International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Reliable Delivery of Point-To-Multi Point Services via Satellite (Multicast & Broadcast): Requirements and Solutions

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***Abstract*— *Wireless multicast networks do not offer guaranteed quality of service (QoS) such as bound transmission delays and error rates. Therefore, group-based applications rely on Data-link multicast protocols and transport-layer multicast protocols for ordering, reliability, group management, and other end-to-end services. Researchers have been directed at the data link layer and application/transport layer. This paper presents some data link layer error control protocols suitable for point-to-multipoint communication over multicast channels, where data are delivered to the destinations in the order they are sent. The protocols were generalized to the case where multiple copies of a message are sent. The optimum number of copies is determined, which depends not only on the round trip propagation delay of the channel, the error probability, but also on the number of receivers that have not yet received the message. The throughput comparison shows that by sending the optimum number of copies of a data frame instead of just a single copy, the performance will be significantly improved. We also show that error recovery and receiver feedback service (retransmissions): achieves high performance such as "low delivery latency and high throughput; efficiently utilizes network and end system resources; Provide flexible error control method suitable for reliable, unreliable and other error control paradigms.*

***Keywords*— *Multicast networks, quality of service, error probability, latency, throughput, eerrro control*.

I. Introduction

Multicast has been seen as a major evolution in the Internet development and a key technology that can save network resources and contribute to the provision of better Quality of Service (QoS) to the Internet users. A number of emerging network applications requires the delivery of packets from one or more senders to a group of receivers (Mase *et al.*, 1983; Inder and Jefferey, 1984; YU Dong and Shi Xin, 1987; Jonathan and John, 1998). This application includes bulk data transfer, streaming continuous media such as (audio, video and text messages to a set of distributed participants), shared data applications, Web cache updating, and interactive gaming. Each of these applications uses the idea of multicasting by sending a packet from one sender to multiple receivers with a single send operation. A single packet is addressed to all intended recipients and the network replicate packets only as needed. Only one copy of multicast message passes over any link (such as router) in the network. Copies of the message are only made when path diverge at a router. Multicasting is natively supported on many LAN technologies such as Ethernet. It aims at delivering data to a selected group of hosts (Don, 1985).

Multicast function:

- Unlike broadcasting, Multicasting allows each host to choose whether it wants to participate in a multicast.
- In wan multicasting, membership information has to be maintained across the entire wan.

II. Multicast in Satellite Communication Networks

Multicast media have often been used to support satellite communication. Because of the increasing amount of information available in electronic form such as Web (low rate inbound, high rate inbound), Email, file transfer, WAP services, Messaging (Global positioning), forward and store information, video/audio, interactive multimedia services, location based services and voice over IP (VoIP). These technological developments have increase enormously the number of machines connected to wired or wireless network, thus able to access multimedia information. This in turn has created many new potential users of information services, making the use of multicast transport protocols an attractive approach for the distribution of these data objects (Bruneel and Moeneclaey, 1986).

Many problems still exist related to the scalability of the techniques used for multicast applications, especially those requiring reliable data delivery. Approach to reliable multicast relies on retransmission on demand of lost packets. Scalability problems arise when the set of receivers becomes large. The existing implementation of reliable multicast, being based on the use of Forward Error Correction (FEC) and the ARQ schemes. (Mase *et al.*, 1983; Inder and Jefferey, 1984; YU Dong and Shi Xin, 1987; Jonathan and John, 1998).

Reliable multicast (RM) protocols are in charge of distributing the same data object (split into a number of data packets) to a set of receivers, with some kind of guarantee on the delivery process. Depending on the application, the protocol might be required to deliver packets in a certain order or. Protocols that are study here guarantees the eventual delivery to all successful receivers of the same object, with no special ordering or timing constraints in the delivery of individual packets.

