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Development of Cross Layer Protocols Using Differential Co-operative Techniques for Wireless Networks.

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ABSTRACT

Errors due to noise at the base station can be minimized using re-transmission & co-operation. To reduce the amount of power loss involved in retransmission we make use of co-operative techniques. In such networks, solution is the cross layer design of link layer protocol, which must reliably deliver sensor nodes data at minimum energy cost. With this objective in mind we shall be using the technique of ‘co-operative protocol’ for physical layer & that of ‘reverse error correction’ for data link layer or media access control is used to design cross layer protocol modules. We make use of differential coding techniques which employ use of additional bits along with data bits called parity bits depending on channel state information of the available channel. We proposed analytical and system modules using simulation software for wireless network scenarios, where the sensor node in co-operation with relay node takes part in retransmission process. Thus system parameters can be enhanced using differential co-operative techniques with the help of simulation software and analysis.

General Terms

Cross layer, Ad-hoc Network. .

Keywords

Radio link protocols, forward error correction, ARQ.

INTRODUCTION

To fully optimize wireless broadband networks, both the challenges from the physical medium and the QoS-demands from the applications have to be taken into account. Rate, power and coding at the physical layer can be adapted to meet the requirements of the applications given the current channel and network conditions. Knowledge has to be shared between layers to obtain the highest possible adaptively. Cross-layer protocol interactions, when used appropriately, can lead to increased network efficiency and better QoS support. A Cross-Layer Design (CLD) is particularly important for any network using wireless technologies, since the state of the physical medium can significantly vary over time. Perhaps information exchange between different layers can even optimize the network throughput. The main building blocks of the wireless network design are power adaptation, medium on each link separately and its goal is to adapt the rate of a transmission to the level of interference at the receiver. Finally, the role of routing is to choose the optimal relaying strategy. Our goal is thus to jointly optimize all these building blocks. The optimal rate adaptation strategy is that every source, when transmitting, should adapt its sources transmitting in parallel. As for the routing, we restrict ourselves to a subset of routes where on each successive hop we decrease the distance toward the destination, and we show that relaying along a minimum energy route is better than using longer hops or sending directly, which is not obvious since we optimize rate and not power consumption. We also show that the optimal power control, medium access, and rate adaptation do not depend on the choice of the routing protocol. A consequence of this is that in the optimal cross-layer design medium access and physical layer should be jointly designed, whereas routing can be incorporated as an independent layer, like it is done in wired architectures. We show this finding by heuristics and numerical simulations on a large number of random network topologies.

Wireless networks have nowadays a significant role in internetworking. However, wireless links are challenging; they are more error-prone than wired links. Challenges for Low signal-to-noise ratio and Multipath fading channels solution is Robust modem waveforms, with FEC and interleaving. For Fades and interference that overwhelm FEC, response is ARQ .For Limited channel capacity, response is Prioritization, flow control. A wide range of solutions have been developed to improve TCP performance over wireless links. Lastly, Radio link protocol at link level solutions is local schemes which attempt to hide wireless losses from TCP. Cross layer protocol using differential cooperative solutions refer to mechanisms which address the challenges as mentioned in the table. In section 2 we examine the basis of framework to combat the challenges. Section 3 describes the issues which are pertaining to system model and signal model. Section 4 presents effect of RLP frames on TCP Throughput in ad-hoc wire less network. Finally conclusion is drawn in the last section.

RLP FRAMES

2.1 The RLP Frames are categories in to Crucial and non Crucial frames. The crucial frames are the frames which has greater impact on the performance and needs to address with differential treatment with respect to FEC coding and ARQ Scheme. Let us formally define the RLP failure probability.RLP failure probability: RLP failure probability is defined as the probability of the RLP failing to deliver all the L frames within its allowed number of retransmissions as a result of which the recovery mechanism will be handed over to the upper layer (e.g., TCP) We show how the differential treatment of the frames affects the performance of the RLP. Let us now discuss the differential FEC and differential ARQ schemes independently before we discuss the combined mechanism.

2.2 Differential FEC

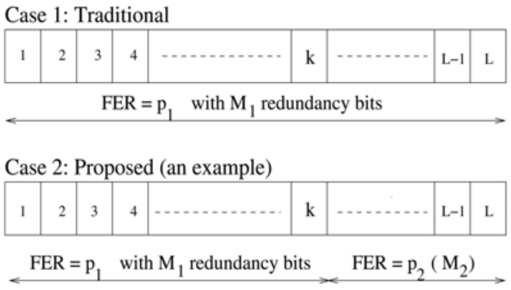


Fig.1. Different FEC schemes

Let us assume that a traditional RLP uses M_1 bits to code each frame, as shown in Case 1 of Fig. 1. It can be noted that each of the L frames is coded with the same number of bits, i.e.,M_2, because of which the FER observed is p_1. The RLP is made aware of the crucial frames and it encodes each of the crucial frames using M_2 bits, where $M_2 > M_1$; as shown in Case 2. This usage of more redundancy bits will result in FER = p_2, where $p_2 < p_1$. The exact reduction in the FER will depend on the values of, M_1,M_2, N and the kind of coding used. We assume that the ARQ scheme used is (1, 1, 1)i.e. three trials of retransmission with one copy of the frame being retransmitted every time.

