

Aggressive Back off Strategy in Congestion Management Algorithm for DBS-RCS

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Abstract. This paper investigates an aggressive back off strategy as part of the congestion management algorithms developed for Direct Broadcast Satellites with Return Channel Systems (DBS-RCS). The satellite architecture considered in this work is based on an asymmetric architecture with the high capacity forward link provided by the DBS and low speed return channel is provided by a constellation of Low Earth Orbiting (LEO) satellites. The network carries both Moving Pictures Expert Group (MPEG) coded video traffic and other data traffic having available bit rates (ABR) which is based on Reliable DBS Multicast Protocol (RDMP). Due to overwhelming complexity of real DBS-RCS systems, unless unduly simplifications are made, an exact analysis of this system becomes impossible. Therefore, we rely on the testbed results for investigation of the proposed aggressive back off strategy. In this paper, we first present a brief background on adaptive resource allocation and management (ARAM) system developed in our earlier work [1]. Then, we provide the proof of concept experiments for the newly introduced aggressive back off strategy. We show that the distributed control provided by the watermarks provides performance comparable to the baseline ARAM model. We also show that an aggressive back off strategy should be used for increased QoS.

1 Introduction

The future broadcast satellite system is under investigation for an asymmetric architecture with high capacity forward link provided by the Direct Broadcast Satellites (DBS) and lower speed return link provided by either a terrestrial link or a constellation of Low Earth Orbiting (LEO) satellites [1]. The challenge is to manage the dynamic bandwidth needs of Moving Pictures Expert Group (MPEG) video traffic while maintaining their Quality of Service (QoS). The purpose of this paper is to present an adaptive control approach for multiplexing heterogeneous traffic types over a Direct Broadcast Satellite (DBS) to end-users located in different regions experiencing varying channel conditions. When the MPEG coded video bit rates are at peak values, then network congestion will typically occur unless the network is designed to accommodate such peaks. Such congestion will degrade performance as evidenced by increased packet delays and packet losses for both the variable bit rate traffic as well as

other traffic in the network. However, if the network is designed for peak rates, then it will be over designed for nominal rates resulting in excess capacity.

Due to stringent service requirements of integrated satellite networks, the admission control and resource management scheme may become more challenging than traditional wired/wireless networks. [2] presents the performance of a movable boundary accessing technique, detailing the admission control and resource allocation procedure, in a multiservice satellite environment. [3] provides performance results for both conventional and dual movable boundary schemes. [4] presents the simulation results for an end-to-end connectivity planning and admission control for a multi-beam satellite network with on-board cross-connectivity. [5,6] propose an adaptive call management system real-time (low-interactive) VBR traffic over GEO satellite links. [7] presents simulation results for the performance of the combined/fixed reservation assignment scheme for aggregated traffic. [8] presents the simulation results for the medium access control of the broadband satellite networks. [9] presents the performance of end-to-end resource management in ATM GEO satellite networks. [10] presents an integrated connection admission control scheme for multiple wireless systems, ranging from terrestrial cellular networks to satellite networks.

The admission control approach described in this paper is based on the Adaptive Resource Allocation and Management (ARAM) algorithms described in [1]. ARAM is intended to ameliorate these problems in three ways:

- Design the network to leverage the statistical multiplexing effects, i.e., not all peaks occur at the same time,
- Adjust the rates of Available Bit Rate (ABR) traffic with less stringent latency requirements,
- Scale the MPEG video to operate within the bandwidth if all else fails.

In this way a balance is maintained between meeting user needs without an over designed network. The rest of this paper is given as follows. Section II presents a brief description of the system architecture envisioned for deployment of the above techniques. Section III presents the aggressive back off strategy in adaptive control algorithm of the forward link satellite channel. Section V describes the testbed and protocol work. Section V presents proof of concept experimental results. Section VI concludes this study.

2 Background

Figure 1 portrays the system concept that is based on an asymmetric architecture such that existing technology may be most effectively employed. The system delivers high volumes of information (data, imagery, video) from Source Systems located in safe havens to Application Platforms, i.e., user systems experiencing different channel problems. The system uses a high capacity forward link provided by a DBS to multicast data, imagery, and video packets from Source System hosts to DBS Field Terminals (DFTs) located at the satellite down link facility. Upon receipt of these packets,

the DFT routes them to the user Application Platform (AP). The DFT is a combination of DBS antenna, RF system, and DVB decoder with an IP router. The interface between the DFT and Application Platforms may be either: local area network, or remote connection by a terrestrial wireless network.

