on performance, this number is limited. Many access control schemes based in contention have been proposed in the literature [1]-[4].

The MAC proposals can be broadly classified into time-framed and not time-framed structures. The most representative of not time-framed MAC proposal is the DQRUMA (distributed queuing request update multiple access) [2].

DQRUMA uses a sequence of time-slotted channels without frame reference. Each channel in uplink transmission is composed of a mini-slot for requesting access (random access) followed by a slot for packet transmission. In this slot a piggybacking request field is also provided; when an MT has more than a cell to transmit, uses this field to inform the BS (base station), thus avoiding the need for a new random access.

An uplink channel can be converted by the BS into several mini-slots for requesting access. Each channel in downlink transmission is composed of a mini-slot for acknowledgment of request access followed by a slot for packet transmission.

DQRUMA is a flexible scheme, but it is not suited for real time applications because cannot guarantee the QoS of each service. However, DQRUMA has an efficient channel reservation based on piggybacking.

Most of the MAC proposals are time-framed structures. In PRMA/DA (packet reservation multiple access with dynamic allocation) [1], a frame is divided into several fields, each field having a number of slots. Each field is reserved for a type of service (for ex.: CBR, UBR, data, etc.), and the boundary of each field is variable.

Although PRMA/DA has variable field, it is not flexible because each field is reserved for each type of service.

A more flexible MAC scheme is proposed in [3] denoted MASCARA (mobile access scheme based on contention and reservation). MASCARA is based on a variable-length time frame which consist of two subframes, one for the uplink channels and the other for the downlink channels. The downlink subframe is divided into two periods: the frame header and downlink periods. The uplink subframe is also divided into two periods: uplink and contention period.

The channel allocation of downlink and uplink periods is made by the BS, using an algorithm called PRADOS (Priority Regulated Allocation Delay-Oriented Scheduling) [7].

MASCARA is a flexible scheme and is prepared to satisfy the QoS of each connection by using distinction of service classes. However, the reservation scheme of uplink channels is very complex.

In this paper, we propose an access scheme that combines the advantage of service class distinction of MASCARA and the efficient channel reservation of DQRUMA. In section 2, the proposed medium access control scheme is presented. The delay analysis of contention channel is carried out in section 3. Finally, the conclusions are presented in section 4.

II - Proposed Protocol: MAC with Service Class Distinction (MAC-SCD)

The proposed access scheme, medium access control with service classes distinction (MAC-SCD), uses an algorithm of cell scheduling in BS based on the priority of service classes. The priority order is CBR, rtVBR, nrtVBR, ABR and UBR, in descending order of priority.

Each terminal sends the request packets and it transmits the data packets, according to a contention and reservation algorithm.

For simplicity two carry frequencies are used: one for uplink transmission (from MTs to BS) and other for downlink transmission (from BS to MTs). But it is possible to adapt the protocol for only one carry frequency.

Fig. 2.1 shows the uplink frame structure. The uplink frame is divided into two fields: random access and cell transmission . The random access field is used by terminals to send request packets. This field is divided into two channels: S and QA. The S channel is used by MTs during signaling phase, that is, when the terminals start the communication with BS (including handoff). The QA channel is used when an MT is active but it stops temporarily to transmit cells and it wants to transmit again. This strategy allows the separation of new connection traffic and on-going connection traffic, reducing the number of collisions. The access identification (A-ID) identifies the connection number that is assigned by BS in signaling phase. The A-ID is unique for each connection in the cover area of BS. When an MT request a channel, it indicates the service class that it wants to transmit. It permits the BS to organize the priority order to schedule the uplink channels.

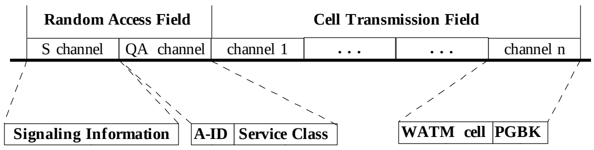

Figure 2.1 : Frame Structure of Uplink Channel

The cell transmission field is used by MTs to transmit data to BS. Each channel can accommodate a WATM cell and piggybacking bits (PGBK) that inform the continuation of transmission and the service class of data to be transmitted.

Several MTs can simultaneously use the S channel, thus collisions can occur. Collisions are handled by slotted Aloha scheme that permits the new attempt of request after random time of non acknowledged request. The length of cell transmission field is variable, being adapted in each new frame. The piggybacking value and the corresponding service classes is shown in Table 2.1.

