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Kobry El-Kobba,
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CODED THROUGHPUT AND DELAY PERFORMANCE ANALYSIS OF THE HYBRID SFH/DS OVER FADING CHANNEL

Abdel-Moneim M. Fouda*, Essam Abdel-Wanees*, Ahmed El-Bakly*

ABSTRACT

This paper presents the performance analysis of throughput and delay, when it is required to transmit data over a packet switched code division multiple access network based on the coded hybrid SFH/DS SSMA. The performance is discussed assuming noncoherent hybrid SFH/DS system which employ independent random direct sequences and random memoryless frequency hopping patterns, slotted ALOHA channel access protocols, and different types of Reed Solomon RS (n,k) forward error control (FEC) coding techniques including; Hamming code, BCH code, and Golay code. The system is operating through multipath fading channel, and uses deferentially phase shift keying DPSK modulation technique. Different performance measures other than the BER will be investigated, those are the system throughput and delay, a closed form expression for the hybrid system throughput and delay is derived for the system under consideration, they are presented and plotted when the system is operating over such fading channel and assuming different coding rate , as well as a comparison for the system performance considering different types of Reed Solomon RS (n,k) forward error control (FEC) coding techniques including; Hamming code (7,4), BCH code (15,7), and Golay code (23,12) are presented.

KEY WORDS: **Network, CDMA, FH, DSSS, Hybrid FH/DS, FEC, Throughput, Multipath Fading Channel.**

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* Egyptian Armed Forces

I- INTRODUCTION

Code Division Multiple Access (CDMA) is a strong candidate for the third generation (3G) wireless personal communication systems. A radio network is a collection of terminals, which can communicate with each other via radio links. A key feature of a radio network is that each radio transmission is a potential source of interference for all terminals within the range of the transmitter. Spread spectrum is a promising signaling scheme in packet radio network due to its various inherent advantages they can combat multi-path fading and provide multiple-access capability. Direct sequence (DS), frequency hopping (FH) and hybrid DS/FH schemes have been proposed for such applications.

From the literature survey, Parasad et. Al. [1] had been discussed the throughput and delay analysis of a slotted DSSS in a shadowed Rician channel , and they found that the number of resolvable paths and the number of users who share a frequency band have a great effect on the system performance. Also, Kwonhue Choi, and Kyungwhoon Cheun [2] discussed the throughput and optimum parameters of FHMA with multilevel FSK. Generally speaking, the DS and FH technology can effectively enhance the anti-jamming ability and throughput of the network. Hybrid systems are attractive because they can combine the advantages of both direct-sequence and frequency hopping systems, while avoiding some of their disadvantages. DS combats efficiency the problem of multi-path fading but suffer from the near-far effect. On the other hand, slow frequency hopping (SFH) is more immune to the near-far effect, though more sensitive to multi-path fading. Thus, hybrid DS/SFH CDMA seems to good solution for confronting these problems.

The system employs hybrid FH/DS SSMA and some of forward error control coding techniques, to improve performance is shown in Fig. 1. The Reed Solomon RS code is one type of the block coding will be considered in our system. A block code consists of a set of fixed-length vectors called code words. The length of a code word is the number of elements in the vector and is denote by " n". A block of "k " information bits is mapped into a code word of length n selected from the set of M code words. We refer to the resulting block code as an (n, k) code, and the ratio k/n is defined to be the rate of the code and is denoted by R_c.

The input sequence is encoded as RS (n,k) based on Golay Field GF(M^m), the parameter n represent the length of code and k is the information symbols length. If we assume $n=M^m$, each code word contains M-ary symbols, and then it is modulated by DPSK modulator. The modulated signal is spreaded by code sequence and then it is transmitted after the frequency hopper. Assume the channel is subjected to the multipath fading effect, and at the same time the signal is affected by the multi-user interference in the network. The transmission packet may be affected by other packets, which are transmitted by the other users in the network; this is referred as collision would occur. Because of the inherent ability of the hybrid system, the system can sustain more collision. During reception, the reverse process as is described above is achieved to get the final decoded data output.

