THROUGHPUT PERFORMANCE OF SELECTED ARQ SCHEMES IN RADIO CHANNEL CONDITIONS

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SUMMARY

In this article we compare the throughput performance of selected modified and adaptive Go-Back-N schemes using quadrature amplitude modulation (QAM) in radio channel conditions. Simulations were done in the condition of Rayleigh fading channels. The results are shown in enclosed graphs.

Keywords: *adaptive Go-Back-N, QAM, Rayleigh fading channel, simulations*

1. INTRODUCTION

The more growth in communication, the higher the quality required. ARQ techniques are widely used for error control in data communication systems. There has been a lot of effort devoted to the problem of modeling all kinds of channel fading because the transition channel characteristics significantly affect the throughput performance of ARQ methods.

2. TRANSITION CHANNEL MODELING

In digital communication, a channel is used in some way in order to transmit the information. The primary source of performance degradation is thermal noise generated in the receiver. Often, external interference received by the antenna is more significant than thermal noise. In radio systems, the propagation medium contains several distinguishable paths connecting the transmitter to the receiver. Several signals with different amplitudes, phases and delays corresponding to different transmission paths arrive at a receiver. This multi path propagation phenomenon results in signal fading at the receiver. The received signal in fading is often modeled by a Rayleigh or Rician distributed envelope. The problem arises not only in cellular systems, but also e.g. in terrestrial long-distance radio communications, and in underwater acoustic communications. Another example is mobile satellite systems.

3. RAYLEIGH FADING CHANNEL MODEL

Let us assume that c_i represents a QAM symbol sample transmitted at time *i*. The corresponding received sample at the input of the demodulator is $r_i = a_i c_i + n_i$ where a_i is a real random variable equal to the envelope of the channel attenuation with corresponding probability density function, and n_i is a sample of a zero mean complex additive white Gaussian noise (AWGN). [1]

The conditional bit error probability for QAM modulation given the fading attenuation due to shadowing a_i in the *i*th channel state is given by

$$P_s = 2.\left(1-\frac{1}{\sqrt{M}}\right) erfc\left(\sqrt{\frac{3}{2(M-1)}.k.\frac{E_S}{N_0}}\right) \tag{1}$$

where E_S represents energy per symbol, N_0 stands for the noise density, k is a real random variable equal to the envelope of the channel attenuation with corresponding probability density function.

3.1 Rayleigh fading channel

The scattering environment, which generates the multiple paths between transmitter and receiver, can often be assumed to be isotropic. That is, waves arrive at the receiver from all directions with uniform probability distribution. Thus, the receiver antenna receives the same amount of power from all directions (there is no line of sight component between transmitter and receiver). The magnitude of the received envelope has a Rayleigh distribution given by [2]

$$p(x) = \frac{x}{\sigma^2} e^{\left(-\frac{x^2}{2\sigma^2}\right)} \quad pre\ x > 0 \tag{2}$$

where σ represents the dispersion of AWGN thermal noise.

4. DESCRIPTION OF SELECTED AUTOMATIC REPEAT REQUEST SCHEMES

In this article, we will focus on modified GBN schemes and selected adaptive GBN schemes based on a standard GBN method.

4.1 Modified GBN schemes

4.1.1 Go-Back-N

The principle of this scheme is shown in Fig. 2 [4]. According to [4] the throughput performance of this method is given by

$$\eta = E(M)^{-1} = \frac{1-P_e}{1+N.P_e} \tag{3}$$

where P_e represents the probability of block error and N is the delay.

4.1.2 GBN r-copy scheme

GBN r-copy scheme is one of the basic modifications of the standard GBN scheme. The working principle is shown in Fig. 3 [4]. According to [4] the throughput of this method is given by

$$\eta = E(M)^{-1} = \frac{1-P_e^r}{r+N.P_e^r} \tag{4}$$

where P_e represents the probability of block error, N is the delay, and r is the number of copies.

4.2 Adaptive GBN schemes

Adaptive GBN schemes try to withdraw the disadvantages of modified GBN schemes. They are based on the estimation of the channel condition, and the transmitter adapts the transmission scheme according to the estimated channel conditions. Adaptive methods achieve much better throughput performance than standard or modified GBN schemes.

4.2.1 Yao's adaptive GBN scheme

The working principle of Yao's adaptive GBN scheme is shown in Fig. 1 [2].