Piggybacking Value	Service Class or Situation
5	CBR
4	rt VBR
3	nrt VBR
2	ABR
1	UBR
0	Station doesn't have data to be transmitted

Table 2.1 Piggybacking Values

Fig. 2.2 shows the downlink frame structure. The downlink channels are composed by three fields: acknowledge, identification and cell transmission. The acknowledge field is used by BS to send the acknowledges of the successful requests of MTs and it is divided into S and QA channels. The S channel has signaling confirmation and access identification (A-ID) that is used by MT while it is active. The QA channel has request confirmation of an active MT (in this case the channel content is only A-ID). If an MT doesn't receive the confirmation in the next frame, an MT must send the request again after a random time.

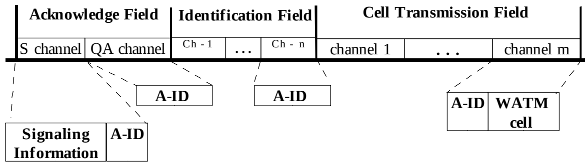

Figure 2.2 : Frame Structure of Downlink Channel

When BS sends an ack of a successful request from an MT, it updates the corresponding entry (A-ID) in the request table. This table has the following informations: A-ID, source terminal address, destination terminal address and piggybacking value.

The identification field is used by BS to inform the MTs the order of transmission in the uplink channels in the next frame. An MT recognizes its identification, it knows that can transmit (an active MT is always checking the identification field to know when it can transmit). The sequence of the A-IDs in the field is the sequence that the MTs must transmit cells in the next frame.

The cell transmission field is used by BS to transmit cells to MTs. A channel in the cell transmission field is composed of an A-ID and WATM cell. An active MT is always checking the A-ID field to know if the cells is transmitted for it (an MT makes the copy of WATM cell if recognizes its A-ID).

An MT has five buffers. Each buffer stores cell of determined service class (CBR, rtVBR, nrtVBR, ABR or UBR). Each MT can make several requests according to its needs. But the order of priority to be followed by the requests is: CBR, rtVBR, nrtVBR, ABR and UBR. The CBR class has the highest priority. An MT always checks the state of each buffer before making the requests.

III - Random Access Delay Analysis for MAC-SCD

In the proposed MAC-SCD protocol, the terminals send signaling information through S or QA channels. Since these two channels are accessed by terminals in a random basis (slotted aloha), contention can occur. When a collision is detected, the backoff strategy used in the proposed MAC-SCD is the new attempt after a random time. This strategy is used in S or QA channel. The time elapsed between a signaling packet arrival for transmission at an MT and the reception of it successfully by BS is main concern of the analysis in this paper. The above time averaged in all MTs is denoted average transfer delay E{T}. In this section, the average number of backlogged terminals E{N} will also be investigated.

For analysis, the following assumptions are made. S and QA channels are statistically independents. Thus only S channel will be analyzed. The same analysis can be applied for QA channel. New signaling packet arrivals to the network obey Poisson process with mean arrival rate ***S*** (packets/frame). The total packet arrival process (new and retransmission packet arrivals) is Poisson with mean arrival rate ***G*** (packets/frame). A transmitting terminal knows whether or not its transmission is successful after ***r*** frames. The processing time of BS is negligible in comparison with propagation delay, and a large or infinite number of terminals is considered.

For the calculation of average transfer delay ***E{T}***, it is necessary to determine the delay due the retransmissions. Fig. 3.1 shows the timing diagram for the S channel using the Slotted Aloha Scheme when the retransmission occurs.

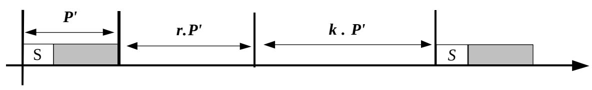

Figure 3.1 : Timing diagram of S channel for retransmission time analysis.

The following times are involved in Fig. 3.1. The transmission time of S channel is ***P***, and the transmission time of whole frame (random access field plus cell transmission field) is ***P'***. ***P'*** can also be written as :

$$P' = \alpha \cdot P$$

where

α is the ratio between frame and S transmission times.

The term ***r·P'*** is the time a terminal must wait until it knows the success or the failure of access attempt. ***r*** is the number of frames.

The term ***k·P'*** is the backoff time where ***k*** is the number of frames a terminal must wait until a new attempt. ***k*** is a random number (integer) defined by backoff strategy. The maximum number of ***k*** is ***(K-1)***.

The retransmission delay can be written as :

$$E\{R\} = E\{H\} \cdot (1 + r + E\{k\}) \cdot P' \qquad (1)$$

where

E{H} is the average number of the retransmission attempts.