In our paper, we will investigate in details different performance parameters other than the SNR , the first parameter is named the throughput which is defined as the number of successful packets per time slot is considered as a function of the offered traffic. The second performance parameter is the packet delay which is defined as the average number of time slots used before a packet is received successfully it will be studied as a function of the system load.

Now after we had been introduced to the system model and illustrate the basic block diagram for the considered system, then we describe the basic principle of operation of the hybrid SFH/DS SSMA system. The paper is organized as follows, in section II the performance analysis of the system throughput is evaluated a closed form expression for the system throughput is derived. In Section III the delay analysis is introduced. While in section IV the numerical results are given and discussed. Finally conclusions are given and discussed throughout section V.

II- PERFORMANCE ANALYSIS OF HYBRID SYSTEM THROUGHPUT

For transmission of computer data, a packet communications schedule can be more efficient than using circuit switched protocol (suitable in speech oriented systems). In a packet network, throughput and delay are appropriate parameters, rather than maximum user capacity. The throughput determines the average number of successfully received packets per time slot, given a certain amount of traffic. For a certain amount of throughput it is important to know what will be the average delay of a packet.

Generally error will occurs and packets are lost if the number of simultaneous active users (k) exceeds the threshold capacity (C). The lost packets are reschedules and retransmitted after a sufficient time delay.

In this part we consider a hybrid DS-SFH/SSMA Packet radio net work utilizing Reed-Solomon codes and study a upper bounds on performance of system with good accuracy approximate and simple computational complexity over indoor multipath fading channel models which are characterized in either Rician or Rayleigh distributions. The throughput are subsequently derived and computed. Then comparison on the performance among different coding rate (n,k) will be given.

Assuming that the basic model is a network with one concentrator and many users. The system model employs the noncoherent hybrid DS-SFH SSMA systems which uses DPSK modulation techniques, also it employs an independent random direct sequence, random memoryless frequency hopping patterns, slotted ALOHA channel-access protocols, and Reed Solomon (RS) error control coding, is considered. A Poisson model for an infinite population is employed to describe the probability of packets to be transmitted in the network during each packet time. All terminals are within range of concentrators. The throughput is the expected number of successful transmissions from these terminals per packet interval, it may be considered as a utilization factor.

The throughput can be calculated as the average number of successfully received packets in the system and can be expressed as [1]:

$$S = 1/C \sum_{k=1}^{C} k\, P_{tx}(k)\, P_{ck} \tag{1}$$

Where the different parameters for such equation are described as follows:

P_{tx} is the probability that k packets are transmitted simultaneously , and it depends on the traffic model (finite, or infinite population model). Assuming the infinite population model, this population is modeled by the Poisson distribution with parameter G, where G is the average population size. Then the probability that K packets are transmitted of the Poisson distribution is given as [3]:

$$P_{tx}(K) = (K!)^{-1} \,.\, G^{K} \,.\, \exp(-G) \tag{2}$$

Where P_{ck} is the probability of correctly receiving a packet, in our system model, a packet is made of H codewords. Each codeword is a (n,k) RS coded, .this probability of correct reception for coded system is given by :

$$P_{ck} = [1 - P1_{e,s}(k)\,]^{H} \tag{3}$$

Employing the extended (n,k) RS code, the average symbol error probability $P1_{es}(k)$ is given by [4]:

$$P1_{e,s}(K) = \sum_{i=t+1}^{n} \frac{i}{n}\binom{n}{i}[P_{e,s}(K)]^{i}\,[1-P_{e,s}(K)]^{n-i} \tag{4}$$

where the RS code will correct up to $t = (n-K)/2$ errors out of n code symbols. and the parameter $P_{es}(K)$ is defined as the average symbol error probability as a function of the number simultaneously transmitting k users at the hard decision output before decoding and it can be written as [5]:

$$P_{e,s}(k)=1-[1-P_{eb}(k)]^{m} \tag{5}$$

Where m is the number of bits in a symbol, when m=1 the SER is reduced to BER and then $P_{es}=P_{eb}$..

