A Simulation Study of a Reliable Dynamic Multicast Environment

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Abstract: *In the dynamic multicast environment, static multicast retransmission modes may lead to congestion and loss of packets due to propagation errors of the wireless network. This paper logically divides the dynamic multicast network into fixed and mobile parts, and focuses on the dynamic wireless environment, where mobile member may enter in non-covered areas. The group is divided into many subgroups of mobile members. Each subgroup has one Designated Receiver (DR), which is responsible of multicast. Simulation studies have been conducted to determine the benefits of integrating an improved Forward Error Control (FEC) codes to a reliable multicast protocol P_Mul in the dynamic environment. Members can leave and join the subgroup based on some distributions. DR can support two modes of FEC, proactive and reactive. The simulation tool using OPNET shows that reactive FEC is better with high rate of leave and low rate of join. However, for proactive FEC, it is the opposite. Also, simulation results show that the number of designated receivers is parabolic with respect to the number of retransmissions. This paper investigates the benefits of an improved FEC mechanism for the reliable dynamic wireless networks.*

Keywords: *OPNET, proactive/reactive FEC, dynamic multicast retransmission, designated receiver.*

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1. Introduction

Most existing multicast protocols adopt static retransmission schemes to retransmit lost packets [17]. Our work extends the paper [17] to dynamic Multicasting. The dynamic multicast is a way of communication between a source and a group of receivers that can leave and join the group members at any time. The multicast source sends out one copy of the information instead of one for each receiver as in unicasting. Therefore, only a single copy of the information moves via shared paths between the sender and receivers, reducing the amount of traffic traversing a network. Only those recipients that belong to a multicast group receive it. For best effort networks, a higher layer protocol — known as reliable multicast protocol, is required to provide satisfactory level of reliability for the information transport. Usually this reliability is obtained by Automatic Retransmission Request (ARQ), such as in P_Mul [18]. P_Mul is a reliable multicast protocol for messaging in sub networks with bandwidth constraints and uncertain feedback response [13]. There are two operational modes, the normal ARQ mode and the delayed feedback mode when some receivers are in EMission CONtrol (EMCON). Our emphasis in this study is to explore the FEC as the ARQ improvement. One of its practical applications is messaging in military VHF and HF networks [13]. P_Mul can operate on User Datagram Protocol (UDP) or other best effort protocols and requires no support from the network apart from multicast routing. Considerable amount of work has been done in the area of reliable multicast transport protocols [10, 13]. Numerous error recovery mechanisms have been proposed [6, 15, 18]. They depend on the type of application that uses multicast service as well as the characteristics of the under- lying network. There is no single solution that fits all different scenarios [5]. Our study of P_Mul was inspired by the work of McAuley [9], Rizzo [14]. They explored applicability of erasure FEC to the multicast transport of data over the internet and wireless links, and suggested and implemented suitable coding techniques. A Canadian research group [2] has done extensive simulation study on the overall P_Mul performance in a subnet environment. Our work is strictly focused on P_Mul's error recovery mechanism described in the ACP142 [12] and error control coding enhancements. The ARQ mechanism of P_Mul is explained in section 2. Then in section 4, improved FEC technique is described. The simulation setup and comparison of results are presented in sections 5 and 6. The last section concludes the paper with an overview of the results and remarks on future work.

2. A Hybrid Model for Static Multicast

Various hybrid FEC/ARQ strategies have been proposed to the amount of retransmissions in multicasting [13, 15, 17, 18]. To study the maximum possible improvements to P_Mul with this type of hybrid ARQ, we initially extend P_Mul error recovery mechanism using FEC code. We assumed the existence of such an ideal block *code = G (n, k)* with erasure decoding, where *(n, k)* are arbitrary integers such that $1 < k < n$, as shown in Figure 1.

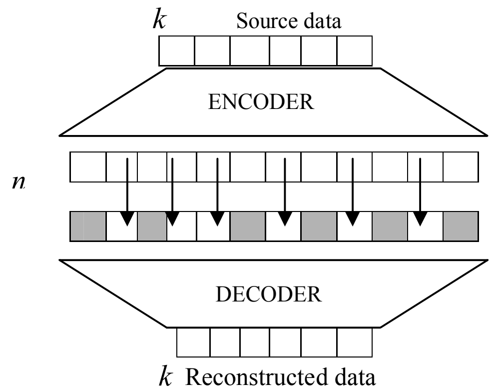

Figure 1. Forward error control.

