Performance of Traffic Scheduling for Wireless ATM Networks

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Abstract: *In this paper, the concepts of the MAC (Medium Access Control) protocol and traffic scheduling in the radio interface, as are currently worked out in the ACTS Project Magic WAND (Wireless ATM Network Demonstrator) are presented. Since the MAC protocol is based both on reservation and contention techniques, it has been named Mobile Access Scheme based on Contention And Reservation for ATM, or MASCARA. We focus on the performance of the scheduling algorithm of ATM traffic in the radio interface.*

Introduction

The Asynchronous Transfer Mode (ATM) technology is one of the fastest growing telecommunication technologies today. Combining it with wireless communications can provide to user a wide range of services together with the freedom of mobility. In order to enable a wireless ATM network, a MAC protocol in the radio interface must be introduced. This protocol must be able to support all or a useful subset of ATM services, and guarantee a QoS (Quality of Service) for every connection.

The MAC protocol is a critical component of WAND as its role is to provide wired-like services to ATM connections, in addition to controlling the access to the radio medium. The multiple access technique used in MASCARA is based on time division multiple access (TDMA), where time is divided in variable length time frames, which are further subdivided in time slots. Time slot duration is equal to the time needed to transmit the ATM cell payload (i.e., 48 bytes) plus the radio and MAC specific header. Uplink and downlink traffic are multiplexed using time division duplex (TDD).

Figure 1 shows MASCARA's components, the data flow (solid lines) and the control information flow (dashed lines). The Scheduler, on which we concentrate here, is responsible for scheduling the traffic transmitted through the wireless medium.

The Multiple Access Protocol

The MASCARA protocol is built around the concept of MAC Time Frame. The MASCARA time frame (Figure 2) is divided into three variable length periods; the downlink period, the uplink period and the uplink contention period used for MASCARA control uplink information.

The AP (Access Point) schedules the transmission of its uplink and downlink traffic and allocates bandwidth dynamically, based on traffic characteristics and QoS requirements, as well as the current bandwidth needs of all connections. The current needs of an uplink connection from a specific MT

(Mobile Terminal) are sent to the AP through MT "reservation requests", which are either piggybacked in the data MPDUs (MASCARA Protocol Data Unit) the MT sends in the uplink period, or contained in special "control MPDUs" sent for that purpose in the contention period.

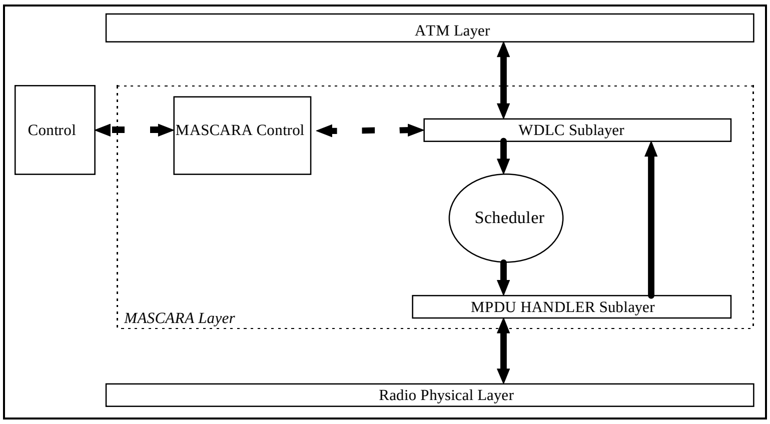

Figure 1: MASCARA components

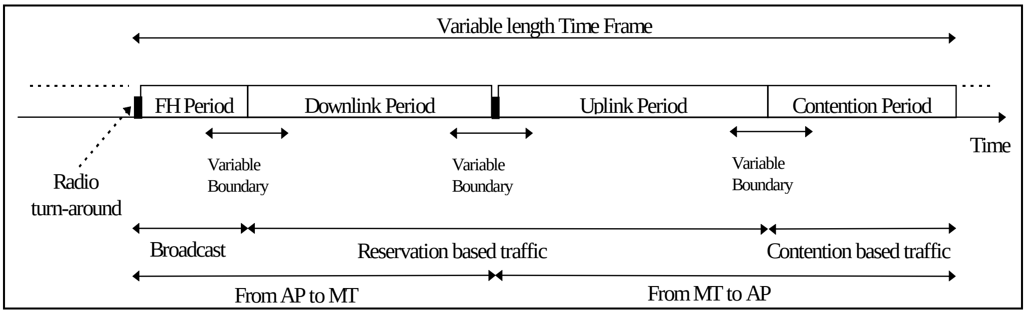

Figure 2: MAC Time Frame Structure

Traffic scheduling is in general used to offer, among other things: statistical multiplexing gain, utilization of bandwidth unallocated or allocated to idle connections, declared and real traffic consistency, maintenance of traffic characteristics of the connections, QoS requirements satisfaction.