2.3 RLP Failure Probability

We need to calculate the probability that all the L RLP frames will not be correctly received at the receiver. In other words, there will be at least one frame in error. For Case 1, where the FER is p1, the RLP failure probability (F1) is simply given by

$$F_1 = 1-(1-p_1^4)^L \quad ….1$$

The exponent 4 is because of the original transmission and the three transmissions, all of which fail at the RLP. For the example in Case 2, where the first K frames experience an FER of p_1 and the last L-K frames experience an FER of p_2,the RLP failure probability (F_2) is given by

$$F_2 = 1-((1-p_1^4)^L (1-p_2^4)^{L-K}) \quad ….2$$

Due to stronger FEC in Case 2, the RLP is able to recover more frames than in Case 1.

We conducted simulation experiments to validate our analysis and to evaluate the improvements achieved by the proposed technique. The simulation was done in a MATLAB. TCP segments generated were transmitted from the transmitter to the receiver. RLP frames derived from these TCP segments were transmitted over the wireless channel back to back. We assumed a two-state Markov model for the channel with a certain frame error rate. By setting appropriate transition probabilities among these two states, we were able to model different channel conditions.. It is also assumed that the number of information bytes per frame (N) is 50 and the number of redundancy bytes, M2, is varied from 0 to 25. M1 was maintained at 0, implying that no FEC was applied to the non crucial frames. As expected, we observe that there is an improvement in the RLP failure probability with the increase in the redundancy bit's as shown in Figs. 2 and 3. This ensures that the RLP is more effective in recovering the lost frames and thereby preventing the information losses propagating to TCP.

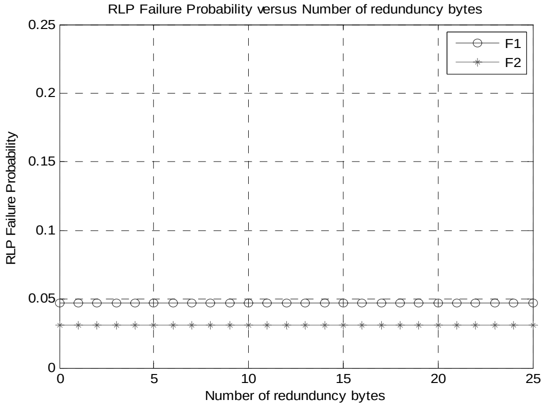


Fig.2 RLP Failure Probability vs redundancy bytes.-Analysis

Simulation parameters:

Attributes	Type/Value
Number of Frames	200
Number of Noncrucial frames	120
Number of crucial frames	80
Coding Techniques	Block coding
Wireless Channel Model	AWGN
Redundant bits(M1&M2)	M1=0,M2=0 to 25

2.4 DIFFERENTIAL ARQ

In the differential FEC case we considered that the underlying ARQ scheme was (1, 1, 1), but with a varying number of redundancy bits.

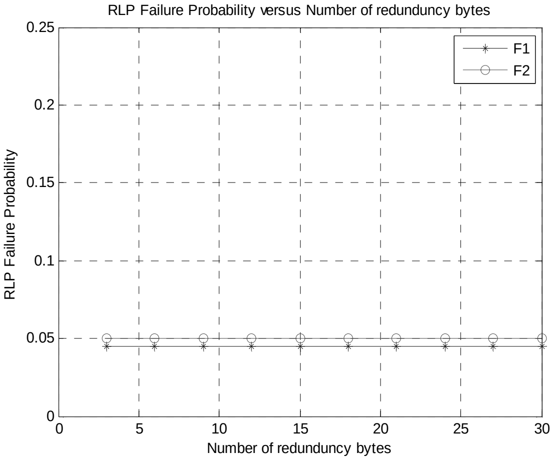


Fig.3 RLP Failure Probability vs redundancy bytes.-Simulation

Now, we consider two different ARQ schemes— (1, 1, 1) for Case 1 and (1, 2, 3) for Case 2, as shown in Fig.4. Scheme (1, 2, 3) means that there would be three trials of retransmission with one copy of the frame being retransmitted in the first trial, two copies in the second trial, and three copies in the third trial. We also assume that the FEC codes used are uniform across all the frames (say, M bytes per frame); therefore, all frames would experience an FER of p(say). Of course, these can be generalized with only the condition that the crucial frames in Case 2 must have a stronger ARQ than the non crucial ones.