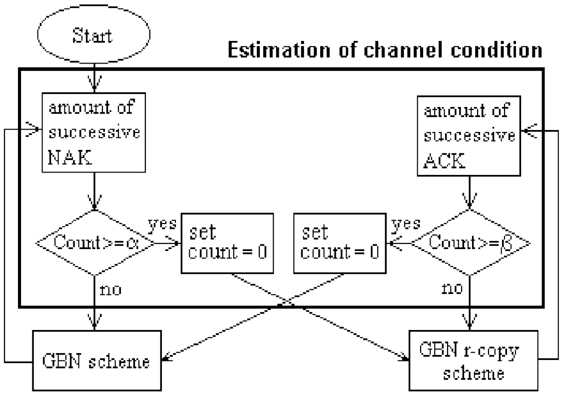

Fig. 1 Working principle of YAO's scheme

The forward channel (from the transmitter to the receiver) is considered to have two states-L states (low error rate) and H state (high error rate). Corresponding to the two channel states, there are two operation modes in Yao's ARQ scheme. If the channel is in the L state, the transmitter follows the classic GBN, and if the channel is in the H state, the transmitter follows the GBN r-copy scheme. When the transmitter is in channel state L, successive NAKs are counted. If the counted amount of NAKs is greater than α, the transmitter considers that the channel to be too noisy, and transits it from L state to H state. Similarly, when the transmitter is in H state, the amount of successive ACKs are counted. If the counted amount is higher than β, the transmitter

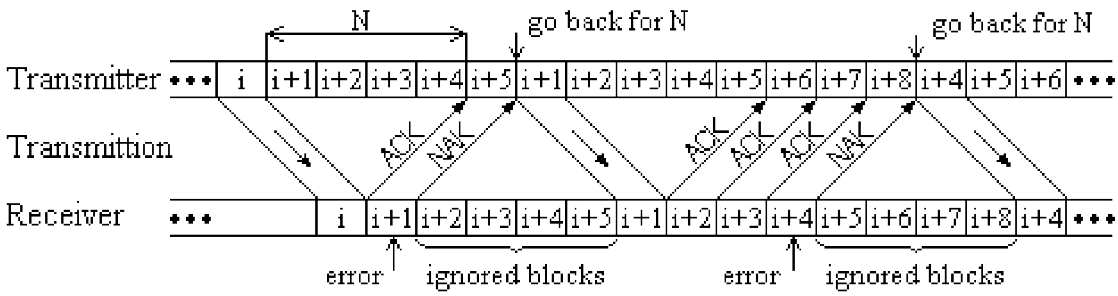

Fig. 2 Working principle of GBN scheme

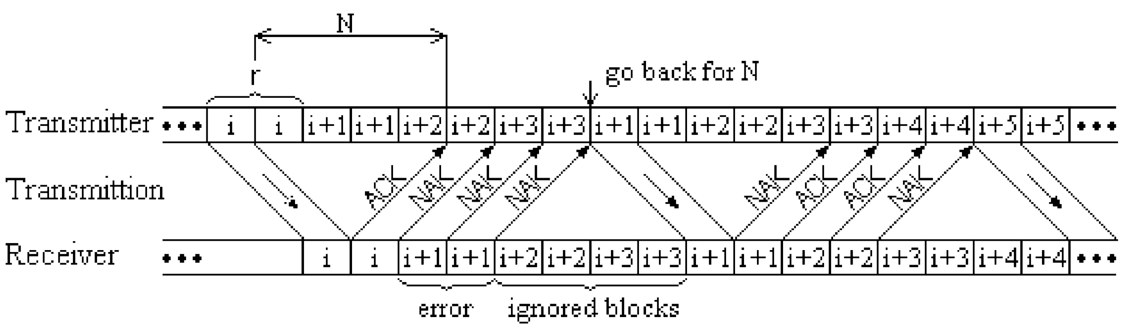

Fig. 3 Working principle of GBN r-copy scheme

assumes that the channel conditions have improved and changes to L state. According to [2] the throughput of this method can be expressed as an average of the throughput values of the two operation modes

$$\eta = \eta_L . T_L + \eta_H . T_H \qquad (5)$$

where T_L (T_H) is the final probability that the channel is in L state (H state).

4.2.2 Adaptive GBN scheme with sliding window mechanism (SWM)

The adaptive GBN scheme is based on the same mechanism as previously explained in Yao's adaptive scheme. The working principle is shown in Fig. 4. [2].