$E\{k\}$ and $E\{H\}$ are given by [5]:

$$E\{k\}=\frac{K-1}{2} \quad \text{and} \quad E\{H\}=\frac{(1-q_n)}{q_t} \qquad (2)$$

where

q_n is the probability of a successful transmission given that is the new transmission and

q_t is the probability of a successful transmission given that the transmission is retransmission.

q_n and q_t probabilities are functions of S, G and K and they are given by [5]:

$$q_n=\left[e^{-G/K}+\frac{G}{K}\cdot e^{-G}\right]^K\cdot e^{-S} \qquad (3)$$

$$q_t=\left[\frac{e^{-G/K}-e^{-G}}{1-e^{-G}}\right]\cdot\left[e^{-G/K}+\frac{G}{K}\cdot e^{-G}\right]^{K-1}\cdot e^{-S} \qquad (4)$$

For slotted aloha, the expression of throughput is given by (according to [5]):

$$S=G\cdot\left[\frac{q_t}{1+q_t-q_n}\right] \qquad (5)$$

The average transfer delay $E\{T\}$ has four components:

- The packet transmission time (P);
- The waiting time after arrival until the beginning of the next frame;
- The delay due to retransmissions ($E\{R\}$), and;
- The propagation delay (τ) .

The average transfer delay ($E\{T\}$) is the sum of the averages of each component. The normalized average transfer delay ($E\{T_n\}$) is the average transfer delay divided by P'. Thus,

$$E\{T_N\}=\frac{1}{\alpha}+0.5+E\{H\}\cdot[r+\frac{(K+1)}{2}]+\tau_n \qquad (6)$$

where

τ_n is the normalized average propagation delay (equal τ/P').

The curves of Figs. 3.2, 3.3, 3.4, 3.5 and 3.6 below are obtained by numerical method using α = 10, r = 1, τ_n = 0.1 and K = 2, 5, 10, 20, 50 and 100.

Fig. 3.2 shows the relationship between throughput and offered traffic and the behavior when K becomes large. The maximum throughput in Fig. 3.2 is 0.3670 for K=100 (near of 0.367879 for K tending to infinite).

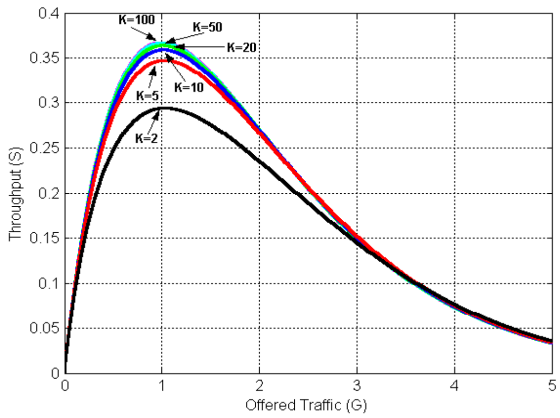

Figure 3.2 : The throughput versus offered traffic

Fig. 3.3 shows the normalized average transfer delay ($E\{T_n\}$) versus throughput (S) for various values of K. The small circles in each curve represent the maximum values of throughput which are obtained when the offered traffic is one. As can be observed in Fig.3.3, after the maximum values, the system operates in unstable conditions. Moreover, it is possible to see that after K=20 the maximum values of S are constant.

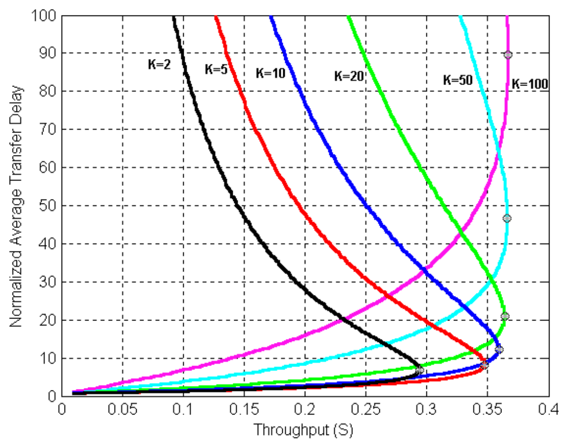

Figure 3.3 : Normalized average transfer delay versus throughput

Fig. 3.4 and Fig. 3.5 show the probabilities q_n and q_t versus offered traffic (G). It is possible to see that after K=20 , in both figures, there is no substantial difference among the curves (for K=20, 50, 100).