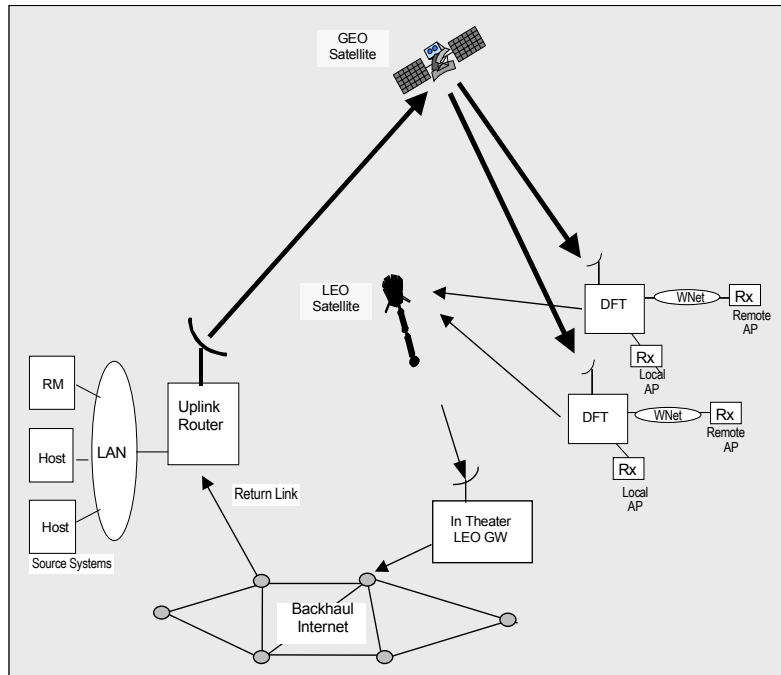


Figure 1. System Architecture

The low speed return link is provided by a constellation of Low Earth Orbiting (LEO) satellites. Since the area of coverage of the LEO satellite may not include the Source Systems, the LEO will downlink return packets to an in-theater gateway. The LEO gateway will then transmit the packets to the Source System via a terrestrial backhaul network. To deliver large volumes of information, this system utilizes the IP multicast protocol as the integrating technology.

The system provides the following two types services:

- Available Bit Rate (ABR) service for the reliable multicast of data and imagery,
- Variable Bit Rate (VBR) service for the MPEG video.

The ABR provides the error free delivery of data (files, images, or objects) to each receiving entity resident in the AP. In the case of transmission errors, it notifies both the sending application and network management for a retransmission. This service which is implemented by the Reliable DBS Multicast Protocol (RDMP), guarantees

the reliable delivery of messages to receivers or identifies an error condition [3]. The RDMP concept in terms of its ARQ (Automatic Repeat reQuest), flow control, synchronization, and recovery capabilities are described in [3]. Based on network congestion, it transmits its packets at a rate ranging from (T_{min}, T_{max}) .

The VBR provides the delivery of variable rate MPEG video via IP multicast from one source to many receivers. Since this service operates in a real-time mode, it does not utilize any acknowledgment techniques but relies on the quality of the underlying network to ensure an acceptable error rate. Analogous to ABR, the VBR service adjusts its offered data rate based on network conditions. While it requires the fixed delivery of 2 GOPs per second, the length of the frames may be adjusted over a range (L_{min}, L_{max}) to control the MPEG coding rate [7].

3 Aggressive Backoff Strategy in Adaptive Control Algorithm

The Adaptive Control concept for multiplexing the ABR and VBR traffic allows for an arbitrary mix of ABR and VBR traffic. A Resource Manager allocates available capacity to the ABR and VBR services based on priority, time window when service is needed, and cumulative queuing time of a request. Since the VBR services operate with a variable data rate, this allocation assumes some statistical multiplexing of VBR services will occur. As described in [1], the number of services allocated is based on the assessment that the capacity allocated to the VBR services will only exceed the assigned capacity a fixed percentage of the time.

