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COMMUNICATIONS

SIMULATION OF ARQ AND HARQ SCHEMES WITH VARIOUS BLOCK LENGTH

Kvetoslava Kotuliaková — Vladimír Hájovský — Ivan Kotuliak *

Presented paper describes and analyses HARQ (Hybrid Automatic Repeat Request) and pure ARQ schemes. We focus on selected HARQ techniques applied to IP protocol and also to LMS channel. The efficiency of HARQ scheme is compared with GBN schemes using different lengths of IP packets. We show that usage of smaller packets and hybrid schemes leads to an improved throughput. Differences between pure and hybrid GBN schemes are also discussed.

Keywords: automatic repeat request (ARQ), hybrid ARQ (HARQ), internet protocol (IP), land mobile satellite (LMS), Reed-Solomon code (RS), go-back-N scheme (GBN)

1 INTRODUCTION

Transmitted data are liable to errors while being transmitted via a physical channel. As errors are inadmissible in most systems, applying guaranteed transmission techniques solves this problem.

Presented paper focuses on HARQ schemes, with stress on factors which influence the effectiveness of the presented techniques (*eg* length of IP packets). We compare these techniques with the pure ARQ techniques.

The examined values are relative throughput of data flow. As stated above, the main factor we examine is the length of IP packet provisioned to the data link layer of OSI model.

2 PRINCIPLE OF GBN ARQ SCHEME

As shown in Fig. 1, the transmitter transmits data blocks. If the receiver receives an erroneous data block (or one block is missing), it sends NACK to the sender. The transmitter interrupts transmission and returns to the erroneously sent block (N blocks backwards) and starts transmitting all the blocks from this one. Otherwise, the receiver sends ACK after each or group of successfully received block. This scheme is most used in wireless and satellite systems because of its simplicity and effectiveness.

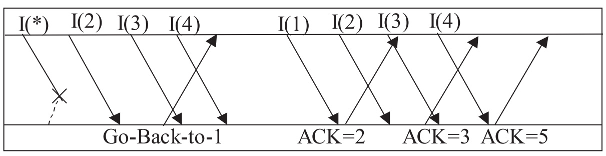

Fig. 1. Principle of GBN scheme.

The next formula shows how to measure the effectiveness of ARQ schemes. Analytical throughput is computed as:

$$\eta_{B\text{-}GBN} = \frac{1-P_e}{1+SP_e}, \tag{1}$$

where S is the number of blocks which could be sent while retransmitting the erroneous block.
$P_e = 1-(1-P_b)^n$ is an n-bits length block error rate and P_b is the bit error rate computed from channel definition.

3 REED–SOLOMON CODES

The codeword has a length of $N = q-1$ symbols. One symbol is mapped into b bits and $q = 2^b$. When using systematical coding, information bits are at the beginning of the codeword separated from parity symbols, see Fig. 2. The number of symbols is $N-K = 2t$.
RS–codes are described with $(N, K, 2^q)$ and code rate $r_c = K/N$.

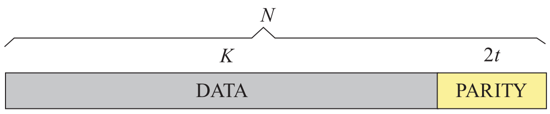

Fig. 2. RS codeword.

It is known about RS codes that [1]:
- minimal code separation space $\mathrm{d_{min}} = N-K+1$,
- number of correctable errors $t = (\mathrm{d_{min}}-1)/2 = (N-K)/2$.

4 TRANSMISSION CHANNEL

The transmission channel is the most erroneous part of any communication system. It is impossible to describe analytically physical causes, which lead to loss of data

* Slovak University of Technology in Bratislava, Ilkovičova 3, 812 19 Bratislava, Slovakia; {kkotul,hajovsky,ikotul}@ktl.elf.stuba.sk

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in the physical channel. The transmission channel is accepted as an entity and the process of error generation is modeled statistically. The primary source of signal degradation is noise generated at the receiver's site. The most popular noise model is Gaussian additive white noise.

