Performance Evaluation of a MAC Protocol for ATM over Satellite

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Abstract

In this paper we first give an overview of various proposed MAC schemes for ATM over Satellite and analyse the performance of an Adaptive Random-Reservation Medium Access Control (MAC) protocol which can support all ATM service classes while providing the required Quality of Service (QoS).

Our study focuses on parameter optimisation of the multiple access schemes for ATM over a GEO satellite with on-board processing capabilities, considering various traffic mixes of CBR, rt-VBR, nrt-VBR and UBR.

It is shown that maximum throughput can be achieved by using this access scheme. A TDMA access protocol combining both Random Access and Demand Assignment Multiple Access (DAMA) is particularly suited for a scenario with a high number of terminals with very bursty UBR traffic (e.g. web browsing). UBR sources with short burst length access the slots remaining after the reservation procedure by random access which drastically reduces the slot access delay, at the expense of lower utilisation. However for UBR sources with burst sizes consisting of several ATM cells, reservation access provides higher throughput but the access delay is considerable longer.

The adaptive MAC protocol was designed to allow statistical multiplexing of ATM traffic over the air interface, especially for the independent and spatially distributed terminals. It is shown that the potential user population which can be served is considerably increased by statistically multiplexing bursty traffic over the air interface.

1. INTRODUCTION

In the recent years, significant progress has been made in the research and standardisation of ATM over terrestrial networks. Whilst optical fibre is the preferred carrier for high-bandwidth terrestrial communication services, satellite systems can play an important role in the B-ISDN. The main strengths of satellites are their fast deployment, global coverage and flexible bandwidth-on-demand capabilities.

After the terrestrial broadband infrastructure will have reached some degree of maturity, satellites are expected to provide broadcast service and also cost-effective links to rural areas complementing the terrestrial network. In this phase satellite networks will provide broadband links to a large number of end users through a User Network Interface (UNI) for accessing the ATM B-ISDN. Portable user terminals are expected to have relatively low average and peak bit rates (up to 2Mbit/s) and the traffic is expected to show large fluctuations. Therefore the access scheme will considerably effect the performance of the
system. Furthermore the cost and size of the terminal will have a large impact on the suitability of the satellite solution.

Recent proposals for broadband multimedia satellite systems [1]-[3] are examples for this scenario and increased the attention paid to ATM access over Satellite links. The ATM-Forum recently formed a Wireless-ATM (WATM) working group to make recommendations on wireless ATM issues including satellites. The methodology and standards developed for wired ATM networks are ported to the wireless environment, where possible. This will allow seamless integration of terrestrial and satellite networks.

The use of standard ATM protocols to support seamless wired and wireless networking is possible by incorporating a new wireless specific protocol sublayer into the ATM protocol model [4] as shown in Figure 1.

![ATM Protocol Model including Wireless Access Layer](image)

**Figure 1** ATM Protocol Model including Wireless Access Layer

Considering that satellite communications uses multiple access on a shared medium, a MAC layer, which is not present in traditional ATM networks is needed. The MAC protocol plays a central role as means of accessing the WPL from the ATM layer. The access scheme refers to the physical layer multiplexing technique to a share a common channel among multiple users of possibly multi-services. The problem of statistical multiplexing at the air interface is slightly different to that in the fixed network as illustrated in Figure 2. In the fixed network the problem is associated with control of bandwidth on an outgoing link from some multiplexing point after buffering has occurred. It is implicitly assumed that the access links from the source are dimensioned in such a way that they do not impose any constraints on the traffic (e.g. sources can transmit at their peak bit rate). In the air interface the constraint is on the bandwidth available in total to all sources before the buffering/multiplexing point.

In this paper we will define an efficient MAC protocol for the satellite environment and specify the assumptions for the proposed access scheme which can support all ATM service classes.
2. SATELLITE NETWORK ARCHITECTURE

The satellite network architectures for the support of ATM services employs a satellite with cell switching capabilities [5]. Network requirements are for a full meshed point-to-point and point-to-multipoint system. Suitable satellite architectures for meshed VSAT networks are expected to employ a spot beam coverage pattern to achieve the high uplink and downlink gain required for mesh connectivity between portable terminals. On-Board Processing (OBP) functions such as switching, channel set-up and multiplexing result in increased complexity on-board the satellite but offer added flexibility and improvement in link performance. The reasons for using OBP functions in this scenario are:

- To maximise the bandwidth utilisation of the satellite.
- To reduce the reservation delay.
- To improve interconnectivity.
- To reduce the ground terminal RF cost.