The control algorithm is based on the concept of watermarks, as measured in the uplink router queue [

12]. The traffic will be multiplexed from several hosts over a LAN to a router that is directly connected to a satellite uplink facility. Since the LAN will have a higher data rate than the satellite uplink, the uplink will be a bottleneck. Therefore, congestion will be detected at the uplink router where packets are passed to the satellite ground station for transmission. In this concept, the watermark is measured as the uplink queue utilization in the router. The router will periodically multi-cast its “uplink queue watermark” over a network management socket to all of the Source System Hosts. When hosts serving ABR traffic receive a watermark message on the net management socket, they will adjust their transmission rate according to its watermark action table which will specify the fraction, f_k , for adjusting the transmission rate for level k. When the watermark indicates the queue utilization is low, then the ABR transmission rate will be increased to T_{max} . Analogously, when the queue is heavily utilized, the transmission will be backed off to T_{min} . When the watermark message is received indicating the current utilization is between Level k-1 and k, the host will determine the closest match in the action table, e.g., Level k. Then if the watermark has changed from the previous report, then the new transmission rate will be set with the rate factor, f_k , at:

$$T_{new} = T_{min} + f_k * (T_{max} - T_{min})$$

The adjustment of the VBR traffic is done analogously except the frame length is adjusted based on the watermark, but the transmission rate stays the same. For example, the new frame length would be determined as:

$$L_{new} = f_k * L_{nom}$$

where L_{nom} is the frame length at the nominal compression rate and f_k is the scaling factor. With watermarks, source systems are alerted of congestion by watermark messages and take action by reducing the source rates. The watermark table may be static or dynamic. For example, as the number of active users changes over time, it is desirable to modify the granularity of the adjustments being made. For example, when congestion occurs with a small number of users, large adjustments per user will be required to alleviate congestion while if there are a large number of users, smaller adjustments may suffice. Therefore, as the number of users changes the Resource Manager may update the watermark action tables.

Since digital signals over satellites have a very abrupt threshold, the video quality may completely degrade when the signal falls below the threshold. When the error rate threshold has been less than the acceptable threshold for N (typically 5) periods, then the FEC rate is increased to the next level. Because of the curves are very steep, decreasing the FEC rate by one level from levels of 7/8, 5/6, or even 3/4 may provide no improvement in performance. Therefore, the ARAM Resource Manager will reduce the FEC rate to either 1/2 or 2/3.

4 Testbed and Protocols

Figure 2 depicts the logical layout of the testbed. Source Hosts (MPEG, emulated MPEG, and RDMP), Resource Manager implements the algorithms, Uplink Router implements the queue management algorithms, Satellite Emulator introduces the delays and error rates representative of DBS satellites, and set of VBR and ABR receivers. The testbed elements are implemented using PCs or workstations. Although the Uplink Router and Satellite Emulator represent separate physical elements, they are implemented in the same PC to minimize testbed resources.

The representation of ARAM in the testbed is a simplified version of simulations because the testbed has the capability to model only a small number of MPEG flows (compared to the 30-40 flows in the simulation). As depicted in the figure, the Resource Manager is driven by the Frame Error Rate report from the Receivers and the Dropped Packet Reports from the Uplink Router. Based on these inputs, the Resource Manager resets the FEC rate and informs the Source Systems of the FEC change via the Scale Factor message. The Scale Factor reflects the change in information capacity due to the change in FEC rate. It is defined as the ratio of current FEC rate to the starting FEC rate. For example, if the starting FEC rate is 3/4 and the current rate is 1/2, then Scale Factor = $(1/2) / (3/4) = 2/3$.

Introduction of the real MPEG stream into the testbed was difficult because of the heavy processing load required for MPEG encoding. Therefore, MPEG compression was performed off-line MPEG data was stored on disk with four compression rates (shown by the four color coded files in the figure). When the ARAM algorithm indi-

cated a change in the compression rate was required, the source selected the corresponding MPEG file for transmission over the network. The decoder then received a video stream with the compression rate changing over time (shown by the file having four shades).

The emulated traffic was introduced using a superposition of two first-order autoregressive, AR(1), processes; one captures the short, and the other captures the long term dependencies of MPEG coded video traffic [12].