In the case of a satellite communication system, the received signal is negatively influenced due to the multipath propagation, shading and fading. The final signal consists of many interferred elements with various amplitudes and phases. Other causes of signal fading are hills, mountains, bridges *etc*.

There are two basic approaches to error modeling of the discrete channel. These are: model with independent error originating and models with dependently originating errors, which are simulated using Markov chains.

The scope of our simulations covers channels with independent errors, specifically LMS channel. Events of error originating will be independent of each other, i.e. each binary symbol will be received with the same error probability P_b, independently of the fact, how the previous symbol was received. The next formula defines the block error rate [3]

$$P_e = 1 - (1 - P_b)^n \,. \qquad (2)$$

As the mobile and satellite systems LMSS (Land Mobile Satellite System) acts in environment with great variance in time, it is desired to use another channel model (*eg* basic AWGN). LMS systems are modeled in conditions of LMS channel. We use this channel in this paper as a wireless channel model in the performed simulation.

Statistical properties of LMS channel depend on the properties of environment. Basing on this criterion, we distinguish 3 kinds of environment:

1. urban area (with full direct wave disturbance),
2. open area (without any wave disturbance),
3. rural and suburban area (with particular wave disturbance).

In our simulation, we are concerned about error functions for open area simulation.

We consider a signal with Rayleigh's pdf, assuming that the coverage of direct signal is constant in open areas, the sum of constant cover and diffused fragment with Ryleigh distribution leads to Rician's distribution, which has the following density of probability: [5]

$$p(x) = 2x(1+F)e^{-F-(1+F)x^2} I_0\big(2x\sqrt{F(F+1)}\big) \qquad (3)$$

where F is the power ratio of the direct and diffused parts of the signal and I_0 is a modified Bessel function of zero dimension.

5 DATA LINK LAYER

Information is encoded to a data-link protocol for being transported via a satellite radio link. The data link layer has two main tasks. First, it controls access to transmission media. This is important, when multiply access is enabled. The second task yields from the properties of unreliable transport environment. The data link layer can ensure error detection and inform the higher layer about an erroneous data unit, or it can manage correction of errors after enabling FEC (Forward Error Correction) methods.

This leads to implementation of HARQ schemes on the data link layer. The frames of the data link layer are processed as data blocks for ARQ schemes — data are directly transmitted without any change to physical medium. At the receiver's site the decoder rebuilds original data link frames.

6 APPROACH TO IMPLEMENTING OF CODING AT DATA LINK LAYER

When using Reed-Solomon coding in commercial applications, the basic task is to ensure higher quality of line and its usage is independent of framing implemented by the data link layer.

Here is the difference from many space applications, where RS framing is used as data link framing at one time. But due to this fact, every data link frame must have the same length equivalent with RS-code block length. The problem originating from this fact is that scientific and engineering packets are not of same length as the RS code block length. [6]

7 GOALS AND CONSTRAINTS OF SIMULATION

When we look at IP packet structure, we have to realize the following facts:

- the total length of IP datagram can exceed to 65535 Bytes and it is variable,
- sometimes the network equipment can not process the packet with its original length and it has to be fragmented,
- single fragments may have various lengths and carry various payload.

When transmitting IP packet, we carry on towards data link layer. First, we have to check if the packet length is smaller or equal to MTU (Maximum Transmission Unit) for the data link layer protocol, which is used at current transmission media.

In this paper, we assume the Ethernet format of the data link layer frame. This was simulated under the condition that all the packets are of the same length. MTU of Ethernet frame is 1500 bytes, it means, we can take a maximum of 1500 bytes of packet data (header+payload).