The 155 and 622 Mbit/s transmission rates conventionally associated with ATM are well above the maximum rates possible with today's portable terminal technology. However, in practice, most individual users will usually require significantly lower traffic rates, especially if there are only a few data or voice terminals located at a remote location. This large number of users with bursty traffic will need a cost-efficient way to communicate between each other and access the ATM/B-ISDN network.
3. FRAMEWORK FOR PROPOSED MAC PROTOCOL

3.1 DESIGN OBJECTIVES

The MAC protocol has to be designed to allow statistical multiplexing of ATM traffic over the air interface, especially in the uplink for the independent and spatially distributed terminals. The following design objectives are taken into consideration:

- Maximise the slot utilisation, especially for bursty traffic.
- Guarantee the QoS requirements for all service classes.
- Maximise frame efficiency by minimising overheads.

The minimisation of overheads is not an easy task, especially for ATM which was designed for channels with very good error characteristics (Bit Error Rates around $10^{-10}$). To minimise cell loss over the satellite link, channel coding has to be used to make the transmission more robust. A LLC header to facilitate error recovery mechanisms is optional and not in scope of this study. Finally a satellite specific header with satellite routing and wireless resource management fields is added to form a MAC packet as shown in Figure 3.

![Figure 3 Encapsulation of ATM Cells to MAC Packets and mapping to TDMA Frame.](image)

3.2 ACCESS SCHEMES

MAC layer access schemes can be typically categorised into four classes: Fixed Access, Random Access, Demand Assignment Multiple Access (DAMA) and Adaptive Access. The first three techniques have evolved to meet the needs of constant high traffic with long duration’s, sporadic traffic with short to medium duration’s, and sporadic traffic with long duration’s, respectively. Finally adaptive access is used to meet the needs of multiple media which consists of traffic with various characteristics. Thus to meet the design objectives an Adaptive Access mechanism seems to be the best choice. In this Section we will consider various proposals.

3.2.1 FIFO Ordered Demand Assignment-TDMA (FODA-TDMA)

In this proposal the TDMA frame is divided into 3 subframes, which are the control subframe, the stream subframe and the datagram subframe (for bulk and interactive data) [6], as shown in Figure 4.

The control subframe contains four small slots assigned cyclically to all the active stations. They are used by the stations to send the requests for stream and datagram capacity as well
as to send control information. The boundary between the stream and datagram subframe is movable.

Fixed-rate Demand Assignment Multiple Access (DAMA) is used for stream traffic and variable-rate DAMA is used for datagram traffic. The datagram allocations generally change in each frame since each station requests slots according to the status of its queue. This system uses three queues with different priorities at each ground station. The stream traffic FIFO queue has highest priority, followed by interactive data traffic FIFO queue. Bulk data traffic has the lowest priority since it is not delay sensitive.

A new station can enter the network by using an access slot which has a fixed position at the end of the frame and its frequency is every 32 frames.

3.2.2 Anticipated Reservation Protocol

In [7], the frame structure is similar, consisting of three parts: reservation subframe, bursty subframe, and stream subframe with movable boundary between the three parts. Delay sensitive traffic is conveyed using fixed-rate DAMA and delay insensitive bursty traffic uses an anticipated reservation protocol. Anticipated reservation means that the request for bursty traffic is sent when the terminal receives the first cell instead of the common store & forward approach. Another signalling packet has to be sent to the satellite when the complete burst has been received to reserve the necessary bandwidth.

The main drawback of this scheme is that if the burst duration is smaller than the reservation cycle, some capacity is lost.

3.2.3 Combined/Fixed Reservation Assignment (CFRA)

This access scheme is a combination of the anticipated reservation protocol [7] and the buffer threshold method and has been called CFRA [8]. It tries to improve the performance of the anticipated reservation protocol by distinguishing between short and long bursts. A fixed rate-DAMA assignment of Rmin is made at the beginning of a burst. If a burst is longer than a certain number of cells, extra capacity is requested. After a time-out interval where no cells are received by the station a capacity deallocation is requested. Fixed-rate DAMA is used for stream traffic as in previous schemes.