Dr. Sadiq Umar, Dr. Evans C. Eshiguike, Dr. Vitalis C. Anye, and Tsado Victor Mamman, “Reliable Delivery of Point-To-Multi Point Services via Satellite (Multicast & Broadcast): Requirements and Solutions,” *International Research Journal of Advanced Engineering and Science*, Volume 4, Issue 2, pp. 482-486, 2019.

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ISSN (Online): 2455-9024

Reliable transport is a fundamental requirement for efficient and reliable distribution of data to a group of receivers. The complexities of group communication necessitate different protocol types to meet the range of performance and scalability requirements of different potential reliable multicast applications and users (Frietman, 2002).

There are many ways to provide reliability for data transfer. Reliability can be implemented at different layers of the protocol stack (Mase *et al.*, 1983; Inder and Jefferey, 1984; YU Dong and Shi Xin, 1987; Jonathan and John, 1998):

- Application/Transport layer: Packet level Forward Error Correction (FEC) packet retransmissions or Automatic Repeat request (ARQ)
- Data Link/Physical Layer: Frame, bit (Byte)-level FEC, frame transport block retransmissions, power scheduling (WCDMA).

A common method is to use ARQ (Automatic Repeat reQuest) in the Transport/Application layer or in the link layer. With ARQ, receivers use a back channel to the sender to send requests for retransmission of lost packets. ARQ has also been an effective reliability tool for point-to-multipoint transmission. Requirement for reliability implies both positive and negative Acknowledgments from the receivers to the transmitter (Mase *et al.*, 1983; Inder and Jefferey, 1984; YU Dong and Shi Xin, 1987; Jonathan and John, 1998).

Unicast ARQ schemes are simple to implement, robust, reliable and generally classified in three basic types (Yu and Shu 1981; Jolfaei and Quernheim, 1993; Deng 1993; Deng 1995);

i. Stop and wait (SW)
ii. Go back-N GB(N)
iii. Selective Repeat (SR)

However, for point to multipoint communication, ARQ have limitations, including the feedback impulsion problem because many receivers are transmitting back to the sender, and the need for a back channel to send these requests from the receiver (Mase *et al.*, 1983; Inder and Jefferey, 1984; YU Dong and Shi Xin, 1987; Jonathan and John, 1998).. Another limitation is that receivers may experience different loss patterns of packets, and thus receivers may be delayed by retransmission of packets that other receivers have lost but they have already received. This may also cause wasteful use of bandwidth, since it is partially used to retransmit packets that have already been received by many of the receivers.

On the other hand, Forward Error Correction (FEC) codes provide reliability that can be used to augment or replace other reliability methods, for point-to-multipoint reliability protocols. Similar to ARQ, FEC can be implemented either at access layer (physical and data link layers), where we are dealing with bits or frames or at packet level at transport layer.

In the general literature, FEC refers to the ability to overcome both erasures (losses) and bit-level corruption. However, in the case of a multicast protocol, the network layers will detect corrupted packets and discard them or the transport layers can use packet authentication to discard corrupted packets. Therefore the primary application of FEC codes for multicast communications is as an erasure code. The payloads are generated and processed using a FEC erasure encoder, and objects are reassembled from reception of packets containing the generated encoding using the corresponding FEC erasure decoder.

III. METHODOLOGY

In this study, series of protocols that are suitable for point-to-multipoint communication over a broadcast channel are described. The sender sends data frames to the receivers and starts the timeout clock. The number of copies sent depends on the number of receivers that have not yet successfully responded K, the error probability p_s, p_i and the round trip delay N. The optimum of copies is denoted by $n^*(K, ps, pi, N)$. (Mase *et al.*, 1983; Inder and Jefferey, 1984; YU Dong and Shi Xin, 1987; Jonathan and John, 1998).

Receivers that receive the data frame and decode it successfully send back $ACKs$ while those decode it in error send back $NACKs$. After a round trip delay, the sender can check whether all the receivers have received the data frame successfully. If not, the sender retransmits the data frame.

