Performance Comparison of DAMA MAC Schemes over Satellite Networks

Dissertation

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by

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Dedicated to

my Family

Dissertation Approval Sheet

This is to certify that the dissertation titled

Performance Comparison of DAMA MAC Schemes over Satellite Networks

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Abstract

Satellite networks provides wide coverage of geographic area and high bandwidth. As satellite capacity is often limiting resource which must be used efficiently. Internet traffic is highly bursty in nature and Demand Assignment Multiple Access (DAMA) techniques are suitable provide bandwidth to match instantaneous requirements and provide significant improvements in the delay/utilization performance of Geo-stationary Earth Orbit (GEO) satellite channels supporting a finite number of users with bursty data traffic. So, the performance of various DAMA *MAC* schemes is important. In this thesis, we investigate the performance of CFDAMA and BTDAMA protocols on satellite networks and proposes an extention to BTDAMA, *User Prioritized-BTDAMA* (BTDAMA-UP) which implements *Quality of Service* (QoS) by user prioritization so that different group of users will get different level of service.

Acknowledgments

I take this opportunity to express a deep sense of gratitude towards my guide **Prof. Sridhar Iyer**, for providing excellent guidance, encouragement and inspiration throughout the project work. Without his invaluable guidance, this work would never have been a successful one. I would also like to thank all my classmets for their valuable suggestions and helpful discussions.

Kalyan Rao D
IIT Bombay
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Chapter 1

Introduction: Satellite Networks

1.1 Overview

Satellite networks are the most widely deployed networks. Though the initial installation cost is more, the benefit of reaching users spread over very large areas makes it a viable and very effective option for sending information in which some loss is tolerable. They provides large channel bandwidth with long transmission delays. The cost of providing a user with access to a satellite resource is independent of location. This is in contrast to terrestrial links where the installation costs are proportional to the distance from the service provider. The unique location of satellites enables direct communications access to and from a large potential user population, ideal for broadcast or multicast applications as many users can listen to a common signal on a common channel without replication of the information for each individual user.

There are three primary classifications of satellite orbit dependent on the orbit altitude:

- Geostationary Earth Orbit (GEO)

  GEO satellites orbit the earth at an altitude of approximately 36,000 km with a corresponding orbit period of 24 hours. The satellites are situated in the same plane as the earth's rotation (the equatorial plane) and therefore appear stationary overhead. GEO satellites are able to provide continuous communications to all users within the coverage area with only three satellites required to cover the entire earth.

- Low Earth Orbit (LEO)

  LEO satellites orbit at a much lower altitude than GEO satellites, typically around 1,200 km above the surface of the earth. The orbit period of a LEO satellite is of the order of 90 minutes, with a single satellite passing overhead every 15 minutes. In order to achieve continuous satellite access, a large network of satellites is required with regular connection handover between them. Achieving ubiquitous coverage poses a significant challenge.

- Medium Earth Orbit (MEO)

  MEO satellites represent a compromise between LEOs and GEOs with orbit altitudes in the region of 18,000 km. On the one hand, a MEO satellite system is reliant on complex handover mechanisms just like LEO systems, with much greater path loss and a longer round trip propagation delay. The handover is much less frequent, however, making the system design much simpler. Compared to a GEO system, MEO satellites offer lower propagation delay and reduced free space path loss at the expense of additional complexity for global coverage.

Different types of satellite scenarios are discussed in next section.

1.2 Satellite Scenarios

There are three generic types of satellite network architecture: point-to-point, multipoint-to-multipoint, and point-to-multipoint.

In a point-to-point network architecture, a single terminal communicates directly with one other. This configuration is useful where a satellite is used to provide a backbone connection between two large terminals, requiring a significant amount of transponder capacity.

In a multipoint-to-multipoint network architecture, a large number of terminals communicate with each other directly. An example scenario of this configuration is a business network with numerous offices linked via satellite. This architecture is also known as a mesh architecture.

In a point-to-multipoint configuration, a group of terminals communicate with a single other terminal. This architecture is common for providing geographically dispersed users with access to a terrestrial network as well as for any kind of broadcast or multicast services. An example scenario of this configuration is video broadcast. Figure 1.1 shows the point-to-multipoint architecture. This configuration commonly referred to as a star architecture.

The uplink channel (from the VSATs to the satellite) is a multiple access channel and it is for this channel that the *MAC* protocols have been developed. It carries user connection and capacity requests along with data packets destined for the gateway terminal. The downlink channel (from the satellite to the ground terminals) is a Time Division Multiplex (TDM) broadcast channel. It carries scheduling information for the uplink transmissions from the VSAT terminals and transfers data packets received on the uplink to the gateway terminal. In this thesis, the topology of interest is a finite number of stations with centralized scheduler at the hub and the uplink is Multiple Access channel and the downlink is TDM Channel.

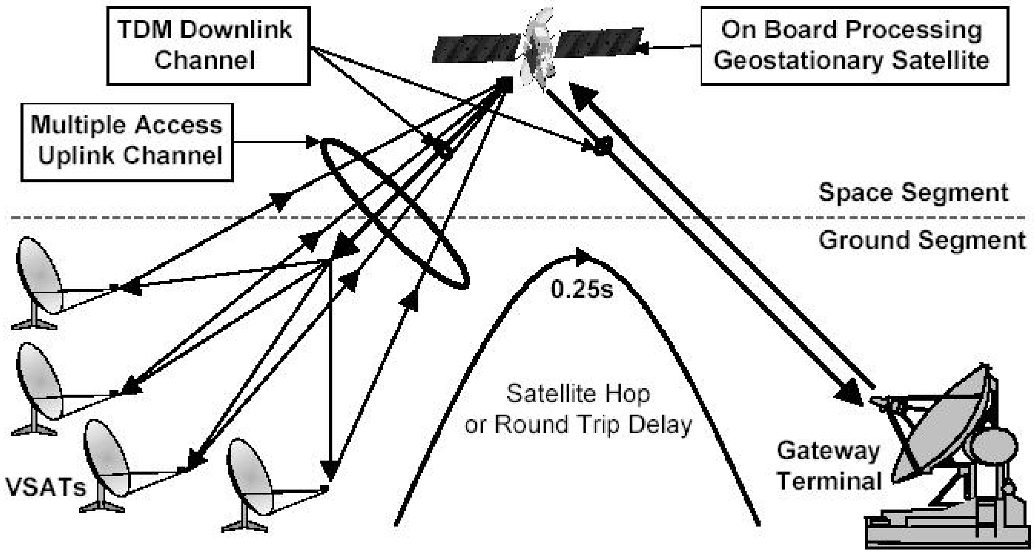

Figure 1.1: Satellite scenario

1.3 Thesis Objective and Scope

This work aims at studying the performance CFDAMA and BTDAMA *MAC* schemes and introducing *User Prioritized-BTDAMA* (BTDAMA-UP) which provide user level priority. The main focus of this work is to present the implementation of CFDAMA and BTDAMA and comparison of these protocols. The implementation of CFDAMA *MAC* and BTDAMA *MAC* in publicly available Network Simulator NS-2 is presented, and simulation results are discussed. The scope of this work is limited to centralized singlehop satellite networks to a large extent.

1.4 Thesis Outline

The rest of the thesis is outlined in this section. In Second chapter, different DAMA approaches, and the choices for DAMA *MAC* available for satellite networks are discussed. Third chapter discusses the implementation of CFDAMA and BTDAMA *MAC*. Fourth chapter gives overview of *User Prioritized-BTDAMA* (BTDAMA-UP). The simulation set up and results are discussed in chapter five. Finally, thesis ends with the conclusion and the scope for the future work in chapter six.

Chapter 2

Capacity Assignment Strategies and DAMA *MAC* Schemes

2.1 Overview

The ability to use on-board processing (OBP) and multiple spot beams enables satellite to reuse the frequencies many time. In satellite network, channel allocation may be static or dynamic, with the latter becoming increasingly popular. There are four generic strategies for bandwidth assignments in relation to the VSAT uplink.