3.2.4 Movable Boundary Random/DAMA Access

A scheme which can support video, voice, and file transfer in a connection-oriented mode as well as connectionless interactive data is proposed in [9]. The frame is divided in three, as shown in Figure 5 by movable boundaries: A reservation subframe operated in random access mode, a Slotted Aloha channel for bursty data traffic, and a DAMA channel for all other traffic. DAMA channels have priority over random bursty traffic. This means that the
DAMA allocation is done first and the remaining bandwidth is available for slotted Aloha access. UBR traffic could be send using random access since no QoS guarantees are provided for this service class. In [10] a performance evaluation of this proposal for voice, video and file transfer is carried out, concluding that this scheme substantially improves the performance of the interactive data users.

Figure 5 Movable Boundary Random/DAMA Frame Format

3.2.5 Combined Free/Demand Assignment Multiple Access (CFDAMA)

This TDMA system [11] first allocates bandwidth to pending requests (fixed-rate and variable-rate DAMA). Reservation can be made using pre-assigned or random-access request slots, or piggy-backing on a data packet. Then it assigns the remaining capacity to terminals on a round-robin fashion. In this way it saves on reservation time for the bursty traffic.

The delay throughput performance is quite sensitive to population size. For low to medium sizes of terminal population pre-assigned reservation has better performance. For large populations and low throughput, random access reservation is more efficient because it reduces the long waiting time for a request slot.

3.3 MAPPING OF ATM SERVICE CLASSES ONTO MAC SERVICE CLASSES

To simplify the conceptual design of the MAC protocol, ATM service classes [12] can be mapped onto MAC service classes.

3.3.1 Mapping of Constant Bit Rate (CBR) Service Category

Fixed-Rate DAMA is ideal for connections with a constant bit rate such as the CBR service class in ATM networks. Before a connection is set-up, the terminal and satellite negotiate the Quality of Service (QoS) parameters. These QoS parameters determine the characteristics of the connection. Since the parameters will not be modified during the connection, the amount of bandwidth allocated for that connection will not be changed until the connection is terminated. For ATM CBR connections the Peak Cell Rate is allocated to the terminal.

3.3.2 Mapping of real-time Variable Bit Rate (rt-VBR) Service Category

Real-time Variable Bit Rate (rt-VBR) services can also be supported with fixed-rate DAMA. For real-time services, the amount of bandwidth assigned to the connection should be close or equal to the Peak Cell Rate (PCR) to avoid cell delay. The major drawback of this scheme is that a major portion of the bandwidth is wasted when the cell transfer rate is lower than the assigned bandwidth. The major difficulty to employ variable-rate DAMA in ATM satellite systems is the effect of the large propagation delay. The computing and negotiation process between the satellite and the terminal may be too long for real-time VBR services.
and result in unacceptable QoS. The use of variable-rate DAMA for rt-VBR is only possible if the arriving traffic can be predicted one hop delay in advance. Since this is not possible except in some special cases fixed-rate DAMA will be used for rt-VBR.

A scenario where fixed-rate DAMA is efficient for rt-VBR services is when the terminal can multiplex traffic from multiple services. In this case the aggregate traffic can be approximated as a constant cell flow by using a small amount of shaping.

3.3.3 Mapping of non-real-time Variable Bit Rate (nrt-VBR) Service Category

VBR services which are not time sensitive can be assigned an effective bandwidth which is between the mean cell rate and PCR. Since the required bandwidth of VBR sources changes with time, there may be instants when the cell transfer rate is higher than the amount of bandwidth (effective bandwidth) assigned to that connection. In this case cells can be buffered in the terminal and in case the queue exceeds a certain threshold more bandwidth can be requested. Thus using variable-rate DAMA the bandwidth of a connection can be adjusted according to the change of the data transfer rate.

3.3.4 Mapping of Unspecified Bit Rate (UBR) Service Category

No numerical commitments are made for the UBR service class and this service category is intended for non-real-time applications. UBR services could be supported by variable-rate DAMA. However the fact that this service class has the lowest priority (because no commitments to CLR are made) has to be considered. We propose that UBR could transmit data directly to the unoccupied data slots without reservation. The unreserved slots are broadcasted on the downlink to be accessed by random access. This is particularly appealing for bursty interactive services with short duration, for which the long slot reservation delay is unacceptable.