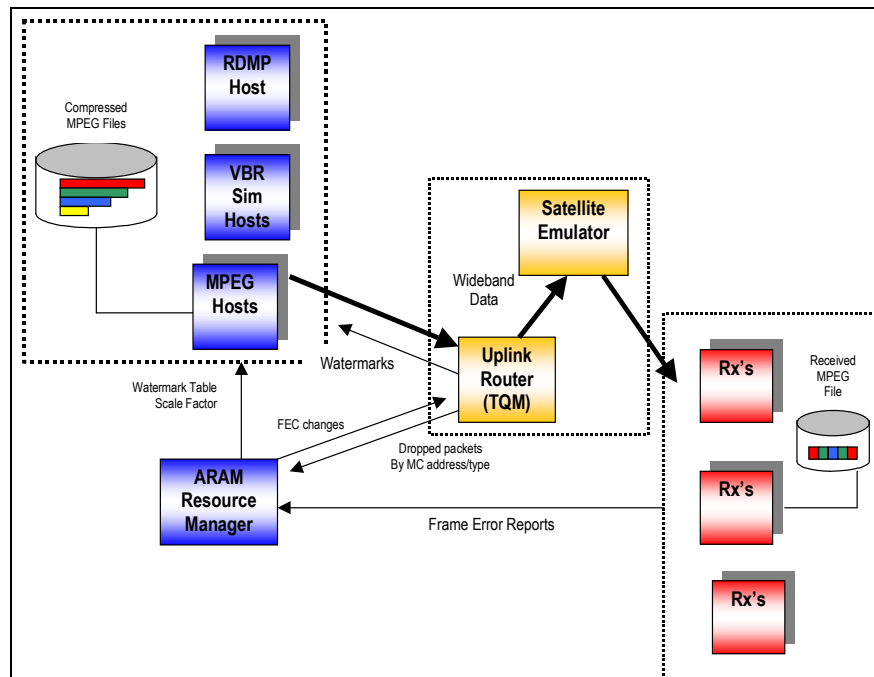


Figure 2. Testbed Concept

RDMP was developed to provide a reliable multicast service over a DBS satellite with a low speed return link. It operates over UDP because it has been developed as a UNIX application. For an operational system, RDMP would be modified to run directly over IP and reside in the UNIX kernel. Details on RDMP and the details of RTP-MPEG header encapsulations are described in [13].

5 Proof of Concept Experiments

This section describes the physical layout and the data display developed to show the experimental results as tests are being conducted. First, Figure 3 depicts the hardware layout, organized in Source and Receiver Systems. It also shows the functional resi-

gency of each device in terms of RDMP sender/receiver, Emulated VBR sender/receiver, and MPEG sender/receiver. For ease of implementation, one of the RDMP receivers (DBS3) collects the watermark, scale factor, and RDMP throughput data and sends it to the MPEG Display host (APOLLO) such that an integrated display can be produced. However, this is for display purposes only and would be implemented in an operational system.

The watermark strategy employed in the experiments was to first backoff the RDMP transmission rate and then backoff on the MPEG rates. The RDMP watermark tables were set to begin backing off when the watermark hit a 50% level. At the 50% level, the RDMP transmission rate was adjusted to 90% of the maximum rate while when the watermark hit 100%, the transmission rate was reduced to 50% of the maximum value.

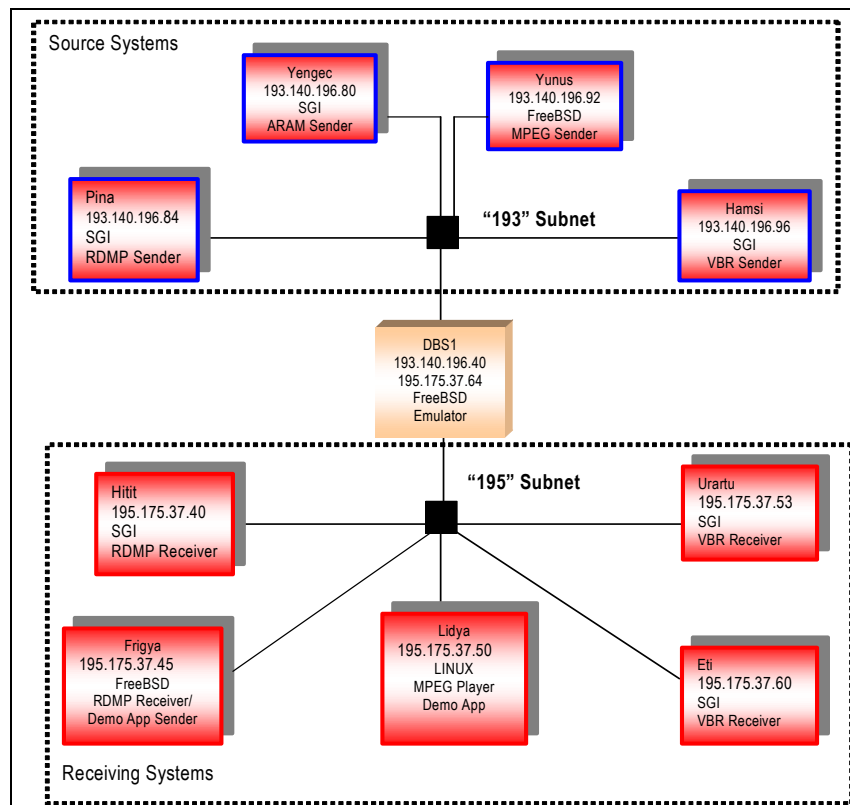


Figure 3. Hardware Layout

For the MPEG traffic, the backoff began when the watermark hit 80%. The following adjustments were used:

80% - transmit at 95% of nominal rate,

90% - transmit at 90% of nominal rate,

100% - transmit at 90% of nominal rate.