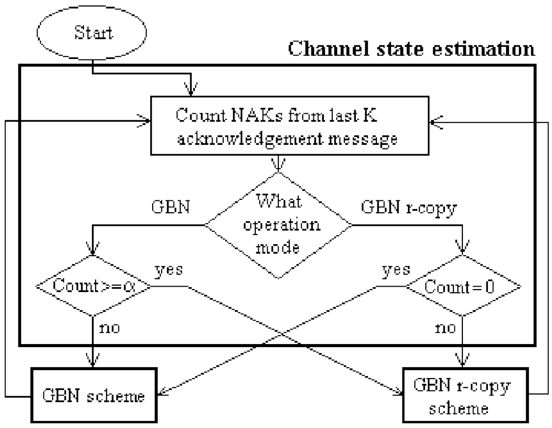

Fig. 4 Working principle of ARQ SWM scheme

The transmitter switches between the two operation modes according to the channel state that is estimated from the last K acknowledgment messages. Parameter α can be expressed by [2]

$$\alpha = \mathrm{int}\left(P_{CO}.K\right)+1, \qquad (6)$$

where P_{CO} is the probability of switch between GBN scheme and GBN r-copy scheme.

The throughput of this scheme can be expressed as an average of the throughput values of the two ARQ operation modes [2]

$$\eta = \eta_L . T_L + \eta_H . T_H \qquad (6)$$

where T_L (T_H) is the final probability that the channel is in L state (H state) and μ is the throughput of ARQ method used in L or H state.

5. SIMULATION OF ARQ METHODS

Simulations of throughput performance were done for all previously described ARQ methods. Further, we also assume that:

1. feedback channel is noiseless
2. 16-QAM is applied
3. detection code is perfect
4. memory less channel models

With the increasing requirements of the service, an important topic is to use a spectral efficient modulation technique to raise the spectrum efficiency in the limited frequency bandwidth. Quadrature amplitude modulation is an effective technique to achieve high spectral efficiency in fading channels when the receiver is capable of estimating the channel state information.

6. THROUGHPUT ANALYSIS OF ARQ SCHEMES IN RAYLEIGH FADING CHANNEL

The main problem is to define the values of system parameters of selected ARQ methods. These values can be found by simulations and would differ according to desired performance.

6.1 The throughput performance of GBN scheme

The throughput performance of GBN versus E_S/N_0 is shown in the next figure.

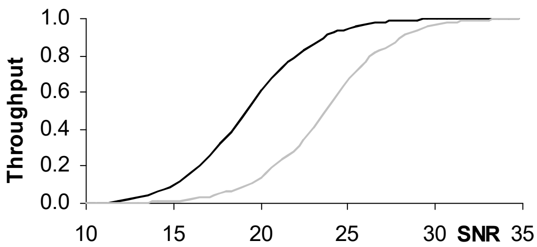

Fig. 5 Throughput performances of GBN schemes for n = 256 : black line – throughput of GBN for N = 10; gray line – throughput of GBN for N = 100

Obviously, the throughput rises with greater E_S/N_0 in simulated channel environments. It can also be seen that the throughput performance gets poorer with increasing value of window N.

6.2 Throughput performance of GBN r-copy scheme

The throughput performance of GBN r-copy versus E_S/N_0 is shown in the next figure.

The figure shows how the parameter *r* affects the throughput of this method. The main disadvantage of r-copy is that the maximum throughput can be *1/r*. Similarly; the throughput falls with increasing value of window N.

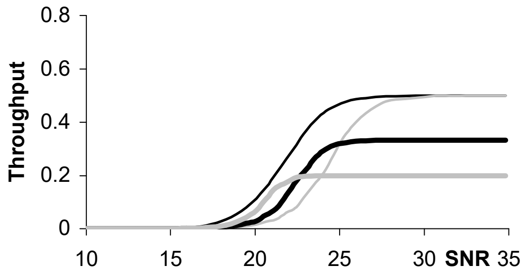

Fig. 6 Throughput for n = 512: black line - GBN 2-copy scheme, N = 10, gray line - GBN 2-copy scheme, N = 100; thick black line - GBN 3-copy scheme, thick gray line – GBN 5-copy scheme; N = 100

6.3 Throughput performance of YAO's adaptive scheme

Yao's adaptive scheme has three system parameters. The impact of these parameters on the throughput is shown in the figures.