2.5 RLP Failure Probability

The RLP failure probability (F1) for the example in Case 1 is obtained as

$$F1=1-\left(1-P_1^4\right)^L \quad …. 3$$

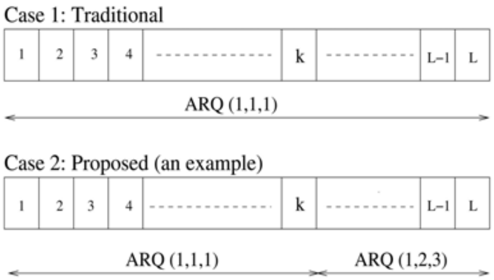


Fig.4. Different ARQ schemes

For the example in Case 2, the RLP failure probability (F2) is

$$F2=1-\left(\left(1-P_1^4\right)^K\times\left(1-P_2^7\right)^{L-K}\right) \quad ….4$$

2.6 Results for Differential ARQ

Just to focus on the ARQ performance, we assume that there are no redundancy bits added to any RLP frame, thus M1=0. The frame error rate p is varied from 0 to 0.3. The plots for (3) and (4) are shown in Fig. 5, which suggests how the RLP failure probability is lowered when differential ARQ is applied. The corresponding RLP failure probability obtained through simulations is shown in Fig.6

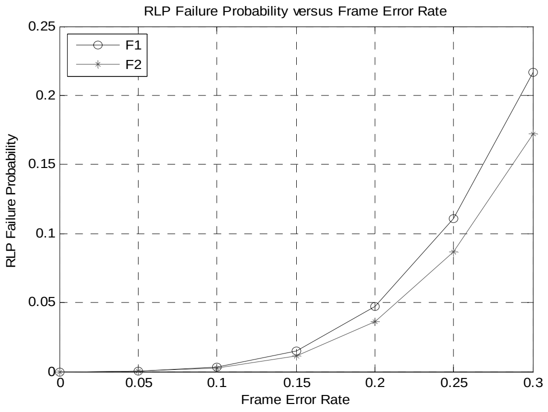


Fig.5 RLP Failure Probability vs Frame error rate –Analysis

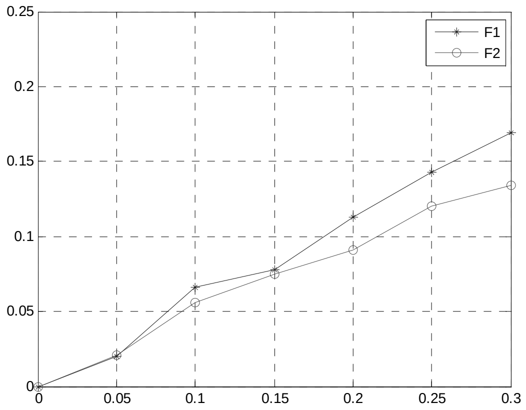
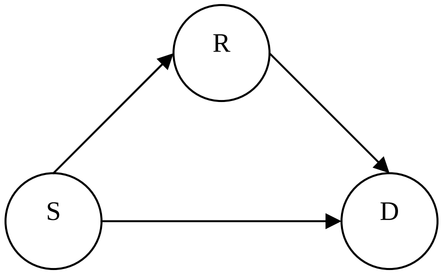


Fig.6 RLP Failure Probability vs Frame error rate –Simulation

3.System model and Analysis :



3.1 System model.

Fig.7 Co-operative wire less relay system.

Consider a wireless relay network depicted in above figure that is composed of one source S , one relay R and one destination D node, where a sequence of symbols are to be transmitted from S to D . To eliminate mutual interference S and R use orthogonal channels for transmission, either by time-, frequency-, or code-division multiplexing. For ease of presentation, we assume time-division multiplexing by which the transmission is divided into *two* distinct phases. During *phase-I* transmission, S transmits a frame of information bits, while R and D listen. During *phase-II* transmission S, is silent, while R amplifies or decodes the received signal, and retransmits it to D.

The baseband signal received at R and D respectively are,

Xr(n) = hsrS(n) + Wr(n) where n = 0,1,2….N

Xd(n) = hsdS(n) + Wd(n) where n = 0,1,2….N

Where hsr and hsd represents fading coefficients, Wr(n) and Wd(n) represents channel noise. The signal received at d is given by

Yd(n) = hrdSr(n) + Ud(n) n = 0,1,…N

Where hrd and Ud(n)denotes the Channel coefficients and channel noise respectively.