4. The Random-Reservation Adaptive Assignment Protocol

The TDMA frame of the adaptive assignment protocol is divided into Reservation slots, Control slots, Data slots and Random Access slots, as shown in Figure 6. The protocol is based on the proposals by [6]-[9] with modifications to achieve the design objectives for multi-service networks.

Figure 6 Frame Structure

A Reservation slot is that period of time in which terminals report their requests to the reservation unit. There are only a few Reservation slots available and a terminal selects one
at random without knowing whether another station is using the same slot. If more than one terminal selects the same reservation slot, a collision occurs and terminals have to retransmit after waiting for a mean retransmit waiting time determined by the collision resolution algorithm. The MAC protocol ensures that the collision probability stays low. The reason for using reservation slots is because ATM networks support different services which have different loss and delay requirements.

If a single request was received for a reservation slot (successful request), the on-board wireless resource management module tries to allocate the necessary Data slots. If no Data slots are available, the request can either be blocked (called blocking probability) or queued. We propose to queue successful requests in a prioritised queue so that the terminal does not need to compete with other terminals for a reservation slot again. By queuing successful reservations, requests can be allocated data slots according to their priorities.

Once the Data slots are reserved (successful reservation), an acknowledgement is transmitted to the terminal in TDM mode on the downlink frame. Data slots represent the part of the frame in which a terminal can transmit its message after a successful reservation. In every frame there are many data slots and the on-board wireless resource management module will assign data slots to a particular successful request. A data slot is assigned to at most one terminal and therefore there is no possibility of collision.

On the other hand Random Access (RA) slots represent the part of the frame in which terminals can transmit without the need of making a reservation. The slots available for random access are broadcasted in the downlink frame. This part is for services which don’t want to wait for the lengthy reservation procedure. In random access mode it is not possible to guarantee a certain QoS to users although the protocol will try to minimise the number of collisions to maximise throughput by using an adaptive collision resolution algorithm. Random Access should only be used by UBR sources with relatively small burst length since RA terminals are not allowed to reserve slots and have to content for each MAC packet.

Unless the number of reservation slots per frame is carefully adjusted the result would be either low capacity utilisation and long delays (too many reservation slots, less capacity available for information transmission) or network backlog (too few reservation slots resulting in successive collisions and high delay). The number of reservation slots should be fixed for system behaviour where the number of collisions can be controlled by broadcasting a message in the downlink that services with lower priority should not send/resend requests till the collisions have been resolved. Our analysis has shown that two reservation slots provide adequate performance. However when the number of collisions can’t be controlled new reservation slots can be added by reducing the number of control slots.

The requests for dynamic slot allocation are done using the Control Slots which are assigned, on a round-robin basis to all terminals which request the variable-rate DAMA MAC class. The number of control slots is set to eight to minimise the frame overhead.

The satellite frame introduces a constant delay equal to the frame length, on the cells of a stream connection. Therefore the selection of the frame size should be small enough to satisfy the delay limit of real-time services (400ms) \[^{[13]}\] taking into account the satellite propagation and processing delays and the delay introduced by the terrestrial B-ISDN.
The MAC packet slot period has been chosen to support a 32 kbit/s CBR stream and corresponds to one frame unit of 384 un-coded information bits every uplink frame. This results in a frame period of 11.9 ms to transmit 84 ATM cells per second using AAL5. There are 64 MAC packet slots to support 2.048 Mbit/s of traffic per spot-beam on the uplink. The actual uplink transmission rate is higher due to ATM and MAC layer overheads.

5. ANALYSIS OF ADAPTIVE RANDOM-RESERVATION MAC PROTOCOLS

5.1 CBR AND nrt-VBR ANALYSIS

By queuing requests when no data slots are available and by using an adaptive collision resolution algorithm the blocking and collision probabilities can be minimised for a traffic mix of CBR and nrt-VBR. Thus this section will mainly focus on the performance of the system in terms of throughput and reservation delay. One of the main evaluating factor of various access protocols is the throughput/capacity defined as:

\[
\frac{\text{throughput}}{\text{capacity}} = \frac{\text{the number of occupied timeslots in a frame}}{\text{the number of time slots in a frame}}
\]

Nrt-VBR connections first have to reserve the initial capacity by using a Reservation slot and can then use a Control Slot assigned to them in round-robin fashion for any other requests. Thus there are two different reservation delay values. The delay for the initial capacity request using the reservation slot is called Call Reservation Delay (or only Reservation Delay) and the delay for the reservations using the control slot is called Burst Reservation Delay. The slot reservation is relinquished during the silence periods. In this way the air interface bandwidth is shared between multiple sources achieving statistical multiplexing on the air interface.