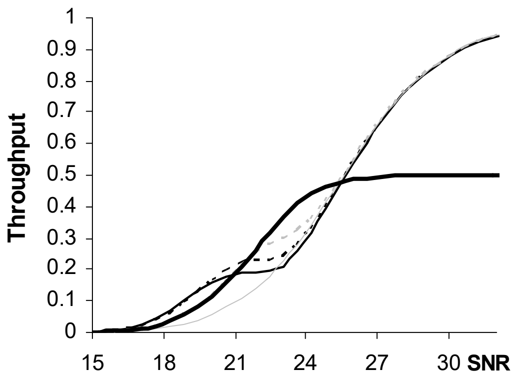

Fig. 7 Throughput for n = 256 and N = 10: gray line - GBN scheme; thick black line – 2-copy GBN; black line - Yao's GBN scheme r = 5; dotted black line – Yao's GBN scheme r = 3; dotted gray line – Yao's GBN scheme r= 2; $\alpha = 2$, $\beta = 10$

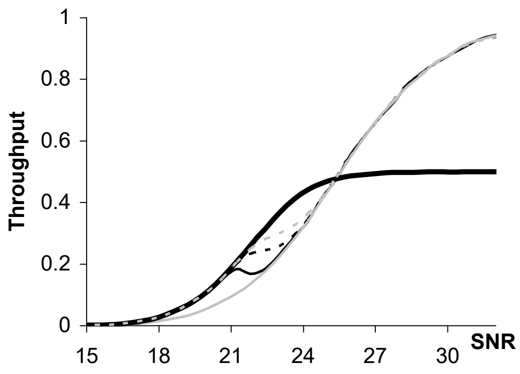

Fig. 8 Throughput for n = 256 and N = 10 : gray line - GBN scheme; thick black line – 2-copy GBN; dotted gray line – Yao's GBN scheme $\alpha = 2$; dotted black line - Yao's GBN scheme $\alpha = 3$; black line – Yao's GBN scheme $\alpha = 5$; r = 2, $\beta = 10$

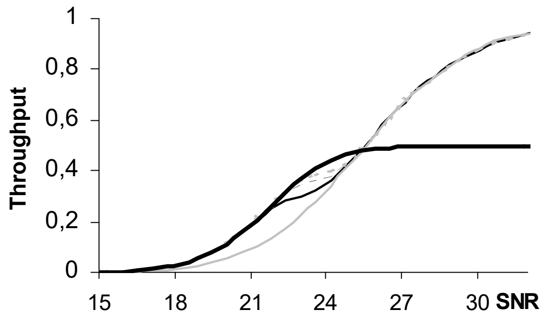

Fig. 9 Throughput for n = 256 and N = 10 : gray line - GBN scheme; thick black line – 2-copy GBN; dotted gray line - Yao's GBN scheme $\beta = 20$; dotted black line – Yao's GBN scheme $\beta = 15$; black line – Yao's GBN scheme $\beta = 10$; r = 2, $\alpha = 2$

In figures 7-9 it can be seen that the throughput of Yao's adaptive GBN scheme depends on the choice of its three system parameters α, β and also r. Variation of throughput can be achieved by different values of the parameter r which determine the number of packet copies sent. The throughput gets higher in the area of high error rates but only at the expanse of lower throughput in the areas of with good conditions (fig. 7). With rising parameter α the gross throughput of the scheme falls (fig. 8). But with rising value of parameter β the gross throughput performance rises (fig. 9).

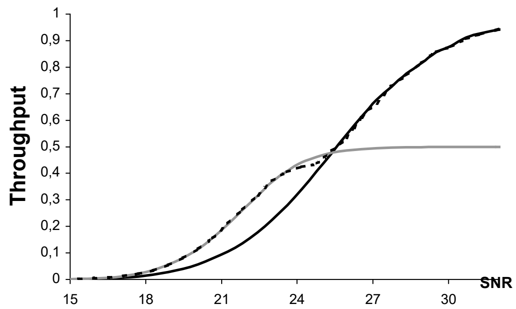

Fig. 10 Throughput for n = 256 and N = 10 : black line - GBN scheme; gray line – 2-copy GBN; dotted black line - Yao's adaptive GBN scheme r = 2, $\alpha = 2$, $\beta = 28$

Yao's scheme withdraws the main disadvantage of the modified GBN scheme, such as high throughput in the areas of high (low) error bite rate but only at the expanse of low throughput in the areas of low (high) error probability. In the area of switching between the two operational modes, loss of performance can be recognized. Its intensity can be influenced by the system parameters of Yao's scheme. The throughput of Yao's is shown on figure 10. As it shows, the throughput performance copies the behavior of standard GBN in the area of low error probability, and the behavior of r-copy in the areas of high error probability.