The k matches to a message size in packets, while n can be arbitrary large to provide sufficient number of repair packets for loss links considered. Using simulation, we observed combining of such code with the P_Mul ARQ scheme into hybrid scheme, while trying to maintain the original P_Mul model as much as possible. The transmissions continue to be organized in rounds led by Address_PDU, and the receivers respond with Ack_PDU as described in the previous section. The first transmission remains the same, i. e., it consists of M messages Data_PDUs. The sender waits the EndAck_PDU response from all, or retransmission timeout, to process the received Ack_PDUs from individual receivers. It, then, observes the number of unacknowledged Data_PDUs and identifies the worse case receiver for that round. That is a receiver with maximum number of unacknowledged packets, max-miss, for that round. By means of FEC code, the sender generates max-miss number of parity packets, which are transmitted in the following round. Every parity packet is unique through the entire process of message transmission and its sequence number distinguishes it. Max-miss number of parity packets is enough to recover all missing Data_PDUs for all receivers. The receiver responds with Ask_PDU to either confirm completion of reception or to report sequence numbers of missing parity Data_PDUs, and the process continues. A main advantage of hybrid FEC/ARQ in multicast is that the minimal number of packets traverses the network. Instead of retransmitting a union of all missing messages Data_PDUs for all receivers, the sender creates equally valuable parity packets that can act as the replacement to any lost packet from the previous rounds. Consequently, it is enough to multicast the number of parities that would satisfy the ‘worst’ receiver. This paper will not go into the detail of the coding technique that could be used. The transmission timer is estimated to:

$$T = (1 + p) * L / r \quad (1)$$

where

p = Rate of loss.
r = rate of transmission of the channel.
L = Maximum size of Ack_PDU list of missing sequence numbers.

3. The Dynamic Multicast

The work in [16] presents an end-to-end reliable multicast protocol for use in environments with wireless access. It divides a multicast tree into sub-trees where sub-casting within these smaller regions is applied using a tree of Retransmission Servers (RS). The protocol is receiver oriented in that the transmitter does not need to know its receivers, hence offering better scalability. However, it does not seek to conserve network resources. This problem could be minimized if a hierarchal protocol is employed.

3.1. Dynamic Multicast Algorithms

A multicast group member may join or leave a multicast session dynamically [3, 4, 15]. It is thus important to ensure that member join/leave will not disrupt the ongoing multicast session, and the multicast tree after member join/leave will still remain near optimal and/or satisfy the Quality of Service (QoS) requirements of all on-tree receivers. If a multicast tree is reconstructed each time a member joins or leaves, on-tree nodes may not switch to the new tree simultaneously, and a seamless transition may not be possible.

We handle dynamic member join/leave by using certain distributions. When a new member intends to join the sub-group, it sends a request for transmission to the nearest DR. We propose a model that switches burden to receivers. Receivers are grouped into subgroups; each one has a designated receiver DR. The multicast is only to DR's as shown in Figure 2.

- DR recovers lost packets for any/all group member.
- Local recovery from DR.
- Reduce control feedback (Acks or NAKs).

Groups can be hierarchically organized.

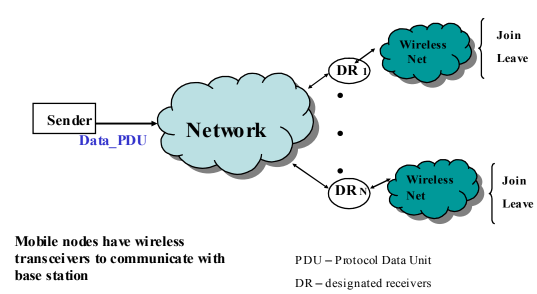

Figure 2. The proposed model.

4. Improved FEC for Dynamic Multicast

Improved FEC-based multicast method is used for dynamic servers where members can leave and join the group any time. Mobile servers sometimes enter to non-covered areas. This method is used for the necessary encoding/decoding in software, for avoiding retransmissions.