Fixed Assignment

With a fixed assignment strategy, each user is provided with a quasi-permanent assignment of capacity corresponding to a periodic and regular time slot allocation in a TDMA scheme, as shown in Figure 2.1. The static nature of the assignment can be inefficient in some cases where a user does not have any data to send, the capacity is unused and therefore wasted. Even during a period of user activity the effectiveness of this strategy is limited as the assignment is not adaptive to changing traffic requirements. With variable bit rate (bursty) traffic, sufficient capacity must be allocated to serve for the peak rate of the traffic, otherwise a significant amount of buffering would be required at terminal. The regularity of the assignment is more suited to constant bit rate (periodic) traffic, but even then is only fully utilized during periods of user activity. Fixed assignment an be an efficient strategy when the traffic demand is highly regular and constant over very long periods of time. The main advantage of this strategy is that it can provide absolute guarantees on throughput and QoS as each user has exclusive rights to use a specific portion of the satellite capacity.

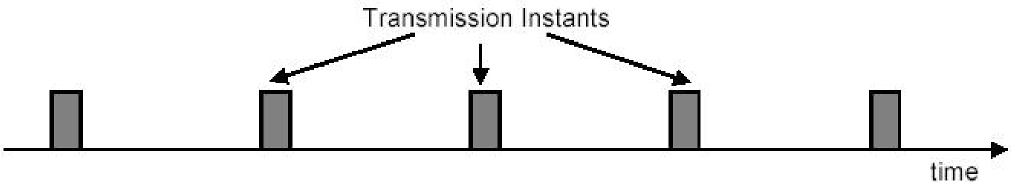

Figure 2.1: Fixed Assignment

Demand Assignment

With a demand assignment strategy, the capacity of the uplink channel is dynamically allocated on demand in response to requests issues by stations based on their queue occupancies. Thus, in principle, the time-varying bandwidth requirements of individual stations can be accommodated and no bandwidth will be wasted. Dynamic allocation using reservation implicit or explicit increases transmission throughput. Typically, demand assignment consist of three phases:

- A first phase dedicated to specifying bandwidth requests by the connections,
- An arbitration phase performed by the satellite, and
- A data transmission phase.

There are two types of demand assignment: *fixed rate* and *variable rate*, relating to the regularity at which the capacity allocation is updated.

Fixed rate demand assignment is suited to connection-oriented services with capacity allocated on a connection-by-connection basis. Figure 2.2 shows the operation of fixed rate demand assignment. At the start of a connection a user makes a request for capacity when user next gets the opportunity. If the connection request is accepted then the user will receive a regular and periodic allocation of time slots for the duration of the connection for exclusive use. When the connection ends, a signal is transmitted to the scheduler to release the capacity back to the network for use by other connections. It can be seen that there is an initial delay in obtaining capacity at the start of a connection, lower bounded by one or two satellite hops for a satellite-based or ground-based capacity assignment scheduler respectively (∼0.25s/0.5s over a geostationary satellite link).

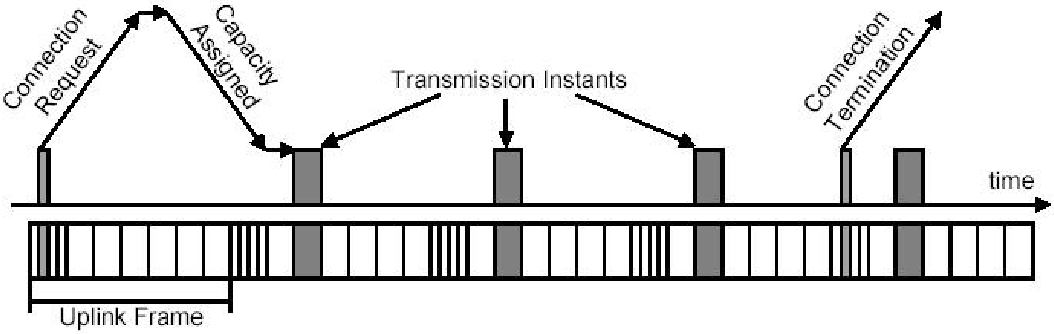

Figure 2.2: Fixed Rate Demand Assignment

Variable rate demand assignment is commonly employed to support any type of traffic where the capacity requirement varies as a function of time. An example implementation of the variable rate demand assignment strategy is shown in Figure 2.3. Individual users make regular requests for capacity based on their instantaneous requirements, requesting for a specific number of slots sufficient to clear their current queue level. A high channel utilization can be achieved with this strategy as capacity is allocated to match instantaneous user requirements, with a direct mapping of slot assignments from requests. variable rate demand assignment places a minimum bound on the end-to-end delay of packet transmissions of two satellite hops for a satellite-based scheduler (one hop for the capacity request and subsequent slot assignment, and one for the data packet transmission). These factors become even more significant with a ground-based scheduler as the capacity requests are further out of date and the end-to-end delay of packet transmissions is lower bounded by three satellite hops.

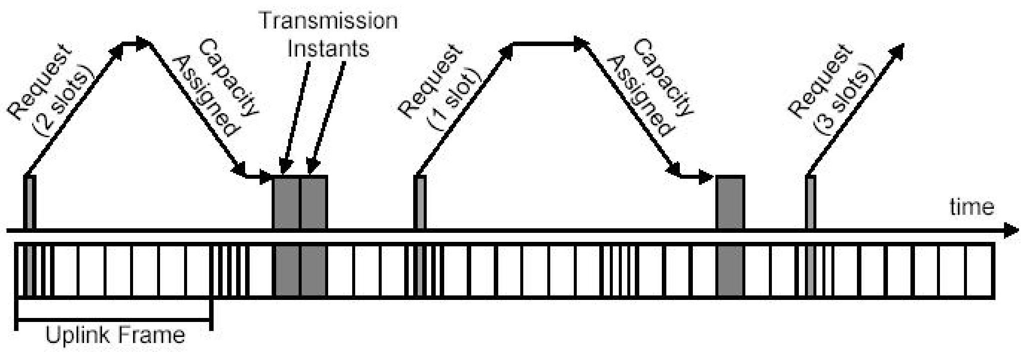

Figure 2.3: Variable Rate Demand Assignment

Free Assignment

In Free assignment, capacity will be allocated without any form of request, in a similar manner to fixed assignment. The primary difference between the two strategies is that fixed assigned capacity is guaranteed to users, whereas free assigned capacity is essentially bonus capacity, useful if users happen to have data packets to send at the instants of the free assigned slots. Fixed assigned slots are provided to users at periodic and predetermined intervals, with a specific slot assigned to a user for transmission in successive frames. The availability of free assigned slots is variable and unknown to the users, with individual slot assignments identified by information transmitted in the downlink frame. Spare capacity is often allocated on a free assigned basis, commonly implemented by assigning the spare slots to a group of users, one-by-one, on a round robin basis. The efficiency of the scheme for handling bursty traffic is difficult to determine, but it is clearly much more inefficient than variable rate demand assignment as there is no attempt to allocate capacity to meet changing requirements. The primary advantage of this strategy is a minimum end-to-end delay of one satellite hop when a free assigned slot occurs immediately subsequent to the arrival of a packet in an empty terminal queue. The delay performance is heavily dependent, however, on the number of users receiving the free assigned slots. As the number of users increases, the regularity of free assigned slots to each user is reduced, increasing the average delay for packet transmissions.

Random Access

Under a random access scheme, a satellite bandwidth is made available for transmission by an user in the system without reservation or explicit allocation and the terminals may contend for the bandwidth in an uncoordinated manner. Slotted ALOHA is a well developed scheme where terminals transmit packets in time slots immediately subsequent to the arrival. If more than one user transmits in the same slot then collision will occur and the collided packets must be retransmitted after a randomized delay. Slotted ALOHA provides virtually instantaneous transmission of data with lower end-to-end delay bound of one satellite hop ($\sim$ 0.25s).

No single assignment strategy provides both high throughput and low end-to-end delay for bursty traffic and so the majority of satellite access schemes utilize a hybrid strategy, aiming to achieve high throughput as well as good delay performance. Effective combination of the strategies represents the primary design challenge and the resulting protocol performance is usually dependent on the type and mixture of traffic types to be supported. The DAMA *MAC* schemes which are are discussed in Section 2.2 and Section 2.3 uses combination of these schemes.