6.4 Throughput performance of GBN with sliding window mechanism

Adaptive GBN with sliding window mechanism has only two system parameters. The impact of these parameters on the throughput is shown in the next figures.

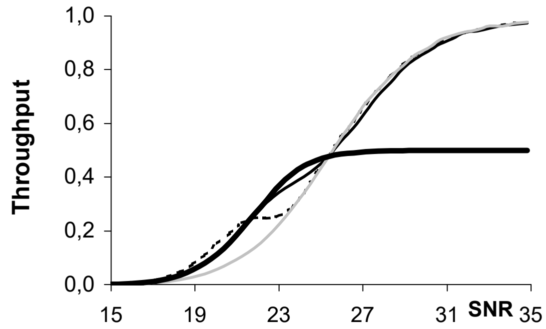

Fig. 11 Throughput for n = 256 and N = 10 : gray line - GBN scheme; thick black line – 2-copy GBN; black line - adaptive GBO with SWM r = 2; dotted black line - adaptive GBN with SWM r = 3; K = 10

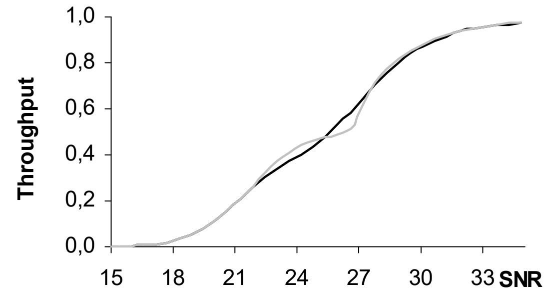

Fig. 12 Throughput for n = 256 and N = 10: black line - adaptive GBN with SWM K = 10; gray line - adaptive GBN with SWM K = 100; r = 2

As it can be seen, the throughput curve is similar to the curves of Yao's scheme. The loss of the performance in the area of switching between the operational modes can be influenced by the values of the system parameters. (fig.11-12)

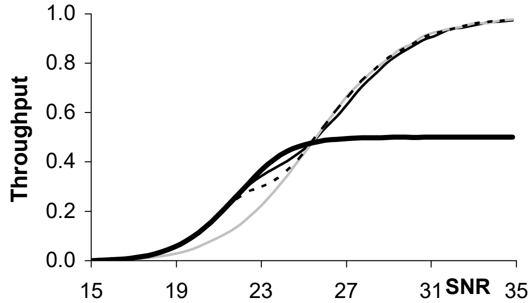

Fig. 13 Throughput for n = 256 and N = 10 : gray line - GBN scheme; thick black line – 2-copy GBN; black line - adaptive GBN with SWM r = 2, K = 10; dotted line – Yao's adaptive GBN scheme r = 2, α = 2, β = 10

The last figures compares the throughput performance of Yao's adaptive GBN scheme with chosen parameters and the performance of adaptive GBN with sliding window mechanism. Both of the methods try to copy the ideal performance curve. As it can be seen, the GBN with SWM achieves better results, and also less system parameters are needed to be optimalized.

7. CONCLUSION

We have compared the efficiency of selected modified and adaptive Automatic Repeat request schemes upon their throughput performance as dependent upon signal to noise ratio SNR.

Besides standard Go-Back-N scheme and its basic modification r-copy GBN, we have also described two adaptive GBN schemes. While classic GBN scheme achieves higher performance when the channel is in the area of low error probability, the throughput of GBN r-copy method is higher in the area of high error probability. None of the modified GBN schemes can eliminate the loss within the whole range of error rate.

This disadvantage can be withdrawn using adaptive methods. These methods are able of estimating the channel state and adjusting the operational mode. The adaptive GBN methods described in this work use standard GBN in the areas of low error probability and r-copy GBN in the areas of high error probability. When the transmitter switches the operational modes, loss of performance can be detected. The main aim is to minimize its intensity, so the throughput curve exactly follows the curve of required throughput. This can be influenced by the system parameters of adaptive methods.

Using the comparison of throughput performance of analyzed adaptive GBN schemes we came to the conclusion that for using 16-QAM in the condition of Rayleigh fading channel the highest throughput can be achieved by using the adaptive GBN method with sliding window mechanism.

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BIOGRAPHY

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