3.2 **CHANNEL STATE CONDITATIONS:**

Additive white Gaussian noise (AWGN): Additive white Gaussian noise (AWGN) is a channel model in which the only impairment to communication is a linear addition of wideband or white noise with a constant spectral density (expressed as watts per hertz of bandwidth) and a Gaussian distribution of amplitude. The model does not account for fading, frequency selectivity, interference, nonlinearity or dispersion. However, it produces simple and tractable mathematical models which are useful for gaining insight into the underlying behavior of a system before these other phenomena are considered. Wideband Gaussian noise comes from many natural sources, such as the thermal vibrations of atoms in conductors (referred to as thermal noise or Johnson-Nyquist noise), shot noise, black body radiation from the earth and other warm objects, and from celestial sources such as the Sun. The AWGN channel is a good model for many satellite and deep space communication links. It is not a good model for most terrestrial links because of multipath, terrain blocking, interference, etc. However, for terrestrial path modeling, AWGN is commonly used to simulate background noise of the channel under study, in addition to multipath, terrain blocking, interference, ground clutter and self interference that modern radio systems encounter in terrestrial operation.

3.3 R-S performance as a function of size and redundancy

For a code to successfully combat the effects of noise, the noise duration has to represent a relatively small percentage of the codeword. To ensure that this happens most of the time, the received noise should be averaged over a long period of time, reducing the effect of a freak streak of bad luck. Hence, error-correcting codes become more efficient (error performance improves) as the code block size increases, making R-S codes an attractive choice whenever long block lengths are desired. As the redundancy of an R-S code increases (lower code rate), its implementation grows in complexity (especially for high-speed devices). Also, the bandwidth expansion must grow for any real-time communications application. However, the benefit of increased redundancy, just like the benefit of increased symbol size is the improvement in bit-error performance. reassembly delay. Otherwise, the frames are noncrucial.Calculation of the starting of crucial frames within total number of frames.

3.4 Implementation

Throughput is calculated considering various parameters

1) **Total number of frames**:

Throughput increases linearly with increase in total no. of frames

2) Number of redundancy bits

FER decreases, time delay increases. Throughput increases with increase in no of redundancy bits.

3) **Variation in Crucial and non-crutial frames :**

Increase in no. of crucial frames results in increase in no. of retransmissions thereby increasing delay & throughput

4) Varying no.of relays :

Bandwidth efficiency slightly increases with increase in no. of relaysCo-operative communication established between 3 nodes-

- -source/base station
- -relay
- -destination/mobile station

4. **Simulation Parameters and Results:**

Co-operative communication established between 3 nodes--source/base station –relay –destination.

Two schemes used-

1. Scheme A: Mechanism of non-crucial frames
2. Scheme B: Mechanism of crucial frames

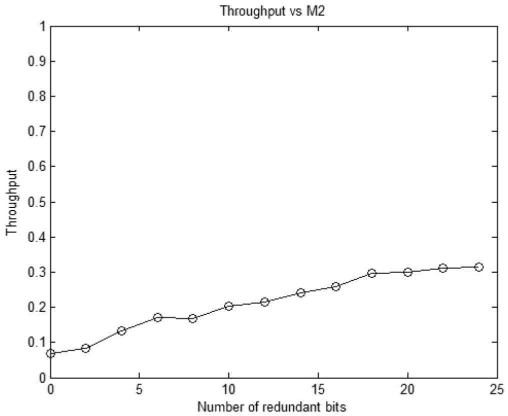
Calculating Throughput as performance parameter

Table-2- Variables in Analysis

Quantity	Notation	Value
Signal to Noise Ratio between S-R_1	SNR1	16
Signal to Noise Ratio between R1-D	SNR2	Varied
Successful packet count between S-R1	$pa1$	Varied
Retransmission packet count between R1-D	$qa1$	Varied
Maximum number of .retransmission	L	4
Packet size	n	7
Total number of packets transmitted	------	500
Modulation Techniques	PSK	8-psk
Channel noise consideration	AWGN	Varied

We evaluate the performance of the proposed scheme implemented with Matlab. We run the simulation for two schemes i.e. scheme A and Scheme B. The simulation parameters are shown in the table 2. Simulation runs for 500 total packets. Result is the average of independent experiments where each experiment uses different randomly generated uniform parameters. We use mean values which are obtained independent experiments as a basic data to get the result.

Fig.8 Result of Throughput vs Number of Redundant bits .



5. Conclusion :

The improvement is more significant when the channel losses are high. The improvement in TCP throughput is due to two reasons. First, the fragmentation of the TCP segments into RLP frames prevents the entire TCP segment being retransmitted if lost. Second, due to the differential treatment of the crucial frames.

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