To calculate the is the average error probability $P_{e,b}(K)$ we will go to the following steps. the upper bound of the average bit error probability is given as [5]:

$$P_{e,b}(K) \le \sum_{K_f=0}^{K-1} P_f(k_f)\, P_{e,b}(k_f) \tag{6}$$

$P_f(k_f)$ is the distribution of the full hits given as : $P_f(k_f) = \binom{(K-1)L}{K_f} P_f^{kf}\,(1-P_f)^{(K-1-K_f)L}$

$P_{e,b}(k_f)$ is the conditional bit error probability given as $P_{e,b}(k_f) = 0.5\, E\,\{\exp(-0.5\gamma A^2_{i,l})$ $A_{i,l}$ is a random variable distributed statistically as non-central chi-square its characteristic function[5]: $E\{\exp(-0.5\gamma A^2_{i,l}) = (1 \quad + \gamma\,\sigma^2_{\varepsilon})^{-1} \exp[-\gamma m^2_{\varepsilon}/(2+2\,\gamma\,\sigma^2_{\varepsilon})]$

Then the final expression of the upper bound on the average BER is given by substituting of the different previous forms and then we get:

$$P_{eb}(K) \le 0.5 \sum_{K_f=0}^{K-1} \binom{(K-1)L}{K_f} P_f^{kf}(1-P_f)^{(K-1-Kf)L}(1+\gamma\sigma^2_\varepsilon)^{-1}\exp[-\gamma m^2_\varepsilon/(2+2\gamma\sigma^2_\varepsilon)] \quad (7)$$

Then the upper bound on the average symbol error probability of RS coded hybrid DS/SFH SSMA system is derived by substituting (7) into (5) and then the new form of the average symbol error probability before decoding can be expressed as:

$$P_{c,s}(k) = 1-[1-0.5\sum_{K_f=0}^{K-1}\binom{(K-1)L}{K_f}P_f^{kf}(1-P_f)^{(K-1-Kf)L}(1+\gamma\sigma^2_\varepsilon)^{-1}\exp[-\gamma m^2_\varepsilon/(2+2\gamma\sigma^2_\varepsilon)]]^m \quad (8)$$

Now using (8) and substituting into (4) we get the final closed from expression for the RS code average SER which is given as:

$$P1_{cs}(k)=\sum_{i=t+1}^{n}\frac{i}{n}\binom{n}{i}\{1-[1-0.5\sum_{K_f=0}^{K-1}\binom{(K-1)L}{K_f}P_f^{kf}(1-P_f)^{(K-1-Kf)L}(1+\gamma\sigma^2_\varepsilon)^{-1}\exp[-m^2_\varepsilon/(2+2\gamma\sigma^2_\varepsilon)]]^m\}^i$$

$$.\{[1-0.5\sum_{K_f=0}^{K-1}\binom{(K-1)L}{K_f}P_f^{kf}(1-P_f)^{(K-1-Kf)L}(1+\gamma\sigma^2_\varepsilon)^{-1}\exp[-\gamma m^2_\varepsilon/(2+2\gamma\sigma^2_\varepsilon)]]^m\}^{n-i} \quad (9)$$

by using (9) and substituting into (3) we get the closed form expression for probability of correctly receiving a packet P_{ck} which is given as:

$$P_{ck}=[1-\sum_{i=t+1}^{n}\frac{i}{n}\binom{n}{i}\{1-[1-0.5\sum_{K_f=0}^{K-1}\binom{(K-1)L}{K_f}P_f^{kf}(1-P_f)^{(K-1-Kf)L}(1+\gamma\sigma^2_\varepsilon)^{-1}\exp[-m^2_\varepsilon/(2+2\gamma\sigma^2_\varepsilon)]]^m\}^i$$

$$.\{[1-0.5\sum_{K_f=0}^{K-1}\binom{(K-1)L}{K_f}P_f^{kf}(1-P_f)^{(K-1-Kf)L}(1+\gamma\sigma^2_\varepsilon)^{-1}\exp[-\gamma m^2_\varepsilon/(2+2\gamma\sigma^2_\varepsilon)]]^m\}^{n-i}]^H \quad (10)$$

