USING ERASURES DECODING WITH COOPERATIVE DIVERSITY FOR WIRELESS AD HOC NETWORKS

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ABSTRACT

This work proposes and studies the usage of Erasure Decoding along with Cooperative Diversity for wireless ad hoc networks. The user will be allowed to send a burst of frames arranged in matrix (M×N) format where the last cell in each column is a parity check frame. This erasures coding matrix can recover all the burst erased frames if the burst size is less than M frame provided that no other lost frames in the columns where the burst lost frames are located. Furthermore, neighboring nodes are cooperating to retransmit the remaining lost frames. A Monte Carlo simulation is built to examine the performance of the proposed approach. It is compared with Cooperative Stop-and-Wait approach suggested in [3] where it shows an outstanding improvement in terms of throughput and packet transmission delay. Moreover, the proposed Erasure Cooperative approach shows a linear increase in terms of packet delay compared to the exponential behaviors of the others. These interesting results make the proposed scheme a viable solution for TCP traffic over wireless ad hoc networks.

Index Terms— Cooperative Diversity, Erasure Coding, Ad hoc Networks, QoS, TCP traffic

1. INTRODUCTION

Recently, wireless ad hoc networks have obtained a lot of momentum in both academia and industry especially for accessing Internet services. Recent studies show that http traffic contributes for more than 80% of the total traffic traversing the internet. TCP, which is the carrier of all http traffic, is very well customized for wired network where congestion is the main source of packet losses. However, the matter is very different over wireless media where the losses are mainly due to channel errors. Consequently, the TCP congestion control will take an action assuming the network is passing through a congestion phase. Therefore, the resulting performance of TCP will suffer a sever degradation in both throughput and delay jitter [1][2].

The research existing in the literature has three main directions: developing new transport protocols, developing new medium access control schemes, developing new physical layer techniques (e.g. channel coding, modulation, etc.) and cross-layer techniques where combinations of previous techniques are proposed.

Considering the new techniques proposed for enhancing the performance of physical, cooperative coding is considered one of the promising techniques and it receive a lot of attention in the recent years [3]-[8]. It introduces space diversity by considering the adjacent nodes as virtual antennas. Wireless Ad hoc networks are the potential candidates for cooperative coding as the whole operation (e.g. routing, packet delivery, etc.) is based on the presumed cooperation among the ad hoc network users.

The work in [3], in particular, is attractive for its simplicity by relying on stop-and-wait (SW) ARQ scheme. The reported results show 30% increase in throughput compared to the traditional (non-cooperative) stop and wait protocol. Regarding the transmission delay, the cooperative SW showed 60% decrease in the average transmission delay. The improvements introduced by the cooperative SW-ARQ should be easily justifiable because the conventional SW-ARQ is totally unsuitable for wireless fading channels. When the channel is in fade, many of the consecutive requested retransmissions will suffer from the same fading resulting in long delays and poor throughput. That explains why the average transmission delay is still more than 150 ms, despite the diversity introduced by the cooperative coding.

In this paper, we propose the usage of the usage of Erasure Decoding along with Cooperative Diversity for wireless ad hoc networks. The user will be allowed to send a burst of frames arranged in matrix (M×N) format where the last cell in each column is a parity check frame. This erasures coding matrix can recover all the burst erased frames if the burst size is less than M frame provided that no other lost frames in the columns where the burst lost frames are located. Furthermore, neighboring nodes are cooperating to retransmit the remaining lost frames.

The rest of this paper is organized as follows. The proposed Erasure Cooperative Diversity Coding is described in section 2. The simulation environment is detailed in section 3.1. Section 3.2 presents and discusses the simulation results. Finally, the paper is concluded in section 4 along with directions for future work.

2. ERASURE COOPERATIVE DIVESRITY CODING

In this paper, we propose the usage of Erasure Decoding with Cooperative ARQ which is expected to improve both: the throughput and the average transmission delay. In this work, we assume that the user is allowed to send a burst of K packets. Each packet is fragmented into M frames and a group of frames will be organized in matrix. The matrix consists of M frames in each row and N frames in each column, as shown in Figure 1. Each column of N frames is protected by a parity check frame. Figures 2&3 illustrate how an erasure decoding using simple parity check frames works.