The sender maintains a list for each outstanding data frame called the $frame\_outstanding$ list.

Analysis of stop and-wait ARQ protocol

Let $B(K)$ be the mean number of time slots elapsed before a data frame is correctly received by all K receivers and $n(K)$ be the number of copies sent when K $ACKs$ are outstanding (YU Dong and Shi Xin, 1987). Then the throughput of a stop-and-wait scheme is $T(K) = 1/B(k)$. For a fixed p_s, p_i, and N, we will maximize $T(K)$ by choosing an optimum $n^*(K)$. $q_j(K)$ be the probability that all K receivers receive the data frame in j copies, then (YU Dong and Shi Xin, 1987)

$$q_j(K) = [1-(1-pi)_j]^k \; if \;\; p_s = 1 \tag{1}$$

either this data frame has been receive before.

$$q_j(K) = \sum_{m=0}^{j} (j) \; p_s{}^m (1-p_s)^{j-m} [1-(1-pi)^m]^k \; if \;\; 0 < p_s < 1 \tag{2}$$

A) M_0 $protocol : B(k)$ can be written as follows:

$$B^*(k) = \min\, n(k) \left\{ \frac{N + n(K) - 1 - \sum_{j=1}^{n(k)-1} [1-(1-pi)^j]^k}{[1-(1-p_i)n(k)]^k} \right\} \tag{3}$$

(B) M_1 $\Pr otocol$: The method used here is dynamic programming where the stage is set to be the number of receivers that have not yet received the data frame (YU Dong and Shi Xin, 1987).

$$B^*(K) = \min\; n(k)\; \{A1/B1\} \tag{4}$$

Where

$$A_1 = (N + n(k) - 1 - \sum_{m=1}^{n(k)-1} (1-(1-p_i)^m)^k + \sum_{j=1}^{k-1} (k)[1-(1-pi)^{n(k)}]^j (1-pi)^{n(k).(k-j)} .B^*(k-j)$$

$$B_1 = 1-(1-p_i)^{n(k).k}$$

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2.2. Analysis of Go-back-N ARQ protocol

For the M_0 and M_1 protocols, the sender effectively ignores any $ACKs$ for a data frame unless the data frame is the $FODF$. Therefore, for these two protocols the throughput can be expressed by focusing on the transmission of only the $FODF$. By using the same notation as before (Sabnani, 1982; Mase *et al*, 1983):

A) M_0 $protocol : \beta(k)$ can be written as follows:

$$\beta*(k) = \min n(k) \frac{\{+n(K)+[1-(1-(1-p_i)^{n(k)})^k](N\_1)\}}{[1-(1-p_i)n(k)]^k} \tag{5}$$

(B) M_1 $\Pr otocol$: We again refer to dynamic programming method, $\beta*(k)$ can be directly obtained from equation (5) as (Sabnani, 1982; Mase *et al*, 1983):

$$B*(K) = \min n(k)\{A_2 / B_2\} \tag{6}$$

Where

$$A_2 = n(k) + K(1-p_i)^{n(k)} + \sum_{m=1}^{k-1}(k,m).[1-(1-p_i)n(k)]m.(1-p_i)n(k).(k-m).[N+n(K)-1+B*(K-m)] \tag{7}$$

$$B_2 = 1-(1-p_i)^{n(k).k}$$

IV. Results and Discussions

The results of the numerical computations using MATLAB Scripting were obtained, it can be seen from the plots that the new scheme has a better performance with r and n getting larger (See fig below). The superiority of the new scheme under high error rate conditions becomes more explicit as N gets larger. Since in the stop-and-wait scheme there can be only one outstanding data frame, there are two protocols discussed: the M_0 and M_1 protocols. Since the sender and receiver operation for all the protocols are similar, there is need to go straight to the analysis of the protocols.