The offered traffic load of the system can be calculated by multiplying the average number of calls originating per unit time with the mean call holding time. Furthermore a source may occupy more than one slot according to its PCR which has to be taken into account:

\[
\text{Offered traffic load (Erlang)} = \text{Call Arrival Rate} \cdot \text{Call holding time} \cdot \text{PCR} / (32 \cdot 10^3)
\]

For VBR source the call holding time has to be divided by the burstiness ($\beta$) to calculate the offered load.

The normalised load is defined as:

\[
\text{Normalised Load} = \frac{\text{Offered Traffic Load}}{\text{Number of time slots}}
\]

Figure 7 The on-off source model

Each nrt-VBR source represented by an on-off source model shown in Figure 7 where $a^{-1}$ is the mean burst period and $b^{-1}$ is the mean silence period which are both exponentially distributed.
The burstiness is defined as:

\[
\beta = \frac{PCR}{SCR} = \frac{a^{-1} + b^{-1}}{a^{-1}}
\]

First the results for only nrt-VBR are presented to show the advantage of multiplexing bursty traffic over the air interface. Simulations (parameters are shown in Table-1) are carried out for traffic with burstiness of 5, 10 and 20. Note that for all the simulations the number of active terminals is equal to the call arrival rate. The confidence interval for all simulations is 95% and not shown on the graphs for the neatness of the results.

Figure 8 (a) Utilisation (b) Reservation Delay for nrt-VBR services with various burstiness values.

The simulation results show (Figure 8) that a throughput of up to 0.95 can be achieved. The reservation delay remains reasonably low, for low burstiness values. As the burstiness is increased so does the mean reservation delay as more sources need to be multiplexed on the air interface to achieve high utilisation.

Choosing a low number of control slots to minimise frame overheads results in increased burst reservation delay as can be seen in Figure 9. The increase in burst reservation delay become more visible as the number of active terminals increases. If each source is assigned an individual control slot then there will be large frame overhead for \( N \) sources while achieving very low burst reservation delays. Since the terminal is expected to buffer bursts at the PCR for the burst reservation delay period, a reduced burst reservation delay results in smaller buffer requirement for the terminal, to avoid cell loss due to buffer overflow.

Figure 9  Burst Reservation Delay
Next the effects of CBR traffic on nrt-VBR traffic is investigated by fixing the nrt-VBR load at 0.6 and varying the CBR load. The increase in the call and burst reservation delay as a function of CBR load is shown in Figure 10. The increased delay is due to the fact that as the total offered load is increased, it exceeds the system capacity and hence request have to be buffered which results in longer delays till bandwidth allocation can be made. Again the burst reservation delay is minimised by allocating a control slot for each VBR source as shown in Figure 10 (b). For eight control slots the burs reservation delay increases since control slots are assigned in round-robin fashion to terminals which can only request bandwidth when the control slot is assigned to them.

![Figure 10 (a) Mean reservation Delay (b) Mean Burst Reservation Delay](image)

The achieved throughput is similar for various burstiness values as shown in Figure 11, due to the low number of collisions and blockings.

![Figure 11 Total System Throughput vs Normalised CBR Load](image)

### 5.2 CBR, VBR AND UBR ANALYSIS

The novelty of the adaptive MAC protocol is it’s ability to support lower priority UBR traffic in both reservation and random access mode according to the terminals burst duration. The UBR load is calculated in the same way as for VBR traffic and the throughput of UBR for a pure-reservation system, (simulation parameters shown in Table-1) in a scenario with a high number of UBR sources with very bursty traffic ($\beta=200-5000$) is shown in Figure 12(a). As it can be seen the amount of carried traffic remains unacceptably low, even for low
to medium load due to the high number of collisions. The pure-reservation MAC throughput increases for traffic with longer burst duration (or lower burstiness). Only for burstiness values lower than 200 can a throughput higher than 25% of the frame capacity be achieved.