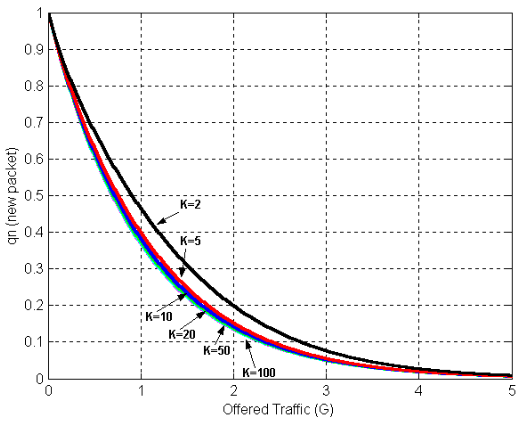

Fig 3.4 : Probability q_n versus offered traffic.

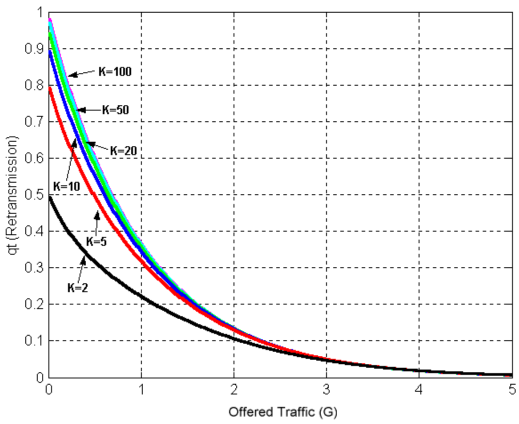

Fig 3.5 : Probability q_t versus offered traffic

Since backoff delay is equivalent to queuing delay in a queuing system, Little's Law can be used to determine the average terminal number in backlog (***E{N}***). The packet arrival rate to the network is given by ***S/P'*** (packets/second). The product of this arrival rate by the average backoff delay is thus the average terminal number in backlog:

$$E\{N\}=S\cdot E\{H\}\cdot\left[r+\frac{(K+1)}{2}\right] \qquad (7)$$

Fig. 3.6 shows the average terminal number in backlog versus throughput for infinite terminals. As it was observed in Fig. 3.3 , the maximum values of ***S*** are constant after ***K***=20.

As an example of network project using Fig. 3.2, 3.3, 3.4, 3.5 and 3.6 , it is considered ***K***=5, ***S***=0.2 and ***P***'=10mseg.

Using Fig. 3.3, the average transfer delay is given by

$$E\{T_N\} = 2.23 \quad \text{and}$$
$$E\{T\} = 2.23 \cdot 10 \text{ mseg} = 22.3 \text{ mseg}$$

Using Fig. 3.2, 3.4 and 3.5 , it can be determined ***G***=0.2800, q_n=0.7687 and q_t=0.6046. The probabilities of successful of a new transmission and a retransmission are 77% and 60% respectively.

The number of backlogged terminals is in average about 1 terminal; that is, a very small number.

From α = 10, then

$$p=\frac{p'}{\alpha}=\frac{10\,mseg}{10}=1\,mseg$$

Thus, the packet arrival rate considering all terminals is

$$\lambda=\frac{G}{P}=\frac{0.28}{1\,ms}=280\ packets/s$$

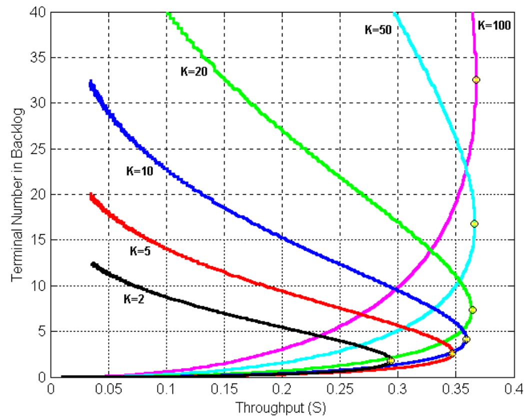

Figure 3.6 : Average terminal number in backlog versus throughput

IV - Conclusions

In this paper a medium access scheme with service class distinction for wireless ATM (WATM) was presented. The proposed protocol uses an efficient scheme of uplink channel reservation and it is prepared to satisfy the QoS of each service.

The proposed access scheme is very flexible and it permits that a terminal sends cells in the priority order, one per frame or several per frame.

By providing two separated contention channels, one for new connection traffic and other for on-going connection traffic, collisions are reduced.

A delay analysis of an uplink contention channel is carried out and the average packet transfer delay and the number of terminals in backlog are estimated.

The results of the analysis show that it is possible to keep a small packet transfer delay and a minimum number of terminals in backlog.

V - References

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