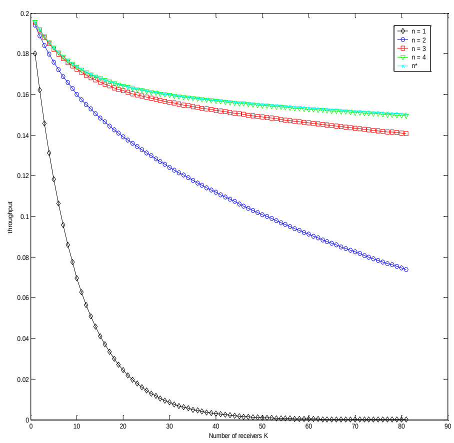

Figure 1: Throughput vs. Number of receivers K for the stop and wait M_0 protocol

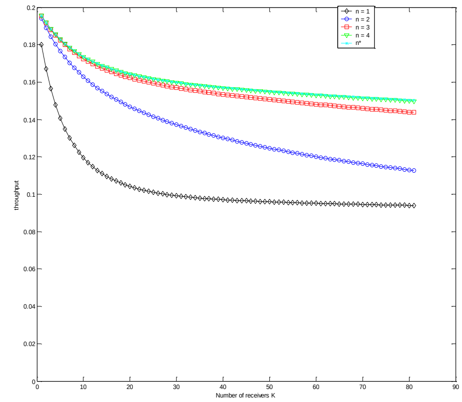

Figure 2: Throughput vs. Number of receivers K for the stop and wait M_1 protocol

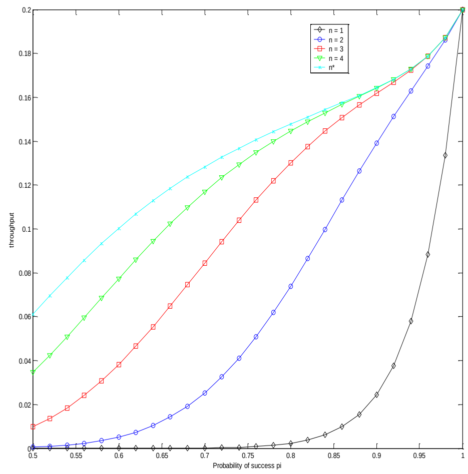

Figure 3: Throughput vs. probability of success Pi for the stop-and wait M_0 protocol

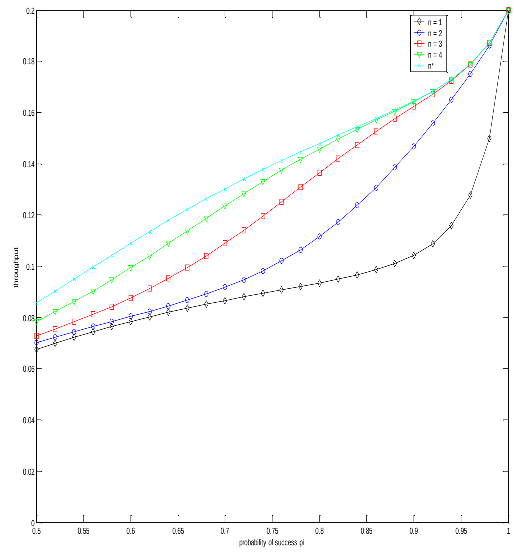

Figure 4: Throughput vs. probability of success Pi for the stop and wait M_1 protocol

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

As shown in Figure (1) to Figure (4) above, M_0 Pr*otocol*, the optimum throughput which is the envelope of the fixed copy curves was achieved by choosing the optimal transmitting copies.