Finally using (10) and (2) and the substituting into (1) , we get the final closed form expression for the noncoherent hybrid SFH/DS system which employ independent random direct sequences and random memoryless frequency hopping patterns, slotted ALOHA channel access protocols, and Reed Solomon RS (n,k) forward error control techniques , this form can be expressed as:

$$S=C^{-1}\sum_{k=1}^{C} k(K!)^{-1}G^K\exp(-G)[1-\sum_{i=t+1}^{n}\frac{i}{n}\binom{n}{i}\{1-[1-0.5\sum_{K_f=0}^{K-1}\binom{(K-1)L}{K_f}P_f^{kf}(1-P_f)^{(K-1-Kf)L}$$

$$(1+\gamma\sigma^2_\varepsilon)^{-1}\exp[-\gamma m^2_\varepsilon/(2+2\gamma\sigma^2_\varepsilon)]]^m\}^i\ .\{[1-0.5\sum_{K_f=0}^{K-1}\binom{(K-1)L}{K_f}P_f^{kf}(1-P_f)^{(K-1-Kf)L}$$

$$.(1+\gamma\sigma^2_\varepsilon)^{-1}\exp[-\gamma m^2_\varepsilon/(2+2\gamma\sigma^2_\varepsilon)]]^m\}^{n-i}]^H \quad (11)$$

Where the declaration of the various parameters for the previous equations are as follows:.

γ is the average desired signal to the sum of the multipath interference, multiple access interference and the channel noise ratio it depends on the modulation type the system uses, it is given for DPSK modulation as: $\gamma=[(E_b/N_o)^{-1}+K_fL/3N]^{-1}$

$m_\varepsilon=\varepsilon/(1+\varepsilon)$ is the mean of the random variable $A^2_{i,l}$

$\sigma^2_\varepsilon=1/(2+2\varepsilon)$ is the variance of the random variable $A^2_{i,l}$

m is the number of bits in the symbol, and C is the threshold system capacity
K is the total active users in the system.
A^2_{ij} is Rician distributed
E_b/N_o is the average signal to noise ratio, and L is the number of the fading path
P_f is the full hit probability (frequency full hit) $P_f= (1-2N_p)q^{-1}$
N_p is the number of data bits transmitted per frequency hop
q is the number of hopping frequencies.

III- DELAY ANALYSIS OF HYBRID SFH/DS SS

The average delay is defined as the average number of slot times it takes for a packet to be successfully received. Thus it is the average time duration between the packet being offered to the transmitter and the packet being successfully received. The average delay in an indoor network, assuming negligible round trip propagation delay and immediate acknowledgement, can be obtained as [6]:

$$D = 1.5 + [\, G/CS \; -1\,]\,(\lfloor \delta_t + 1 \rfloor + 1) \qquad (12)$$

Where:
G/CS -1 is the average number of retransmission for a packet to be successfully received
$\lfloor \delta_t + 1 \rfloor$ the delay due to each transmission.
δ_t is the mean of the retransmission delay, which is uniformly distributed over the range from which the retransmission delay is selected
C is the user's threshold capacity
Here it is assumed that the minimum delay for slotted system (that use slot time protocol for transmission) is 1.5 slot durations. This time consists of one time slot being the average time between the time the packet is offered to the transmitter and the beginning of the next slot.

IV- NUMERICAL RESULTS

The system throughput S (in packets/slots), and the system delay D (in time slots) are computed against the offered traffic G for the hybrid SFH/DS SSMA system using DPSK modulation. The calculations of the hybrid SFH/DS over multipath Rician fading channel with fading factor ε=15 is performed Assuming K=10 active users, number of frequency hopping q=32 which is equal to the DS spread factor N=32, the number of bits per frequency hop N_p=128, and the number of multipath L=4.