2.2 The CFDAMA Schemes

The *Combined Free/Demand Assignment Multiple Access* (CFDAMA) protocols aims to provide significant improvements in the delay/utilization performance of geostationary satellite channels [7]. The combination of free assignment and demand assignment provides a minimum end-to-end delay of one satellite hop at low channel loads with the high maximum channel utilization of demand assignment as a result of capacity allocation tracking user demand. There are a number of variants of the CFDAMA protocol, differing in their provision and strategy for making DAMA requests. Three different schemes have been described by Le-Ngoc. These are:

- CFDAMA with Fixed Assigned requests (CFDAMA-FA).
- CFDAMA with Random Access requests (CFDAMA-RA).
- CFDAMA with Piggy-Backed requests (CFDAMA-PB).

And another improvement over above schemes is,

- CFDAMA with Round Robbin requests (CFDAMA-RR).

The scheduling algorithm which is common across all the CFDAMA schemes and request strategies are described below [1].

2.2.1 Scheduling and Request Strategies

Scheduling Algorithm

The CFDAMA schemes operate with a centralized scheduling algorithm located either at the satellite or at a ground-based hub station. The advantage of an On-Board Scheduler (OBS) is reduced delay for DAMA requests and subsequent acknowledgments, which improves the *Quality of Service* (QoS) of DAMA techniques. With a satellite-based scheduler there is a minimum delay of one satellite hop from the instant a request is made to receiving a response from the scheduler, compared with two satellite hops for a ground-based scheduler. This scheduling strategy is common to all the CFDAMA variants. The operation of the scheduling algorithm for each new slot assignment is shown in flow diagram form in Figure 2.4.

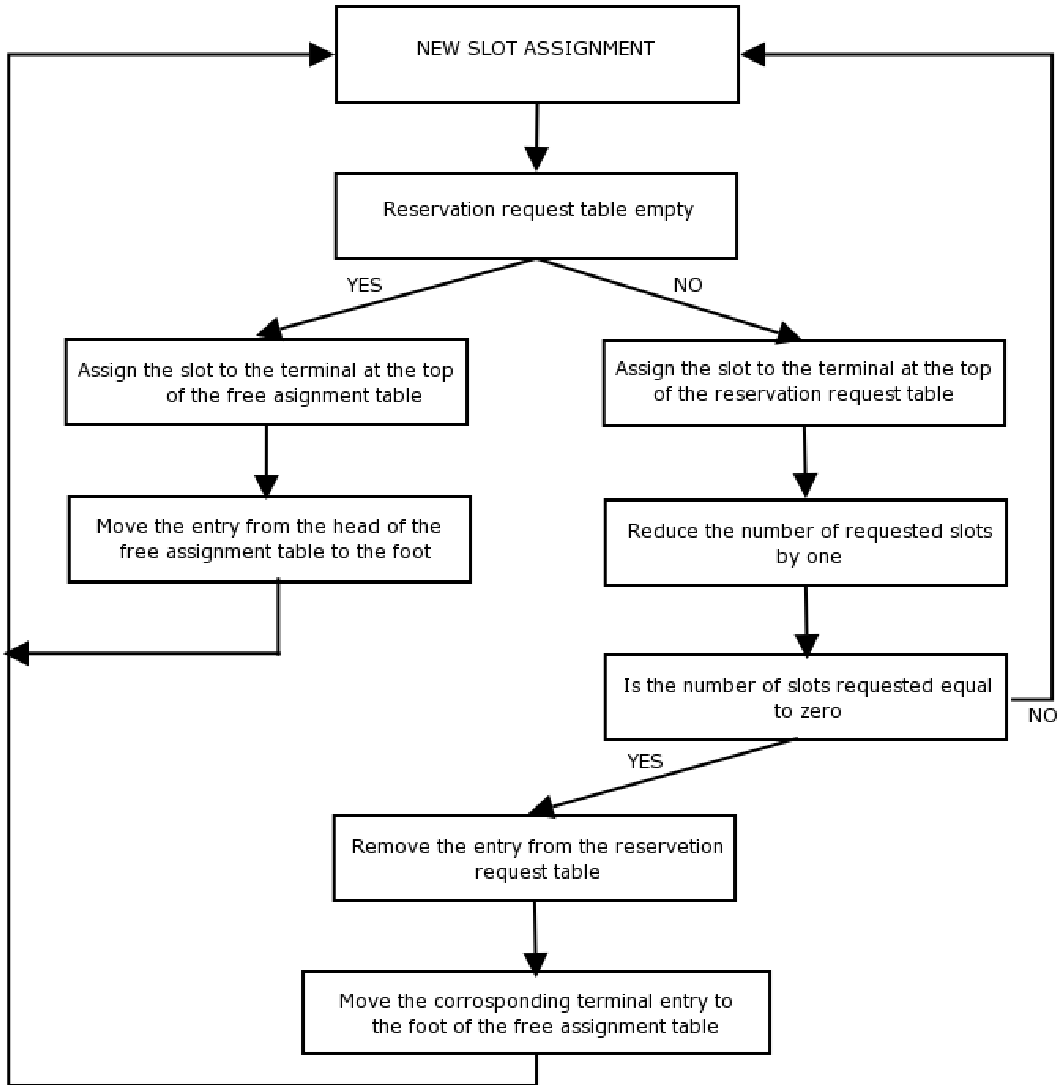

Figure 2.4: CFDAMA scheduling algorithm

The scheduler maintains two tables: a reservation request table and a free assignment table. The reservation request table queues ground terminal requests for demand assigned slots, with each entry containing the source address of the requesting terminal and the corresponding number of slots requested. The requests enter the foot of the table on arrival and are served from the head of the table on a first come, first served basis. The free assignment table consists of the source addresses of all terminals in the network. The scheduler allocates time slots on a frame-by-frame basis, transmitting the assignment information in a single packet in the data slot assignment region of the downlink frame. In the first instance, the scheduler serves entries from the top of the reservation request table by demand assigning a set of contiguous slots to the corresponding terminal, based on the number requested. When a terminal has been allocated the requested number of slots, its entry is removed from the reservation request table. In the absence of any queued requests, the scheduler free assigns slots to terminals on a round robin basis. This is achieved by assigning successive slots, one-by-one, to the terminal currently at the head of the free assignment table, moving each terminal to the foot of the table after each slot allocation. Each time a terminal receives a set of demand assigned slots and is removed from the reservation request table, the corresponding terminal is also moved to the foot of the free assignment table, enabling those without a reservation to propagate up the free assignment table much faster.

Request Strategy

All the CFDAMA schemes presented in this section implement the controlled reservation strategy. Each terminal keeps a count of the number of slots requested that are yet to be assigned (the due slot count), and at the instant of a request slot will make a request for enough slots on top of those outstanding, sufficient to clear the current queue level. The differences between the different CFDAMA schemes lie in the provision made for making requests in the uplink frame as well as in the request slot access strategy.

CFDAMA-FA

The first scheme proposed was CFDAMA with *Fixed Assigned request slots* (CFDAMA-FA), with the uplink frame format as shown in Figure 2.5. The frame consists of a number of slots equal to the number of terminals (N), with each slot subdivided into a request slot and a data slot. Each terminal has a dedicated request slot in the frame and so each user is able to make a contention-free request once every N slots.

CFDAMA-RA

A second variant of CFDAMA incorporates *Random Access request slots* (CFDAMA-RA). The scheme may feature request slots interleaved throughout the frame or alter-

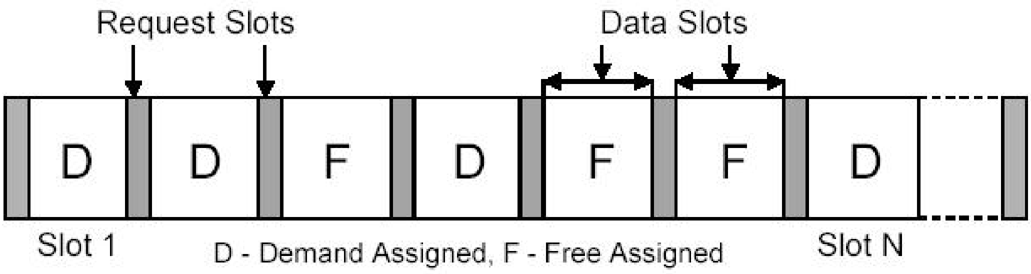

Figure 2.5: Uplink frame format for CFDAMA-FA

natively may have a separate area of request slots at the start of the frame. The uplink frame format with interleaved request slots is shown in Figure 2.6. The request slots are available to any terminal wishing to make a request, accessed via slotted ALOHA.