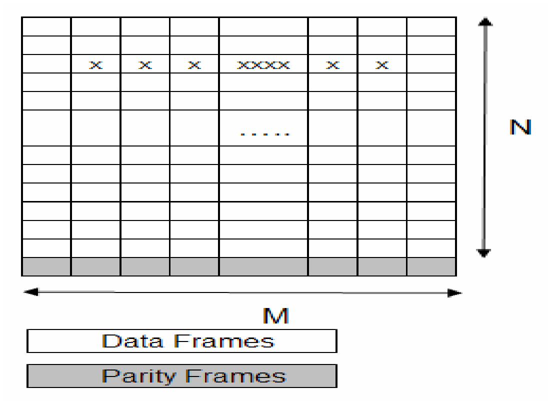

Figure 1: M×N matrix for the data and one dimension party frames

01111	10111	11001
01001	11101	10011
10101	10110	11011
10011	11100	10001

Figure 2: Simple example of a single parity erasure matrix

01111	10111	11001
10101	10110	11011
10011	11100	10001

Figure 3: Up to one full row of lost frames can be recovered by a single parity erasure matrix

Any lost frame is recovered by modulo-2 addition (or XOR operation) of the frames in the same column as shown in Figure 4.

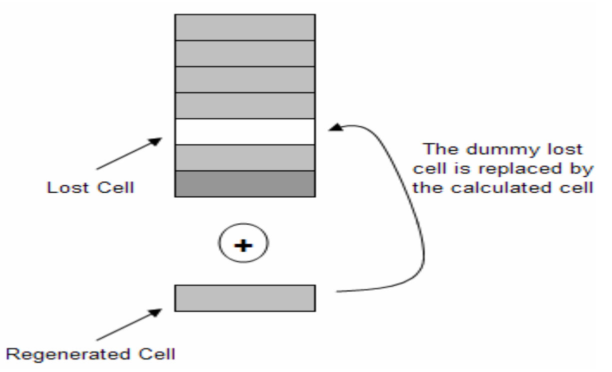

Figure 4: Lost frame regeneration

For this phase, the receiver will collect all successfully received frames and place them in their positions in the matrix. In case, there are frames which can’t be correctly received, they will be discarded and no retransmission is required at this stage.

The receiver will keep receiving these frames till the matrix is filled. At this stage, the receiver will check for any lost frames and whether they can be recovered by the erasures decoding matrix. A retransmission request will be necessary for any remaining lost frames in the matrix that the erasures decoding can not recover (if any). It is expected that the proposed scheme will minimize the number of retransmissions that the cooperative NCSW-ARQ will request.

3. SIMULATION RESULTS AND DISCUSSIONS

3.1. SIMULATION SETUP

To be able to compare this work with the reference work in [3] we assumed the same frame and packet duration; that is each packet is divided into 20 frames and each frame duration is 5ms. The transmitter will send 10 packets and assume that each packet (20 frames) is a row in the erasure matrix. The 11th row of the matrix contains the parity check frames. This implies that our erasure matrix consists of 200 data frames. When the full matrix is fully received then it tries to recover the lost packets using erasures decoding.

Otherwise, a retransmission request will be sent for any remaining lost frames in the matrix that can not be recovered. In this work, two neighboring nodes are cooperating to retransmit the remaining lost frames. We have also evaluated the performance of the proposed scheme without cooperation.

The channel between the nodes is assumed to suffer from Rayleigh flat fading. It is also assumed that the fading channel is quasi-static which implies that the fading level doesn't change during the frame duration. The relative speed of the mobile nodes is assumed to be 5 Km/h with 2400 Mhz carrier frequency. The simulation is performed for different levels of fading margin (L_p). When cooperation is used, the fading margin of the cooperating channels is assumed to be -1 dB. Table 1 summarizes the simulation parameters.

Table 1: Simulation parameters

Parameter	Value
Matrix size M×N	20×10
Frame transmission duration	5 ms
Erasure Matrix duration	1000 ms
Mobile speed	5 km/h
Carrier frequency	2400 Mhz
Fading channel	Flat Rayleigh
Cooperative channel fading margin	-1 dB

3.2. RESULTS AND DISCUSSIONS

Two scenarios have been considered. The first is when erasures decoding and ARQ are used to recover any remaining lost frames without node cooperation while the second scenario does include node cooperation. Figure 5 shows the throughput performance for four schemes, namely pure Stop-and-Wait (SW), Node Cooperation Stop-and-Wait (NCSW) as in [3], Erasure/ARQ with and without cooperation. It clearly illustrates the outstanding performance (20% improvement compared with [3] and 37% compared with SW) of the Erasure decoding even without cooperation. The obtained improvement in the throughput introduced by the erasures decoding along with cooperation shows itself over all levels of fading margin. However, the Erasure decoding without cooperation could not sustain its high performance under high fading margin. When the fading margin is in the low-moderate levels (relatively good channel) using the erasures decoding and ARQ without cooperation will give a better throughput compared the node cooperation in [3]. However, when the fading margin is high, there will be a lot of lost frames to the level that the erasure decoding will not be able to recover most of the frames. That will make the throughput worse than the node cooperation in [3].