In MASCARA, maintenance of traffic and QoS characteristics is even more important due to the limited and varying available bandwith. The proposed algorithm schedules transmissions over the radio interface, based on the priority class, the contractual characteristics, and the delay constraints of each connection, as indicated by its name: **P**rioritized **R**egulated **A**llocation **D**elay **O**riented **S**cheduling (PRADOS).

The algorithm operates at the beginning of each frame, and can be separated in two independent but simultaneously performed actions:

1. specification of how many ATM cells from each active connection will be serviced in the current frame, and,
2. determination of the exact time slot each serviced ATM cell will be transmitted.

For the first action, PRADOS combines priorities with a leaky bucket traffic regulator. A priority is introduced for each connection, based on its service class:

Priority number	Service class
5	CBR (Constant Bit Rate)
4	rt-VBR (real time-Variable Bit Rate)
3	nrt-VBR (non real time-Variable Bit Rate)
2	ABR (Available Bit Rate)
1	UBR (Unspecified Bit Rate)

The greater the priority number, the higher the priority of a connection.

For the second action, PRADOS is based on the intuitive idea that, in order to maximize the fraction of ATM cells that are transmitted before their deadlines, each ATM cell is initially scheduled for transmission as close to its deadline as possible. To attain high utilization of the radio channel, the algorithm is "work-conserving", meaning that *"the channel never stays idle as long as there are ATM cells requesting transmission"*. Consequently, the final transmission time of an ATM cell will be the earliest possible. PRADOS is described in detail in [1].

Simulation results

The simulation models were built using the OPNET tool and the built-in Proto-C language [4]. The radio channel has a capacity of 19.2 Mbits/sec. A time slot is used as a time unit. Its duration is $T_{slot} = 2.2 \times 10^{-5}$ sec. Since it carries an ATM cell (53 bytes) the capacity of the link is C = 45283 slots/sec.

We consider VBR sources with mean rate 512 kbits/sec, peak rate 2048 kbits/sec, and variance σ^2 (σ = 256 kbits/sec). Each source generates traffic modelled by means of a discrete-state discrete-time Markov process belonging to the class of D-BMAP (discrete-time batch Markovian arrival processes) [2]. CBR sources are modeled by a simple periodical generator with rate 64 kbits/sec and CDT (Cell Delay Tolerance) 10 msec (454 slots).

Performance of PRADOS algorithm using VBR connections with different delay constraints

In the following simulation results we have considered two VBR classes of connections with different delay constraints. The VBR1 class with CDT 5 msec (227 slots) and the VBR2 class with CDT 20 msec (908 slots). We consider that we have a constant number of 10 VBR1 connections (low delay class) and we examine the impact that will have on the loss probability and the mean delay of the VBR1 connections the gradual addition of VBR2 connections (high delay class).