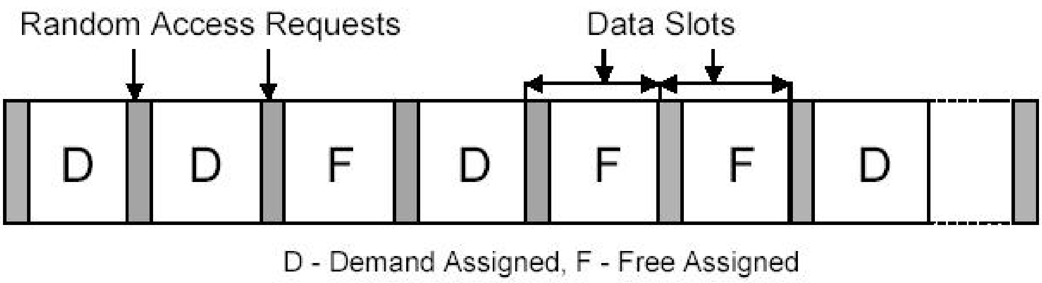

Figure 2.6: Uplink frame format for CFDAMA-RA

CFDAMA-PB

The third variant of CFDAMA incorporates *Piggy-Backed request slots* (CFDAMA-PB). The uplink frame format for the CFDAMA-PB scheme is as shown in Figure 2.7. Requests are piggy-backed onto data packet transmissions, with access rights to a particular request slot limited to the user transmitting in the associated data slot.

CFDAMA-RR

The last variant of CFDAMA incorporates *Round-Robin request slots* (CFDAMA-RR). The uplink frame format for the CFDAMA-RR scheme is as shown Figure 2.8. It consists of a region of round robin request slots followed by data transmission slots. The request slots are allocated on a round robin basis to individual terminals.

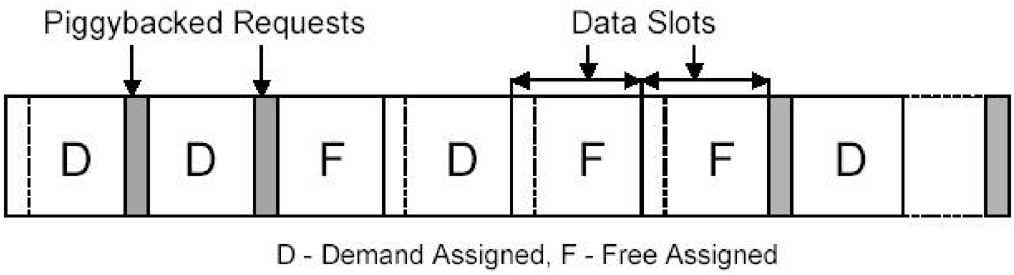

Figure 2.7: Uplink frame format for CFDAMA-PB

Each terminal will make a request for a quantified number of slots, sufficient to clear the instantaneous queue, given by:

$$NSR = NPQ - NOR \tag{2.1}$$

Where,

NSR = Number of slots requested

NPQ = Number of packets queued

NOR = Number of outstanding requests

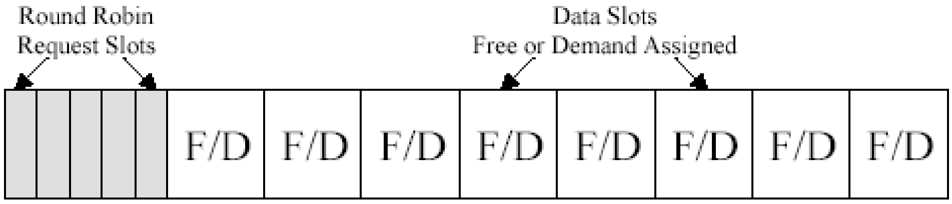

Figure 2.8: Uplink frame format for CFDAMA-RR

2.3 The BTDAMA Schemes

This section introduces a new family of schemes called *Burst Targeted Demand Assignment Multiple Access* (BTDAMA), which employs an original approach to implement DAMA, designed to eliminate the limitations of traditional DAMA techniques. BTDAMA has been subject to significant development and analysis, generating a number of different variants. Two variants have discussed in this section: *Pure Demand* BTDAMA

(BTDAMA-PD) and *combined Free and Demand assignment* BTDAMA (BTDAMA-FD) [5].

2.3.1 BTDAMA-PD

The uplink frame format for the BTDAMA-PD scheme is shown in Figure. 2.9. The request slots are allocated to terminals on a round robin basis for contention-free request packet transmission with the request region in the downlink frame consisting of request slots assignments instead of acknowledgments.

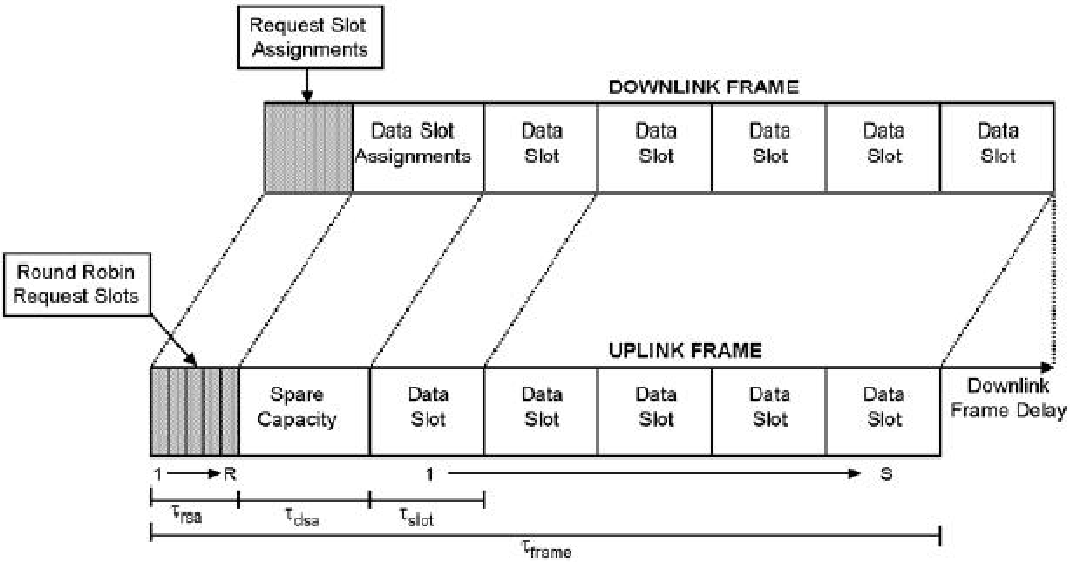

Figure 2.9: Uplink and downlink frame format of the BTDAMA-PD scheme

Request and Scheduling Strategies

Request Strategy

All BTDAMA family protocols shares request strategy is common to all . The request slots are allocated to individual terminals on a round robin basis and are used for capacity signaling on a burst-by-burst basis. This is different from the standard approach where terminals make a request for a quantified amount of capacity on a regular basis. At any instant in time each terminal exists in one of two possible states:

- ON if there is a requirement for capacity
- OFF if there is no requirement for capacity

When the first packet in a burst is received in a ground terminal queue, the current terminal state ($CSTAT$) is set to ON, as the terminal needs capacity. When the last packet in a burst is transmitted on the uplink and the ground terminal queue becomes empty, $CSTAT$ is set to OFF, indicating that the terminal no longer needs capacity. Terminals use the request slots to signal their current state to the scheduler, identifying either the start or end of a requirement for capacity. The request algorithm for the BTDAMA-PD scheme is shown in Figure 2.10. At the instant of a request slot, a terminal determines whether the current state is different from the last requested state ($LRSTAT$) and transmits a request packet signaling the state change if the current state is different from the previously requested state. Alternatively, terminals can repeatedly signal their current state at every request opportunity, not just when there is a change in terminal state. This is the preferred method for satellite channels that may be subject to bit errors or connection loss for brief moments in time.