Figure 12 (a) Throughput vs normalised UBR load (b) Reservation Delay vs Arrival Rate per minute

Since the offered UBR traffic load is dependent on the burstiness of the traffic Figure 12 (b) shows the delay as a function of the UBR terminal numbers (which is also the number of arrivals per minute). As it can be seen, UBR traffic is increasing the call reservation delay of higher priority CBR and VBR. Since all the terminals contend for the same reservation slots, UBR traffic increases the collision probability and the access delay.

To improve the UBR throughput and the access delay we propose that UBR sources access the MAC slots remaining after the reservation procedure by Random Access (RA). This way the lengthy reservation procedure is avoided and the number of collisions reduced. The reservation delay of terminals using reservation (CBR and VBR terminals) is unaffected by RA terminals.

The UBR throughput using RA is limited by 37.56% of the available RA capacity (theoretical Slotted Aloha limit). This throughput is higher than the pure-reservation throughput for very bursty traffic ($\beta=500-5000$). Our simulations showed that in order to minimise RA collisions and access delays, the UBR load has to be kept around 25% of the available RA capacity [14].

6. CONCLUSIONS

As user demands become more complex, satellite networks are expected to support a much wider range of services. As satellites will play an important role in the deployment of ATM networks, we addressed the optimisation of the capacity allocation scheme, using performance results for an adaptive MAC scheme.

It has been shown that considerable improvements in delay performance and satellite bandwidth utilisation are possible if next-generation satellite technology (OBP) and an adaptive MAC protocol is used. The traditional demand-assignment scheme using a ground terminal as control station has two important drawbacks: long set-up and reservation time and limited channel utility. Both are due to the long propagation delay of the satellite link. Both disadvantages can be removed by processing channel requests in the satellite to allocate frame slots.
The mapping of ATM service classes to MAC classes and the use of a prioritised request queue provides the QoS differentiation required by ATM networks. It was shown that a pure reservation system performs poor for very bursty user traffic and that the user population which can be supported using RA is much higher.

Finally it was shown that by using variable-rate DAMA and RA the utilisation of the frame capacity and the total number of users served is drastically increased by statistically multiplexing traffic over the air interface.

7. REFERENCES


<table>
<thead>
<tr>
<th>Parameter</th>
<th>Brief Description</th>
<th>Values</th>
</tr>
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<tbody>
<tr>
<td>Average number of CBR and rt-VBR calls (per minute)</td>
<td>The number of calls generated are assumed of Poisson arrival with a certain mean which determines the arrival rate</td>
<td>20-60</td>
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<td>CBR, nrt-VBR and UBR Call holding time</td>
<td>The average call holding time per CBR, VBR and UBR terminal (in minutes)</td>
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<td>Average number of nrt-VBR calls (per minute)</td>
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<tr>
<td>Average number of UBR calls (per minute)</td>
<td>The number of calls generated are assumed of Poisson arrival with a certain mean which determines the arrival rate</td>
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<td>Required Bandwidth for CBR and UBR source</td>
<td>The requested bandwidth per terminal</td>
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<td>Parameter</td>
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<td>-----------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>--------------</td>
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<tr>
<td>Required Bandwidth for nrt-VBR source</td>
<td>The requested bandwidth per terminal</td>
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<td>Data Slots/Frame</td>
<td>The number of data slots per Frame Period</td>
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<td>On-board Request Buffer Size</td>
<td>This buffer queues requests when no data slots are available reducing the blocking probability</td>
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<td>Header Period</td>
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<tr>
<td>Frame Period</td>
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<td>Normalised CBR Load</td>
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<td>Mean VBR Burst Period</td>
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<tr>
<td>Mean VBR Silence Period</td>
<td>The mean duration of the inactivity period of VBR traffic following the burst</td>
<td>100*(β-1)</td>
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<tr>
<td>Mean UBR Burst Period</td>
<td>The mean duration of the burst for UBR traffic</td>
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<tr>
<td>Mean UBR Silence Period</td>
<td>The mean duration of the inactivity period of UBR traffic following the burst</td>
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<td>Control Slots</td>
<td>The number of signalling slots used by nrt-sources to request or relinquish bandwidth</td>
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<tr>
<td>Propagation Delay</td>
<td>The delay introduced through the satellite link</td>
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Table-1 Simulation Parameters