The DR's can support two modes of FEC: Proactive and reactive. Proactive FEC is a mechanism by which parity packets are sent along with the data packets. The receivers use the parity packets to recover the missing data packets.

Reactive FEC is a mechanism by which the sender encodes and sends parity packets only if it gets notification about missed data packets. The sender sends parity packets instead of retransmitting the data packets. The receivers are able to repair different lost packets with these parity packets. With reactive FEC, for a window of *N* packets, the sender only has to retransmit a number of parity packets equal to the maximum number of lost packets in the window for any descendant. We divide the system into 2 parts: The first part between the sender and DR's is studied in [17]. In this paper, we focus on the second part which deals on the retransmission among DR's and mobile receivers. Mobile members can use wireless transceivers to communicate with base stations. Each subgroup is viewed as region with limited range of communication as shown in Figure 3.

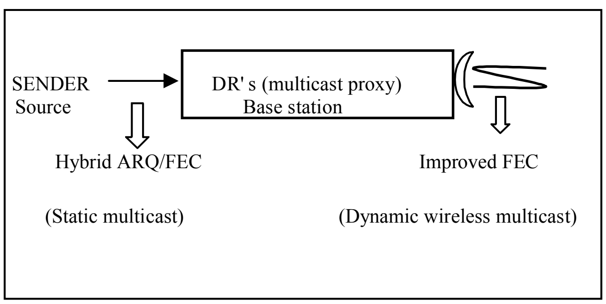

Figure 3. The 2 parts of the proposed model.

4.1. The Proposed Algorithm of the Second Part

Designated Receiver (DR) (see Figure 4) can do both proactive and reactive FEC:

- Compute and send more redundancy packets depending on the packets loss in a sub-tree.
- Send NAK (Ack-PDU) to the source sender whenever there is a loss or errors.
- Reply to NAK whenever possible by sending more redundancy packets.
- A joining member must send NAK with IP class D address.
- A leaving member is supposed to join an another region.
- DR's cannot leave the subgroups.

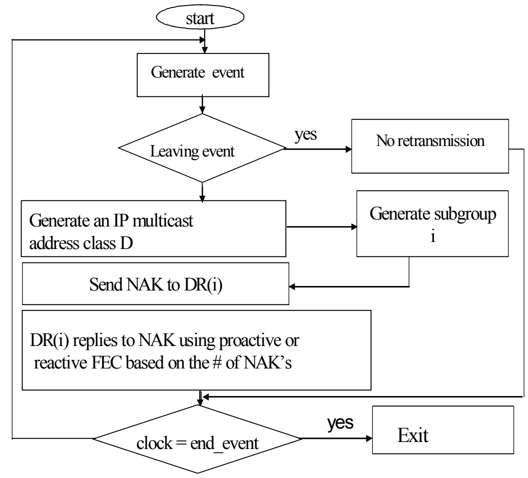

Figure 4. The abstract simulation model for the second part.

5. Simulation Model

The Optimized Network Engineering Tool (OPNET) provides a comprehensive development environment for the specification, simulation and performance analysis of communication networks [11, 17, 19]. OPNET is developed by MIL3, Inc. and runs on both UNIX and Windows NT machines. The package contains the following tools:

- *Hierarchical model building*: Network, node, process, and parameters editors.
- *Running simulation*: Probe editor, and simulation engine.
- *Analyzing results*: Analysis tool and filter editor.

We used OPNET simulation tool to develop simple models of the P_Mul ARQ and hybrid FEC/ARQ error recovery mechanisms. The network consists of a sender and a number of base stations located at fixed topology. Every base station has a region with limited range of communication. The system consists of 30 mobile receivers. The number of DR's varies from 1 to 30. The links between the sender and DR's are modeled as a single hop channel. All channels are mutually independent and have the same average Bit Error Rate (BER). The packets are dropped randomly according to Bernoulli distribution with mean dependent the packet length. Table 1 lists the values of the variable and fixed simulation parameters used. Mobile receivers join and leave the region according to certain distributions.