Scheduling Strategy

The BTDAMA-PD scheme employs a centralized scheduling algorithm, located either at the satellite or at a hub station on the ground. A satellite-based scheduler is preferred due to the shorter DAMA request to acknowledgment time. The scheduler maintains two lists, one containing the terminals that have signalled ON, and the other consisting of the terminals that have signalled OFF. Each time a request packet is received, indicating a change of requirement, the corresponding terminal is removed from its current list and placed at the bottom of the other list. Capacity is assigned on a frame-by-frame basis to terminals in the ON state only. Successive slots are allocated one-by-one, to the terminal currently at the head of the ON list. Terminals are moved to the bottom of the ON list following each slot allocation. This strategy ensures that capacity is targeted only to terminals that need it, and that each terminal receives an equitable share of the available capacity.

2.3.2 BTDAMA-FD

BTDAMA with combined Free and Demand assignment (BTDAMA-FD) is an extension of BTDAMA-PD with a fixed proportion of the uplink frame dedicated to free assignment. Demand assigned capacity is allocated in the same manner as before to the ON terminals on a round robin basis, and the free assigned capacity is allocated on a round

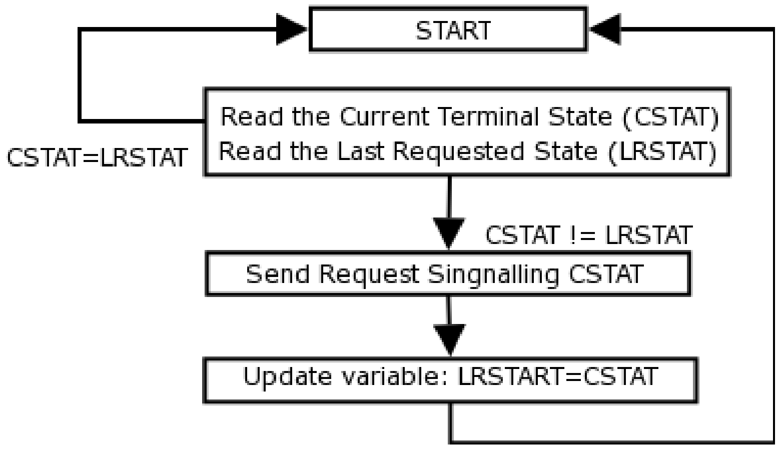

Figure 2.10: BTDAMA-PD request algorithm

robin basis to the OFF terminals, for use if they happen to have packets to send at the instants of the free assigned slots.

2.3.3 Summary

CFDAMA with Round Robin requests and BTDAMA-PD shares common uplink and downlink frame format. Therefore, simulation of the two schemes with the same frame parameters enables the relative performance of the request and scheduling strategies to be effectively compared.

Chapter 3

CFDAMA and BTDAMA Implementation in NS-2

3.1 Existing *MAC* Architecture in NS-2

Figure 3.1 provides a detailed look at how satellite links are composed. In this section, we describe how packets move up and down the satellite stack, and the key things to note at *MAC* layer [8].

To send packets to the physical layer, *MAC* layer draws packets from the queue (or deque trace) object-a handshaking between the *MAC* and the queue allows the *MAC* to draw packets out of the queue as it needs them. The transmission time of a packet is modelled in the *MAC* also-the *MAC* computes the transmission delay of the packet , and does not call up for another packet until the current one has been sent to the next layer down. The transmit time is encoded in the *MAC* header; this information can be used at the receiving *MAC* to calculate how long it must wait to detect a collision on a packet, for example. The outgoing packet is next sent to a SatChannel, which copies the packet to every receiving interface (of class SatPhy) on the channel.

To receive packets, the Phy_rx sends the packet to the *MAC* layer. At the *MAC* layer, the packet is held for the duration of its transmission time (and any appropriate collision detection is performed if the *MAC*, such as the Aloha *MAC*, supports it). If the packet is determined to have arrived safely at the *MAC*, it next passes to an ErrorModel object, if it exists. If not, the packet moves through any receive tracing objects to the SatLL object. The SatLL object passes the packet up after a processing delay. Currently,

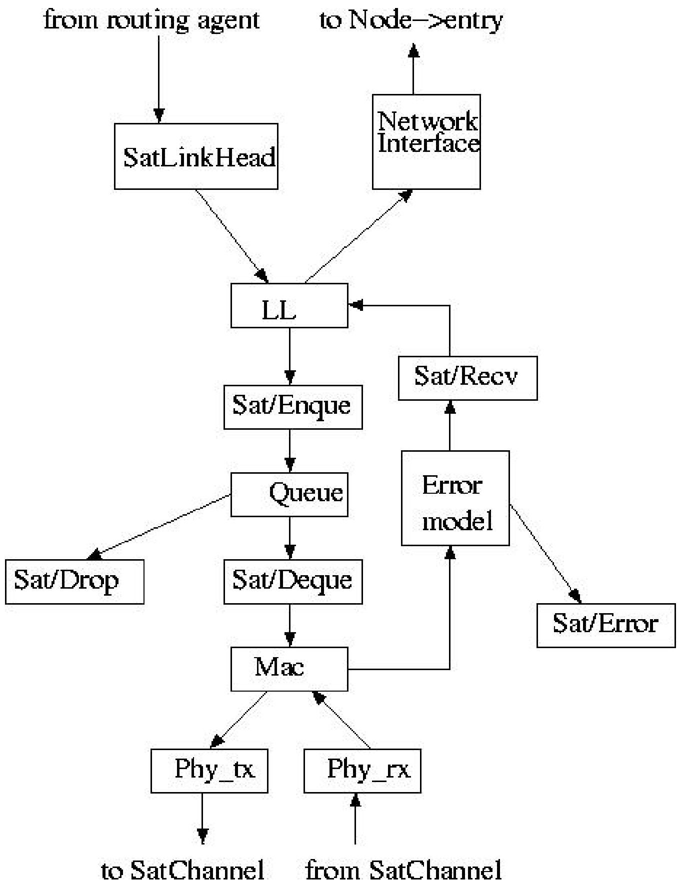

Figure 3.1: Detailed look at network interface stack

unslotted ALOHA is available as satellite *MAC* in NS-2.

3.2 Implementation

To incorporate CFDAMA and BTDAMA *MAC* functionality, *Packet* class has been changed. Following parameters are given as input to simulation script: Number of VSAT Terminals (N), Number of round robin request slots (R), Number of data slots in the uplink frame (S).

3.2.1 CFDAMA

CFDAMA *MAC* is implemented as two classes. First, CFDAMA node *MAC* (class *CFDAMANode_Mac*) is implemented by deriving the existing *SatMac* class in NS-2. The *CFDAMA_Node_Mac* object encapsulates *SatMac* object. The pseudo code for working of CFDAMA Node *MAC* in NS-2 is shown in Figure 3.2.

CFDAMA Node sends reservation request in controlled manner. It calculates the number of slots to request by using the queue length and uplink bandwidth. To transmit a packet, it checks the slot allocation table and waits for corresponding data slot.
The CFDAMA Scheduler *MAC* (class *CFDAMA_Scheduler_Mac*) is implemented by deriving the *CFDAMA_Node_Mac* class in NS-2. The *CFDAMA_Scheduler_Mac* object encapsulates *SatMac* and *CFDAMA_Node_Mac* objects. The operation of the CFDAMA Scheduler *MAC* is summarized in Figure 3.3.

CFDAMA Scheduler sends periodically frame start packet. After receiving the each reservation request from the node, it will be added to reservation request table. Nodes which haven't request will be added to free assignment table. Round Robin scheduling will be performed and the slot allocation table will be broadcasted.

3.2.2 BTDAMA

The pseudo code for working of BTDAMA Node *MAC* in NS-2 is shown in Figure 3.4. The BTDAMA Node *MAC* (class *BTDAMANode_Mac*) is implemented by deriving the existing *SatMac* class in NS-2. The *BTDAMA_Node_Mac* object encapsulates *SatMac* objects.

BTDAMA Node sends state signal if there is any change from previous state. If the queue is nonempty then node will be in ON or else OFF. To transmit a packet, it refers slot allocation table and send in respective data slot.