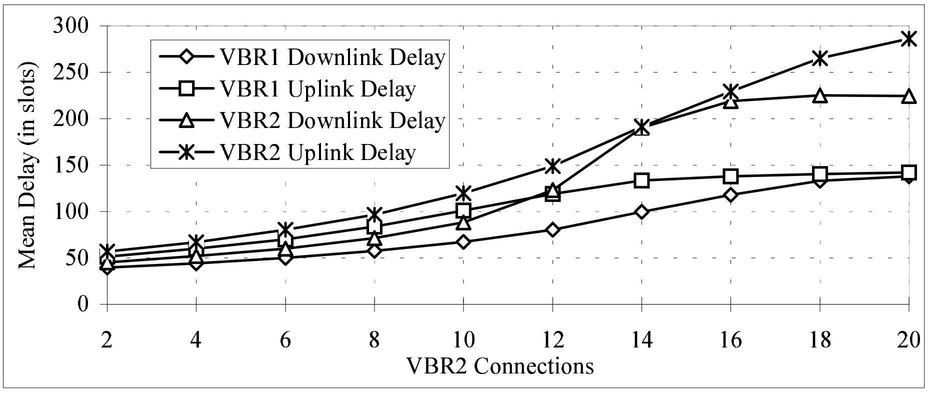

Figure 3: Mean delay for PRADOS with variable delay classes

We observe that as the total traffic load of the system increases (due to the addition of VBR2 connections) the increase in the delay of VBR1 connections is lower compared to the increase in the delay of VBR2 connections (Figure 3). This means that the algorithm intentionally delays the cells of VBR2 class (since those cells can survive long delays) while trying to serve as quickly as possible the VBR1 class' cells.

Concerning the loss probability, we observed that the rejection rate rises steeper for the uplink than the downlink connections for both classes as the traffic load increases. The loss probability for the high delay class remains in much lower levels than the one for the low delay class. This is because the PRADOS algorithm gives more chances to connections with loose delay constraints to be allocated than those with strict delay constraints.

VBR connections added to a constant number of CBR connections

In these simulation results we have considered a constant number of 50 CBR connections, and we gradually add to the system VBR connections.

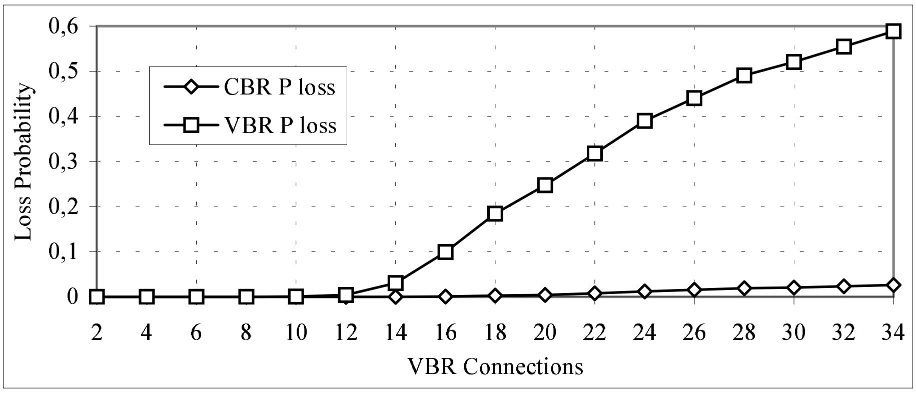

Figure 4: CBR loss probability vs VBR loss probability for PRADOS

We observe in Figure 4 that, as the total load increases, the loss probability for CBR connections remains in much lower levels than the one for VBR connections, meaning that the CBR connections receive a preferential treatment over other types of connections (which is the desired behavior of the scheduling algorithm) Note that the CBR loss probabilities is not particularly sensitive to the increasing number of VBR connections.

Performance of MASCARA with Multimedia Applications

In this section, we elaborate deeper into the performance of MASCARA in a "real" traffic situation. In a real application environment, MASCARA has to be able to effectively schedule all kinds of traffic, from real time audio and video to ftp file transfer and telnet sessions, all with very different QoS and traffic parameters. We tried to simulate this kind of scenario, using the Ptolemy simulation tool.

Simulation parameters

The simulations include three MTs sending traffic in the uplink direction. Each MT has 4 CBR, 2 rt-VBR, 1 nrt-VBR, 1 ABR, and 1 UBR connection. The downlink traffic consists of 6 CBR, 6 rt-VBR, 3 nrt-VBR, 1 ABR and 3 UBR connections.

We ran seven simulations with varying load of traffic. The number of connections remained the same in all the simulation runs, while the load produced by connections was set according to the parameters presented in Table 1. A lossless radio channel with a raw capacity of 20 Mbit/s was used.

The main objective was to observe the cell loss rates (CLR) and cell transfer delays (CTD) on a per traffic class basis.

Table 1: Traffic parameters

Run	1	2	3	4	5	6	7
	kbit/s	kbit/s	kbit/s	kbit/s	kbit/s	kbit/s	kbit/s
CBR	64	64	64	64	64	128	256
rt-VBR (μ/σ)	64/32	128/64	256/128	384/128	512/128	640/128	768/256
nrt-VBR(μ/σ)	128/64	256/64	256/64	512/256	640/256	758/256	896/256
ABR	1)	1)	1)	1)	1)	1)	1)
UBR (μ/σ)	64/32	64/32	128/64	128/64	256/64	256/64	256/64
Input load	3800	5300	7700	10900	14100	18100	22300

1) on/off 512 kbit/s CBR source, 50 ms on period, 50 ms off period

Results

In each simulation we calculated values for the buffer occupancy, transfer delay and loss probability. In this section we present the results for the delay experienced by the cells and the fraction of lost cells.