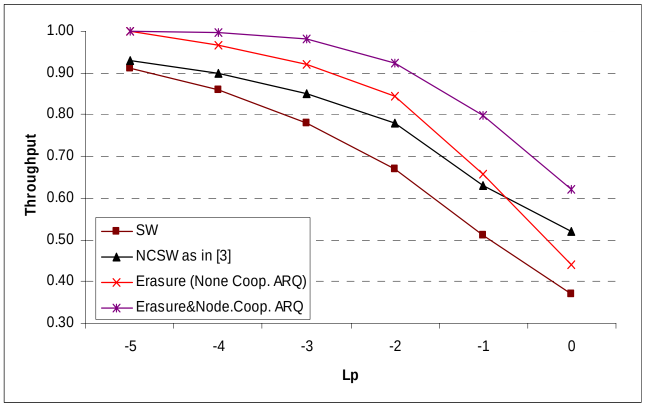

Figure 5: Throughput comparison of different schemes vs. fading margin L_p

Focusing on the proposed scheme with/without cooperation, we can observe the power of cooperation in enhancing the throughput. These results lend itself easily to TCP applications over wireless ad hoc networks as low number of retransmissions leads to low delay which eventually means less number of time out events. Hence, the TCP throughput will be improved as well as the minimum delay jitter.

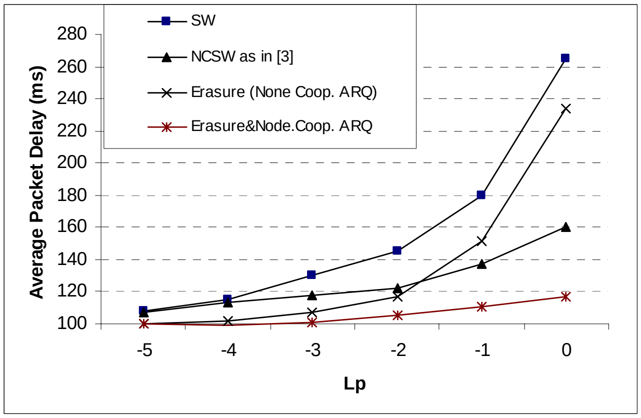

Figure 6: Average packet delay comparison of different schemes vs. fading margin L_p

In [3], the propagation delay is assumed to be negligible making the transmission and retransmission delay is the main factor in delay analysis. Following the same assumption, we evaluated the average packet delay.

It is obvious from Figure 6 that the average packet delay is generally decreased using both proposed schemes. Examining the Erasure decoding without cooperation, we notice that it shows low packet delay for $L_p < -2$ dB while beyond this point the delay exceeds what is experienced by NCSW.

When cooperation is used with erasures decoding, the average packet delay is the minimum. Even for very low fading margin, we can still obtain about 8% decrement in the delay. It illustrates 55% decrement in the average delay for L_p=0 dB. These results can again be attributed to the low number of retransmissions that are required to recover lost frames. Furthermore, the Erasure/ARQ/Cooperation shows very interesting behavior when it varies linearly across a wide range of fading margin. On the other hand, all other schemes, including Erasure/ARQ without cooperation, have shown exponential increase in the average packet delay.

4. CONCULSIONS AND FUTURE WORK

Using Erasure decoding have shown a good improvement in frame lose recovery in case of low fading margin. The improvement in both throughput and delay is greater and takes place any fading margin if the node cooperation is incorporated along with the erasures decoding.

As a suggestion for future work, the Erasure scheme can be further improved to recover more erased frames by considering two dimensional parity frames as shown in figure-7. The recovering capability of this product code is discussed in [9].

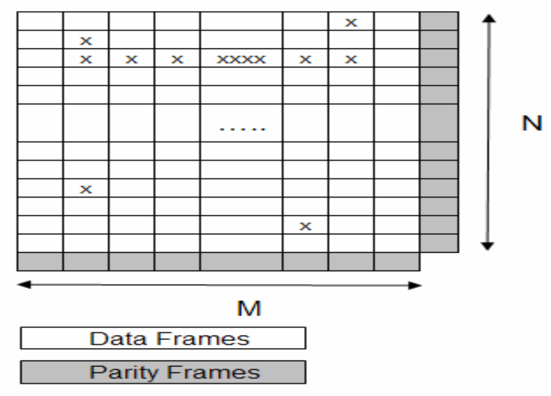

Figure 7: M×N Erasures decoding matrix for the data and two dimensions party frames

5. ACKNOWLDEGMENT

This work is supported by King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia under Fast Track project FT 2005-16.

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