The BTDAMA Scheduler *MAC* (class *BTDAMA_Scheduler_Mac*) is implemented by further deriving the existing *BTDAMA_Node_Mac* class in NS-2. The operation of the BTDAMA Scheduler *MAC* is summarized in Figure 3.5. BTDAMA Scheduler maintains ON list and OFF list. After receiving signaling request from node, it adds to ON list. Then it schedules the data slots by using pure demand assignment algorithm or combined free/demand assignment algorithm. Slot allocation will be broadcasted.

```
CFDAMA_Node_Mac :: send(packet)
{
        Read the slot allocation table;
        Wait for respective slot and transmit the packet;
        return;
}

CFDAMA_Node_Mac :: send_reservation_req(packet)
{
        Read the Queue length and calculate
        No. of slots to request = No. of packets queued -
                                  No. of outstanding requests;
        Wait for respective request slot and
        Send the reservation request;
        return;
}

CFDAMA_Node_Mac :: recv(packet)
{
        receiver_id = receiver id in packet header;
        if ( receiver_id is not broadcast address OR not node_index ) {
                drop the packet;
                return;
        }
        else {
                if ( received packet is frame start packet ) {
                        start send_reservation_req_timer;
                        upon timeout call send_reservation_req();
                        return;
                }
                if ( received packet is reservation request ACK ) {
                        start recv_slot_alloc_timer;
                        upon timeout call recv();
                        return;
                }
                if ( received packet is slot allocation packet ) {
                        save the slot allocation table;
                        start the send_timer;
                        upon timeout call send();
                        return;
                }
        }
}
```

Figure 3.2: CFDAMA Node *MAC* implementation in NS-2

```
CFDAMA_Scheduler_Mac :: send_frame_start(packet)
{
        Periodically send the frame start packet;
        return;
}
CFDAMA_Scheduler_Mac :: send_slot_alloc(packet)
{
        Wait for last node to send reservation request;
        while( available data slots is not equal to zero ) {
                if ( reservation request table is empty ) {
                        Assign the slot to the terminal at
                        the top of the free assignment table;
                        Move the entry from the head of the
                        free assignment table to the foot;
                        Reduce available data slots
                        in the frame by one;
                }
                else {
                        Assign the slot to the terminal at the top
                        of the reservation request table;
                        Reduce the no. of requested slots by one;
                        if ( no. requested slots equal to zero ) {
                                 Remove the entry from the
                                 reservation request table;
                                 Move the corresponding terminal
                                 entry to the foot of the
                                 free assignment table;
                                 Reduce available data slots by one;
                        }
                }
        }
        Broadcast the slot allocation table;
}
CFDAMA_Scheduler_Mac :: recv(packet)
{
        receiver_id = receiver id in packet header;
        if ( receiver_id is not broadcast address OR not node_index ) {
                drop the packet;
                return;
        }
        else {

                if ( received packet is reservation request packet ) {
                        Add the sender_id and no. of slots requested
                        to reservation request table;
                        Send acknowledgment to the sender;
                        return;
                }
        }
}
```


Figure 3.3: CFDAMA Scheduler *MAC* implementation in NS-2

```
BTDAMA_Node_Mac :: send(packet)
{
        Read the slot allocation table;
        Wait for request slot to end and transmit the packet;
        return;
}

BTDAMA_Node_Mac :: send_state(packet)
{
        Read the Queue length and Last Requested State(LRSTAT);
        if ( Queue is not empty ) {
                Set Current Terminal State(CSTAT) to ON;
        }
        if (CSTAT=LSTAT) {
                return;
        }
        else {
                Wait for respective request slot and
                send the request signaling CSTAT;
                Update variable LRSTAT to CSTAT;
                return;
        }
}

BTDAMA_Node_Mac :: recv(packet)
{
        receiver_id = receiver id in packet header;
        if ( receiver_id is not broadcast address OR not node_index ) {
                drop the packet;
                return;
        }
        else {
                if ( received packet is frame start packet ) {
                        start send_reservation_req_timer;
                        upon timeout call send_state();
                        return;
                }
                if ( received packet is reservation request ACK ) {
                        start recv_slot_alloc_timer;
                        upon timeout call recv();
                        return;
                }
                if ( received packet is slot allocation packet ) {
                        save the slot allocation table;
                        start the send_timer;
                        upon timeout call send();
                        return;
                }
        }
}
```


Figure 3.4: BTDAMA Node *MAC* implementation in NS-2

```
BTDAMA_Scheduler_Mac :: send_frame_start(packet)
{
        Wait for last and some delay then send the packet;
        return;
}

BTDAMA_Scheduler_Mac :: send_slot_alloc(packet)
{
        Wait for last node to send signaling packet;
        while( available data slots is not equal to zero ) {
                if ( Signalled_ON table is empty ) {
                        Assign the slot to the terminal at
                        the top of the Signalled_OFF table;
                        Move the entry from the head of the
                        Signalled_OFF table to the foot;
                }
                else {
                        Assign the slot to the terminal at the top
                        of the Signalled_ON request table;
                }
        }
        Broadcast the slot allocation table;
}

BTDAMA_Scheduler_Mac :: recv(packet)
{
        receiver_id = receiver id in packet header;
        if ( receiver_id is not broadcast address OR not node_index ) {
                drop the packet;
                return;
        }
        else {
                if ( received packet is signaling request packet ) {
                        if ( Signal is ON ) {
                                Add the sender_id and node state
                                to Signalled_ON request table;
                        }
                        else {
                                Add the sender_id and node state
                                to Signalled_OFF table;
                        }
                        send acknowledgment to the sender;
                        return;
                }
        }
}
```

Figure 3.5: BTDAMA Scheduler *MAC* implementation in NS-2

Chapter 4

User Prioritized-BTDAMA (BTDAMA-UP)

4.1 Need for BTDAMA-UP

The MAC schemes discussed in earlier chapters provides equitable channel access for all users, with each user contributing an equal traffic load to the channel in most instances. In some cases, different groups of users may have different requirements and/or expectations from a network based on differing service level agreements. Providing all users with the same level of channel access and common performance may result in inefficient use of the available resources. Some users may wish to have a higher quality of service than others or may require a larger amount of capacity. Offering different levels of service to users on a common network provides flexibility, allowing them to choose a level of service to match their requirements in terms of capacity, quality of service, and cost. Users can be prioritized through selection of appropriate request and scheduling strategies in the MAC protocol.

4.2 Overview of BTDAMA-UP

Request Strategy

Alternatively, requests for demand assigned capacity could be ordered to ensure that high priority users always obtain the capacity they require in preference to others. Users can be divided in to different groups. At scheduler, each group will have corresponding

ON list. User requests will be added to corresponding ON list.

Scheduling Strategy

In terms of scheduling, multiple round robin assignment tables can be used in BTDAMA. So that different groups would be provided different capacity allocation rates, and reserving free slot assignments for high priority users. This would provide better delay performance for these users at the expense of lower priority ones. The BTDAMA-UP scheduler operation is given in Figure 4.1.

```
BTDAMAUP_Scheduler_Mac :: send_slot_alloc(packet)
{
        Wait for last node to send signaling packet;
        while( available data slots is not equal to zero ) {
                if ( Signalled_ON table is empty ) {
                        Assign the slot to the terminal at
                        the top of the high priority
                        user group OFF table;
                        Move the entry from the head of the
                        Signalled_OFF table to the foot;
                }
                else {
                        Assign the slot to the to the terminal
                        at the top of the high priority
                        user group ON table with
                        corresponding allocation rate;
                }
        }
        Broadcast the slot allocation table;
}

BTDAMA_Scheduler_Mac :: recv(packet)
{
        receiver_id = receiver id in packet header;
        if ( receiver_id is not broadcast address OR not node_index ) {
                drop the packet;
                return;
        }
        else {
                if ( received packet is signaling request packet ) {
                        if ( Signal is ON ) {
                                Add the sender_id and node state
                                to corresponding user group ON table;
                        }
                        else {
                                Add the sender_id and node state
                                to Signalled_OFF table;
                        }
                        send acknowledgment to the sender;
                        return;
                }
        }
}
```

Figure 4.1: BTDAMA-UP Scheduler *MAC* implementation in NS-2

Chapter 5

Simulation and Results

5.1 Simulation Setup

This chapter describes the simulation of CFDAMA-RR *MAC* and BTDAMA-PD *MAC*. The simulation are done by using the public domain simulator NS-2. These schemes has been simulated for the scenario outlined in Figure 1.1. The simulation parameters are listed in Table 5.1.