While fragmenting, the original packet data are divided into smaller parts. After adding a quasi copy of IP header to the fragment of payload, their length cannot exceed MTU. If we send packets with need of fragmentation, these packets would be disadvantaged to packets with no need. Consequently, the throughput can change simultaneously with changing of packet's length. This is

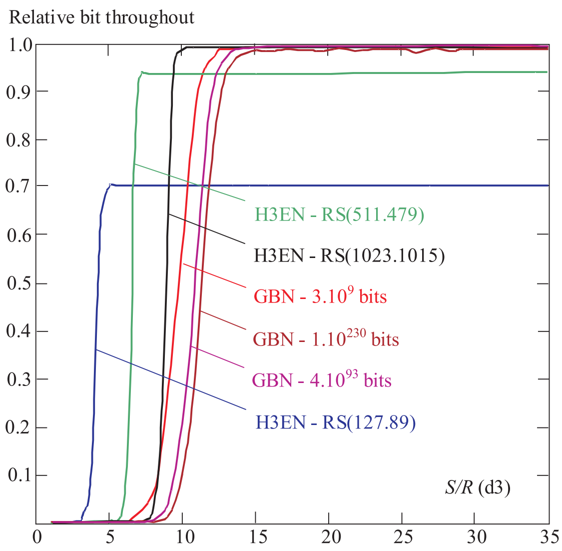

Fig. 3. Throughput of GBN and HGBN, RTD (Roundtrip delay) = 20 blocks.

Table 1. Used RS codes

RS code(N,K)	Galois Field	Correctable Errors	Block length[bits]
(127, 89)	GF (7)	19	889
(511, 479)	GF (9)	16	4599
(1023, 1015)	GF(10)	4	10230

the reason why we examine constant length packets (in time units). Also, the length of code blocks for HARQ schemes would have to change while sending packets. Last but not least, traffic is splitted into packets which can be encapsulated as a whole into data link frame, especially for satellite and space conditions.

Using the Ethernet frame is chosen because it is used in communication with low orbit satellites [6].

8 SIMULATION

Simulation was carried out for three block lengths — 889, 4599 and 10230 bits with using error functions for LMS channel and open area without direct wave interference. Simulations were done for pure ARQ techniques and for HARQ techniques with RS codes in Tab. 1.

Simulation was made with using error functions for LMS channel in open areas.

The relative block throughput η_B was simulated with BPSK modulation and the output value for increasing SNR was computed according to the next formula:

$$\eta_B = \frac{succesfully\_received\_blocs}{all\_sent\_blocks} \tag{4}$$

and relative bit throughput: $\eta_b = \frac{m}{n}\eta_B$,

where m represents the number of information symbols and $n =$ number of all symbols in block. Note that $m = n$ in pure ARQ schemes.

In Fig. 3, we can see the dependence of the relative bit throughput on SNR for pure and hybrid ARQ schemes.

From this simulation, we can conclude that the throughput is rising with increasing SNR in the presented range of SNR. This is expected as a natural fact.

ARQ and HARQ schemes, which were simulated using longer blocks, achieve smaller bit throughputs for the same value of SNR.

In Fig. 3, the block length is increases from the left to the right for HARQ schemes (first 3 curves form the left) and also for ARQ schemes (other 3 curves).

The throughput is decreased due to the longer block retransmissions when an error (ARQ) or inadmissible number of errors (HARQ) is present in the received data block. It means that more redundant bits are transmitted when an error is encountered. The same fact is notable in ARQ as well as in HARQ schemes.

It is obvious that for achieving the same relative throughput we need a smaller SNR for shorter blocks. Anyway, throughput of HARQ schemes are limited by the code rate from the top. This fact does not have to be limitation, if we know what throughput we need. In this case, we can exploit the lower SNR need for HARQ schemes.

9 CONCLUSION

It was proven that the length of IP packet has an influence on the throughput of ARQ and HARQ schemes. On the basis of simulation results in LMS channel we can say that the relative bit throughput is increased as the length of block decreases. Since, there is immediate retransmission in pure GBN schemes; every error causes repetition of longer redundant data. This difference is even bigger while simulating HARQ schemes using RS codes, despite using codes with various numbers of correctable errors and some limitations in the code rate.

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