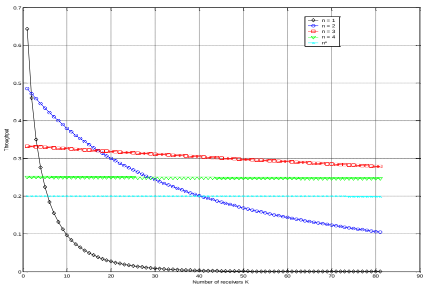

Figure 5: Throughput vs. number of receivers K for the Go-back-N M_0 protocol

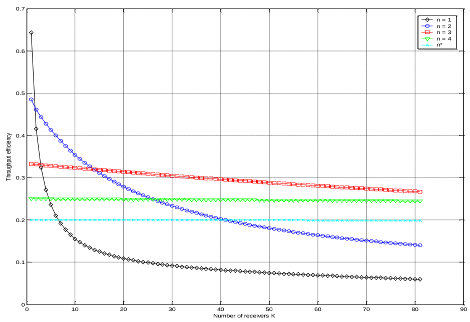

Figure 6: Throughput vs. number of receivers K for the Go-back-N M_1 protocol

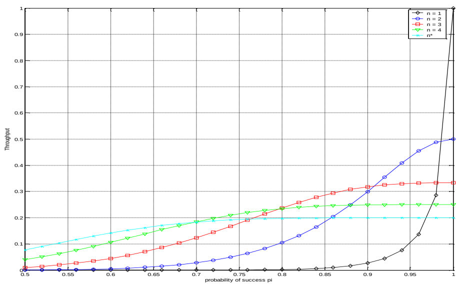

Figure 7: Throughput vs. probability of success Pi for the Go-back-N M_0 protocol

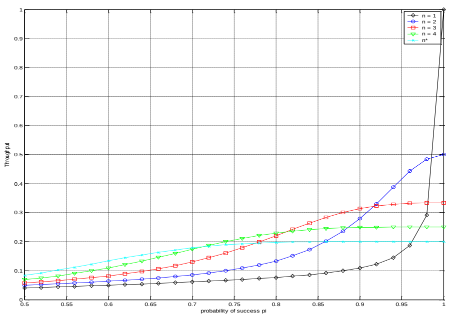

Figure 8: Throughput vs. probability of success Pi for the Go-back-N M_1 protocol

As seen above in Figure 5 to Figure 8, the throughput efficiencies versus Number of receivers for the go-back-N M_0 and M_1 Pr*otocol*. The protocols differ in the way that the sender utilizes the outcomes of previous transmissions. The protocols to optimize the throughput efficiency in both stop-and-wait and go-back-N schemes were used to determine the optimal number of copies of a data frame the sender should send. The optimal values can be stored in memory for further selection. The optimization problem is solving for M_1 by using dynamic programming techniques. The result shows that as the sender's memory is increased, higher performance can be achieved; however the performance decreases as the sender transmit optimal number of copies of a data frame instead of single one. It was observed that the system throughput can be greatly increased, by sending optimum number of copies of a data frame.

V. Conclusions

In this study, series of optimal adaptive go-back-N *ARQ* suitable for point-to-multipoint communication were studied. These protocols were based on the protocols discussed by (Inder *et al.* 1984) instead of sending a single copy of the data frame to multi-destinations, the sender transmits multiple numbers of copies to the receivers in order to maximize the throughput. It was shown that a new scheme can be modified through the numerical analysis to yield better throughput performance. This scheme is called end-to-end error control scheme, where the uplink and the down-link use different error control schemes. This was achieved by written MATLAB Scripting for implementing go-back-N *ARQ*, where a control block is used to indicate the occurrence of retransmission to all the receivers. The preliminary results suggest that the mechanism is attractive for reliable multicast in wireless environments, since it can perform well under high error rate conditions. The throughput efficiency of the tandem go-back-end is higher than that of the end-to-end go-back-end *ARQ*.

Furthermore, the use of protocols to optimize the throughput efficiency in stop-and-wait *ARQ* schemes was also investigated. The optimal number of copies of a data frame the sender can send was determined. The optimization problem was solved for the M_1 protocol by using dynamic programming techniques. The results show that as the sender's memory is increased, higher performance can be obtained. It can be concluded that the system throughput can be greatly increased by sending optimum number of copies of a data frame.

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