Parameter	**Value**
Number of VSAT terminals(N)	200, 400
Channel load	0.1 - 0.9 Erlang's
Channel data rate	4 Mbits/s
Number of round robin request slots (R)	100, 200
Number of data slots in the uplink frame (S)	256
Simulation duration	1000s

Table 5.1: Simulation parameters for the BTDAMA-PD and CFDAMA-RR schemes

5.2 Discussion on Results

5.2.1 CFDAMA-RR Vs BTDAMA

Figure 5.1 and 5.2 shows comparison of CFDAMA-RR and BTDAMA-PD. CFDAMA-RR gives good performance at low channel loads. The reason is free assignment which will be efficient at low channel loads. In the case of BTDAMA-PD, capacity allocated only to terminals which requires it and not to all terminals in the network. BTDAMA-RR performance is constrained by the initial delay to signal for capacity at the start of a burst even at low channel load. As a result, some proportion of packets incur longer end-to-end delay which increases average end-to-end delay.

As the number of terminals increased, the average end-to-end delay increases. Because the regularity of successive slot assignments decreased in both schemes.

At high channel loads, BTDAMA-FD gives less average end-to-end delay when compared to CFDAMA-RR. The reason is CFDAMA-RR operates with pure demand assignment only, and free slots availability will be less. So the resulting end-to-end delay performance is constrained by the variable rate DAMA delay bound of two satellite hops. BTDAMA-FD gives less average end-to-end delay because of their request and scheduling strategies. Once the initial delay in obtaining capacity at the start of a burst has elapsed, a continual supply of slots is provided for the entire duration of a traffic burst. Therefore, once the initial queue build up has been cleared, subsequent packets are transmitted virtually instantaneously on the channel with a corresponding lower end-to-end delay bound of one satellite hop.

Comparison of CFDAMA-RR and BTDAMA-FD is shown in Figure 5.3 and 5.4. BTDAMA-FD performs well compared to BTDAMA-PD because of free assignment at low channel loads. At high channel loads the performance is similar to BTDAMA-PD. Free assignment of capacity to terminals that are in the OFF state enables a number of packets to be transmitted prior to the commencement of demand assigned capacity following the start of a burst. This technique provides lower end-to-end delay for the packets at the start of bursts, assisting with clearing queue build during the signaling period more rapidly which will subsequently reduce the end-to-end delay for packet arrivals within the demand assigned slot allocation period.

5.2.2 BTDAMA-UP

The performance of BTDAMA-UP is shown in Figure 5.5. The station are divided into three different groups. First group contains 100 terminals, second 60 terminals and third 20 terminals. At both low channel load and high channel load, group 3 incurs less end-to-end delay compared to group 2 and group 3, because of multiple round robin queues and different allocation rates. High priority group of terminals gets low end-to-end delay at cost of low priority group of terminals.

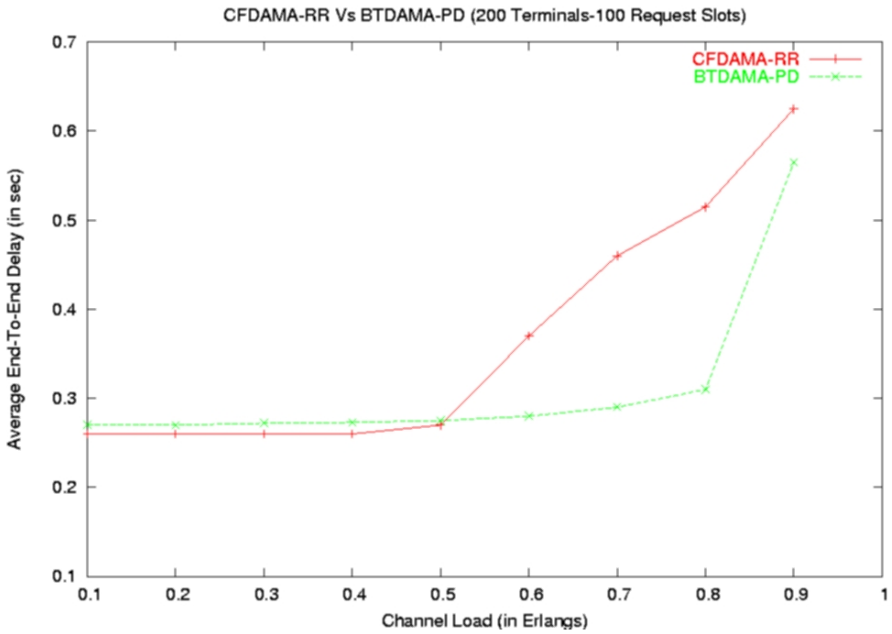

Figure 5.1: Performance comparison of CFDAMA-RR and BTDAMA-PD (200 Terminals) schemes

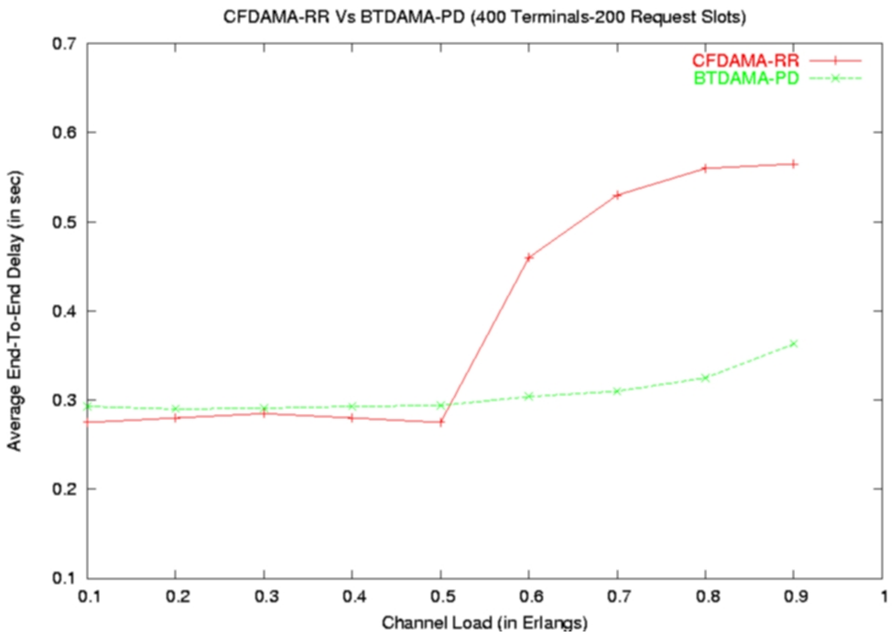

Figure 5.2: Performance comparison of CFDAMA-RR and BTDAMA-PD (400 Terminals) schemes

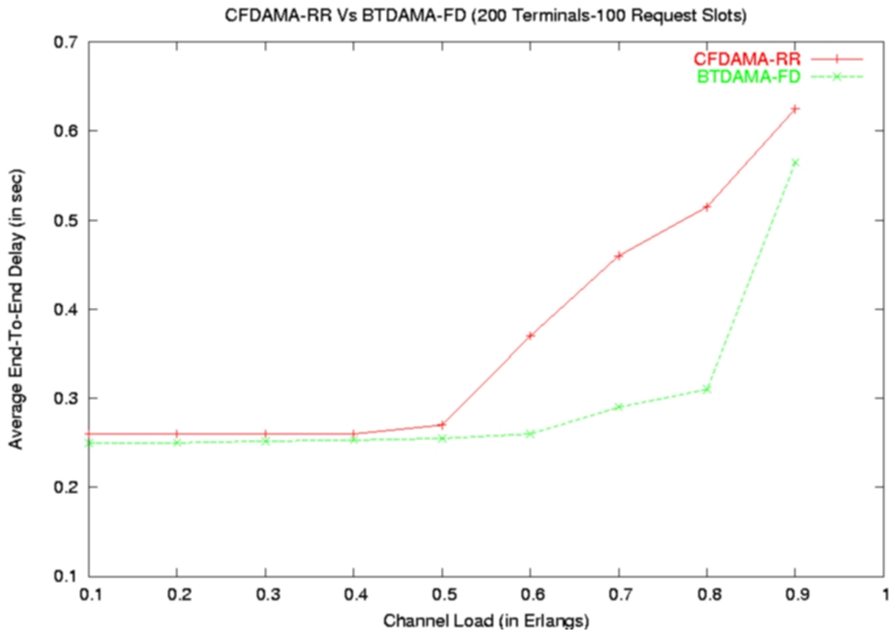

Figure 5.3: Performance comparison of CFDAMA-RR and BTDAMA-FD (200 Terminals) schemes