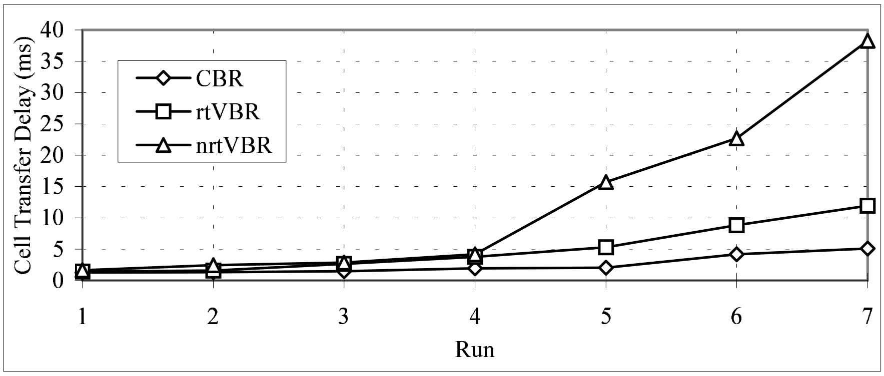

Figure 5: Cell Transfer Delay

The mean cell transfer delays are presented in Figure 5. The CBR and rt-VBR connections experience CTD not greater than 5 ms with a low to moderate load (runs 1 to 4). In runs 5 to 7, in which the input load is near the channel capacity limit or exceeds the limit, the mean delay slowly rises and settles close to the wireless hop CDT value given for these connections.

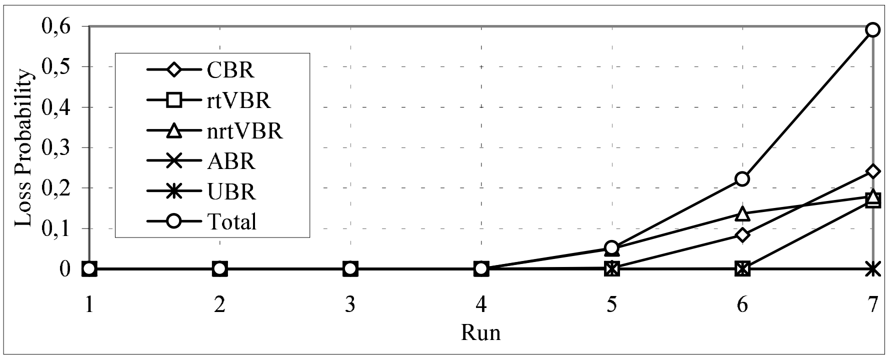

Figure 6: Loss Probability

Figure 6 shows mean cell loss probabilities of the traffic classes. We can see the CLR is under control as long as the input load stays under 10 Mbit/s (run 4). After that, the loss probability for delay-critical connections (CBR, rt-VBR and nrt-VBR) begins to rise starting from 0,06 (run 5) up to 0,6 in run 7. This is due to the relatively strict delay constraints set for these connections. In simulation runs 5-7, some cell loss is inevitable since the input load is near the channel capacity limit or exceeds it.

ABR and UBR traffic experience zero CLR at all load conditions. It seems that ABR and UBR traffic find enough time slots to get their cells over the radio interface, provided that they have enough lifetime. This behaviour is desirable since the ABR and UBR traffic classes are used for data traffic that requires a low CLR, but is more tolerant to CTD.

Conclusion

Based on these simulations, we concluded that the MASCARA protocol together with PRADOS scheduling algorithm is able to effectively prioritise the traffic according to the connections' traffic classes and QoS parameters. Delay-critical connections (CBR and rt-VBR traffic) experience a smaller CTD and cell delay variation than data-oriented connections (nrt-VBR, ABR and UBR traffic). On the other hand, because of the stricter delay requirements, CBR and rt-VBR (and also nrt-VBR) connections experience some cell loss under heavy traffic conditions, while UBR and ABR connections have a loss probability of zero.

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