These rates are very aggressive because there are only two MPEG streams. In order to display results as the experiments are being performed, the real-time display is developed. The proof of concept experiment was successfully conducted for both a good channel scenario and a Gilbert channel alternating between good and bad channel conditions. It was demonstrated that the source rates for both the emulated and actual MPEG streams and the RDMP stream could be successfully changed in response to the watermark message. It was also demonstrated that the FEC rate could be adjusted by the ARAM algorithm. Figure 4 depicts the representative screen display showing data captured during the experiments.

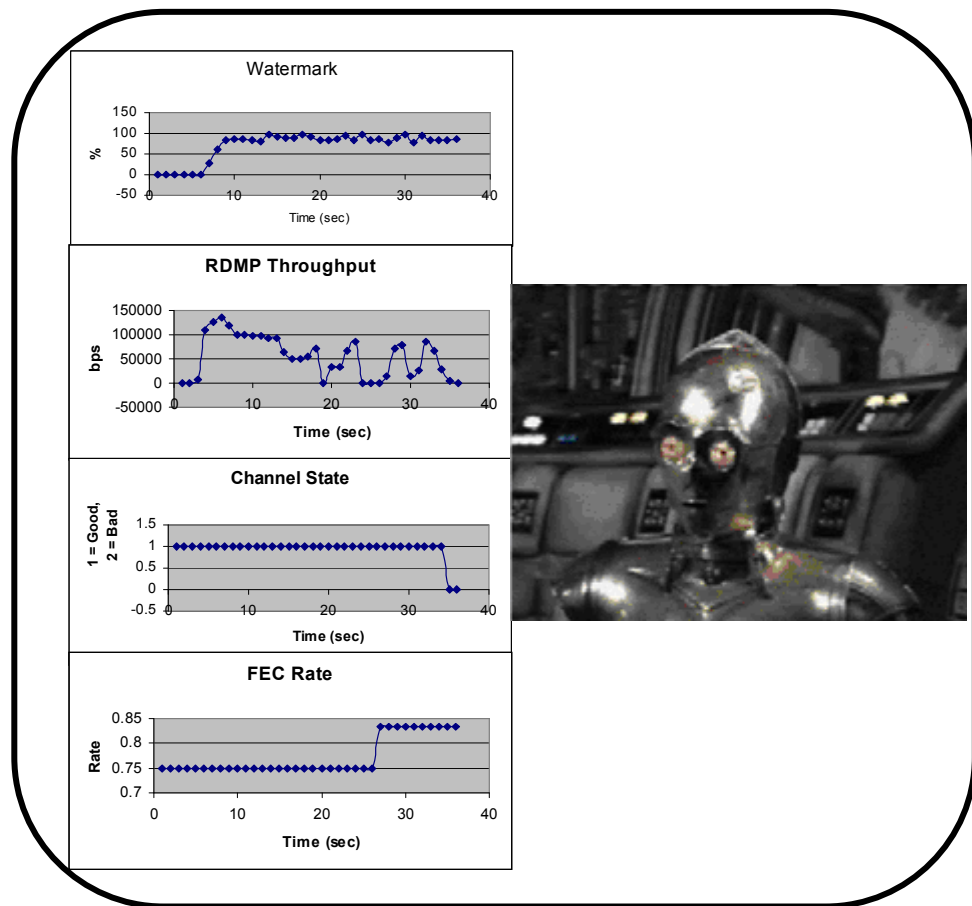


Figure 4. Representative Screen Display

6 Conclusions

In this paper we presented the testbed performance results of an aggressive back off strategy for congestion control in integrated satellite networks. We demonstrated a proof concept for implementation of the adaptive resource allocation and management (ARAM) algorithms based on the use of watermarks, to detect congestion in the system. It has been shown by simulation that the distributed control provided by the watermarks provides performance comparable to the baseline ARAM. Also, the testbed results show that utilizing an aggressive back off strategy, i.e., back off later rather than sooner, provides a higher quality of service even though more frames are dropped because performance will not be unnecessarily reduced.

7 Acknowledgment

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