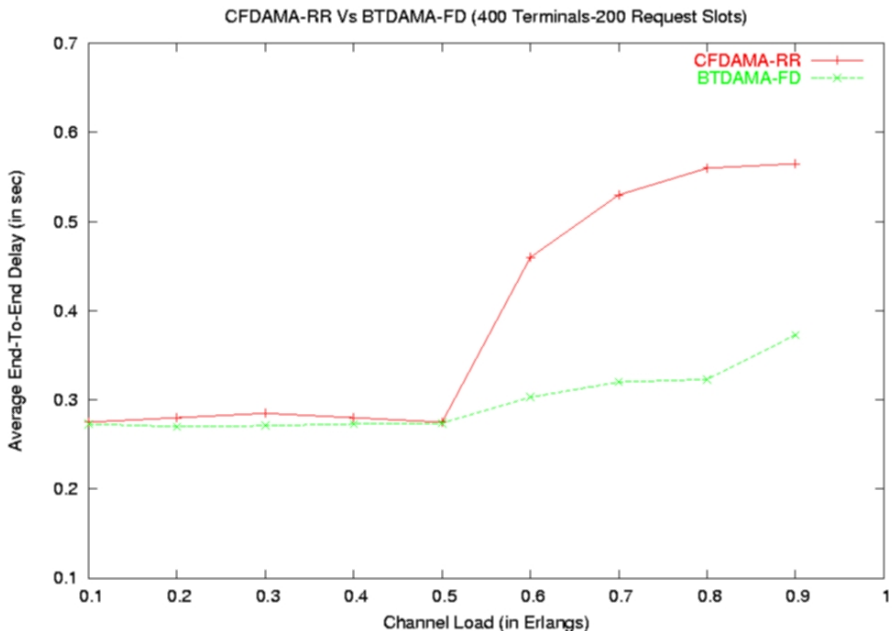

Figure 5.4: Performance comparison of CFDAMA-RR and BTDAMA-FD (400 Terminals) schemes

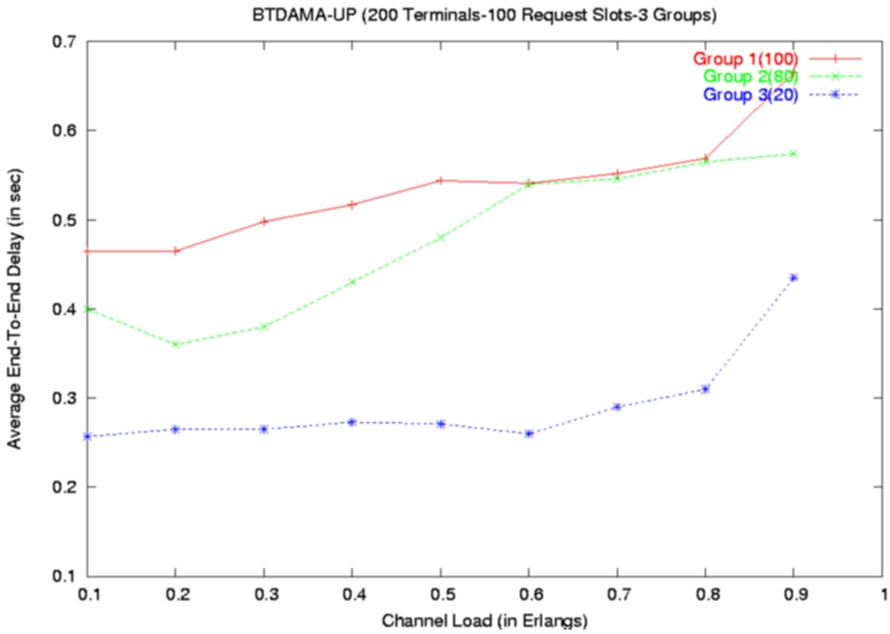

Figure 5.5: Performance of BTDAMA-UP (200 Terminals-100 Request slots) scheme

Chapter 6

Conclusion and Future Work

6.1 Conclusion

Performance comparison of Demand Assignment Medium Access (DAMA) protocols for a geostationary satellite system have been investigated in this thesis. Satellite capacity is a key commodity which must be used as efficiently as possible to support the highest number of users with the best quality of service. The achievable channel utilization efficiency and the resulting delay performance is governed by the underlying MAC protocol. It has been shown that BTDAMA-FD performs well with low end-to-end delay in both low and high channel loads.

BTDAMA-UP gives different type of service to different terminals according to their needs. High priority users gets better end-to-end delay at cost of low priority users.

6.2 Related Work

The BTDAMA-UP MAC aims at providing different level of service to different users in the network. Very little work has been done on centralized satellite star topologies. Most of the previous work has been on reducing end-to-end delay with different request and scheduling strategies.

6.3 Future Work

The BTDAMA schemes could be implemented in a distributed fashion, with each user terminal implementing the similar scheduling policies. This approach enables operation with a conventional transparent transponder, offering the same delay in signaling for capacity and associated performance of a processing satellite architecture with an On-Board scheduler at the expense of increased complexity and cost of the user terminal equipment. A distributed architecture is advantageous in that there is no single point of failure, with the potential for continuous operation in the presence of individual terminal failures.

Bibliography

[1] P. D. Mitchell, D. Grace, T. C. Tozer, *Comparative performance of the CFDAMA protocol via satellite with various terminal request strategies*, IEEE Global Telecommunications Conference (GLOBECOM), vol. 4, pp. 2720-2724, 2001.

[2] P.D. Mitchell, D. Grace, T.C. Tozer, *Burst targeted demand assignment multiple-access for broadband Internet service delivery over geostationary satellite*, Selected Areas in Communications, IEEE Journal on , Volume: 22 , Issue: 3 , Pages:546 - 558 April 2004.

[3] P. D. Mitchell, D. Grace, T. C. Tozer, *Performance of the combined free/demand assignment multiple access protocol with combined request strategies via satellite*, IEEE Personal, Indoor and Mobile Radio Communications Conference (PIMRC), September/October 2001.

[4] P. D. Mitchell, T. C. Tozer, D. Grace, *Improved medium access control for data traffic via satellite using the CFDAMA protocol*, IEE Seminar on Broadband Satellite: The Critical Success Factors Technology, Services and Markets, vol. (Ref No. 00/067), pp. 18/1-7, 2000.

[5] P.D. Mitchell; Tozer, T.C.; Grace, D., *Burst targeted demand assignment multiple access (BTDAMA) for on-off type data traffic via satellite*, Personal, Indoor and Mobile Radio Communications, 2002. The 13th IEEE International Symposium, Volume: 3, Pages:1392 - 1396 vol.3, 15-18 September 2002.

[6] P.D. Mitchell, T.C. Tozer, D. Grace, *Effective medium access control for satellite broadband data traffic*, Personal Broadband Satellite (Ref. No. 2002/059), IEE Seminar, Pages:3/1 - 3/7, 22 January 2002.

[7] J.I. Mohammed, T. Le-Ngoc, *Performance analysis of combined free/demand assignment multiple access (CFDAMA) protocol for packet satellite communications*, Communications, 1994. ICC 94, SUPERCOMM/ICC '94, Conference Record, Serving Humanity Through Communications. IEEE International Conference on , 1-5 May 1994, Pages:869 - 873 vol.2

[8] The VINT project, *NS-2 notes and documentation*, editors: Kevin Fall and Kannan Varadhan, `http://www.isi.edu/nsnam/ns`.