The Data_PDU header is kept constant 16 bytes. The Address_PDU has got fixed header size of 24 bytes, and 8 bytes for every receiver entry. The size of Address_PDU is initially large, especially for large networks. The timer is set to the period that corresponds to the worst receiver round trip propagation time plus the transmission time of EndAck_PDU plus a small guard time. The following statistics were collected:

- Message delivery time.
- Number of retransmissions.
- Number of retransmitted packets.

These statistics are used for observing and comparing the performance of the protocol under different error recovery schemes and different protocol, network and link parameters (BER, *L*, Data_PDU size). All statistics were collected on a basis of a single message transfer and over several hundred-simulation runs. The main performance measure is the number of retransmissions.

Table 1. Simulation parameters and settings.

Variable Parameters	Values	Comments
Data_PDU payload	1.5 Kbytes	Size of a Data_PDU payload
BER	10^{-3}	Bit error rate on forward channel
N	30	Number of receivers
L	50	Ack_PDU list size
Fixed Parameters	**Values**	**Description**
BER (return links)	0	Bit error rate on return channels
Data rate	2400bits/sec	Fixed for all nodes in the network
Propagation delay	0.1 sec	Constant for all nodes in the network
Message size	30 Kbytes	Size of a single message
Number of messages	100	Average over 7 simulation runs
Duration	1.5 days	Time to send 100 messages
Distributions	**Values**	**Comments**
Exponential	2 – 6 hours	Distribution for leaving the group
Exponential	2 – 6 hours	Distribution for entering the group

6. Simulation Results

The following charts summarize simulation results. It is clear that using 2 types of FEC yields an improvement in the field of retransmission. Type 1 and 2 mean the proactive and reactive FEC respectively, which are displayed in the following figures. Figure 5 and 6 show a comparison of the number of retransmission for the P_Mul with ARQ and hybrid FEC/ARQ schemes with high rate of leave and low rate of join, *N = 30*, *L = 50*, Payload size = 1500 bytes and 10 DR's. Figure 7 shows that the number of DR's with respect to the number of retransmissions of the sender is parabolic. Table 2 shows the summary of the simulation results for both types.

7. Conclusion

This work investigated the benefits of the improved FEC scheme for dynamic environment with wireless and packet loss. Simulation results show considerable improvement in the number of retransmissions when both proactive and reactive are used. However, the drawbacks are the delay and the computation requirements.

Future work includes analyzing the influence of size, frequency of packet loss and vary channel characteristics; designing the model by *analytical results* to find the true optimal number of DR's; and integrating intelligence at the DR's; level to decide whether to use proactive or reactive.

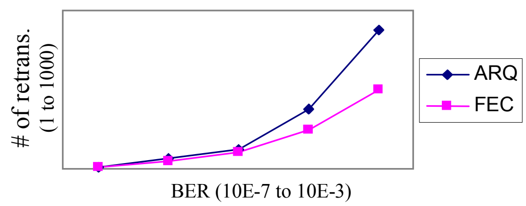

Figure 5. Comparison of ARQ versus FEC/ARQ with type 1.

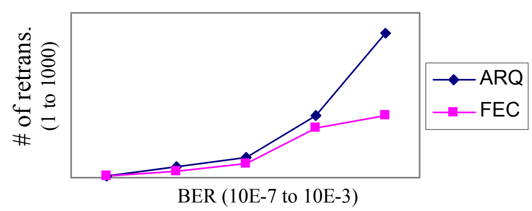

Figure 6. Comparison of ARQ versus FEC/ARQ with type 2.

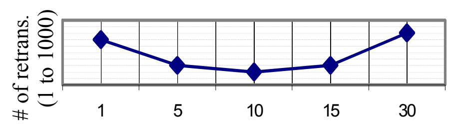

Figure 7. The number of DR's behavior with respect to the number of sender retransmissions is parabolic.

Table 2. Simulation results of type 1 and 2 for the dynamic environment.

	Proactive FEC Type 1	Reactive FEC Type 2
High rate of leave & low rate of join		recommended
High rate of leave & high rate of join	recommended	
Low rate of leave & low rate of join		recommended
Low rate of leave & high rate of join	recommended	

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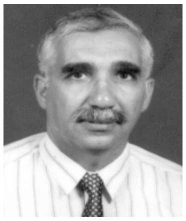

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