In Fig.2 the system throughput is plotted as a function of the offered traffic G at SNR = 10 dB, for hybrid SFH/DS SSMA, .and for different types of RS coding including Hamming code (7,3), BCH code (15,7) and Golay code (23,12) [7]. It is noted from the figure that the throughput increases with the increases of the offered traffic, until certain point at which collision between competing packets occurs then the throughput is decreasing. Also it is shown from the figure that the Golay code outperforms the BCH code which is better than the Hamming code.

In Fig.3, the system delay (in time slots) is plotted as a function of the offered traffic with the same parameter of Fig.2. it is noted that the larger the system throughput the lower the system delay , this is due to the fact that the number of succeeded received packets increases with the increase of the system throughput, and thus reduces the delay. Also the delay increase with the increase of the offered traffic this is due to the increase of the number of packets competing for transmission.

Fig. 4 presents the performance of the normalized system throughput as a function of the offered traffic for the RS coded hybrid system, while in Fig.5 the performance of the system delay as a function of the offered traffic for the RS coded hybrid SFH/DS SSMA over Rician fading channel for different RS (n,k). values when fixing the number n=64 which represent the length of code and change the value of k which represent the information symbols of the .ranged from 10, 20, and 30 thus we have RS with (64,10), (64,20), and (64,30), it is noted that as k increases the throughput is enhanced and the system delay is reduced, this is due to the increase of the code rate R_c=k/n, thus the number of transmitted bits increases.

While to study the effect when we fix k, and increase n keeping that k≤n thus we have RS with (20,16), (40,16), and (80,16). The effect for such situation is plotted in Fig. 6 for the normalized system throughput as a function of G , while Fig.7 for the delay as a function of G.

Finally we study the effect of the code rate for the different system performance. Considering the hybrid system under scenarios presented previously. The code rate have the values 1, 0.5, and 0.25 respectively, this is illustrated in Fig.8. for S as a function of G, and Fig.9. that provide D as a function of G. it is noted that as the code rate increases the system throughput increase , as well as the increase of the code rate leads to the decrease of the system delay ..

V- CONCLUSION

Throughout this paper we have been presented and derived a closed from expression of the throughput and delay for the RS coded, noncoherent hybrid SFH/DS system employing the DPSK and operating over multipath fading channel of Rician fading type. The system throughput S (in packet/slots) and the system delay D (in time slots) are computed against the offered traffic when using different code rate, as well as the system throughput S (packets/slots) are plotted against system delay for such hybrid SFH/DS system. The performance is compared when using different types of RS coding; including Hamming code (7,3), BCH code (15,7) and Golay code (23,12) [6] .it is found that the Golay code out perform the two other types of the studied block codes, then followed by the BCH code and then the Hamming code has the lowest performance from the point of view of throughput and delay. This is due to the larger value of the parameter "n" and the parameter 'k" for the Golay code.
Generally due to the previous analysis and plotting, it is found that the throughput increases with the increase of the offered traffic this is due to the fact that the number of packets through the network increase, thus the probability of correct reception

increase, until certain point at which collision between competing packets occurs, which leads to increase of the error rate, then the throughput is decreasing.
As well as the increase of the offered traffic, provides to the increase the system delay, this is due to the increase of the number of packets require transmission. Generally, it is concluded also that as the code rate increases the system throughput increase, as well as the increase of the code rate leads to the decrease of the system delay.

The effect of increasing the parameter "k " which represent the information symbols, while keeping fixed value of the parameter "n" is studied such that $k \leq n$. It is found that the increase of k , implies to the increase of the code rate $R_c=k/n$, and so the number of transmitted packets increases, thus the throughput is enhanced and the system delay is reduced, this is due to the increase of the code rate,.

Also the investigation to the effect of increasing the parameter "n " which represent the information symbols while keeping the parameter k at fixed value such that $k \leq n$ is presented. It is concluded that the increase of k , implies to the increase of the code rate $R_c=k/n$ thus the number of transmitted bits increases, thus the throughput is enhanced and the system delay is reduced, this is due to the increase of the code rate.

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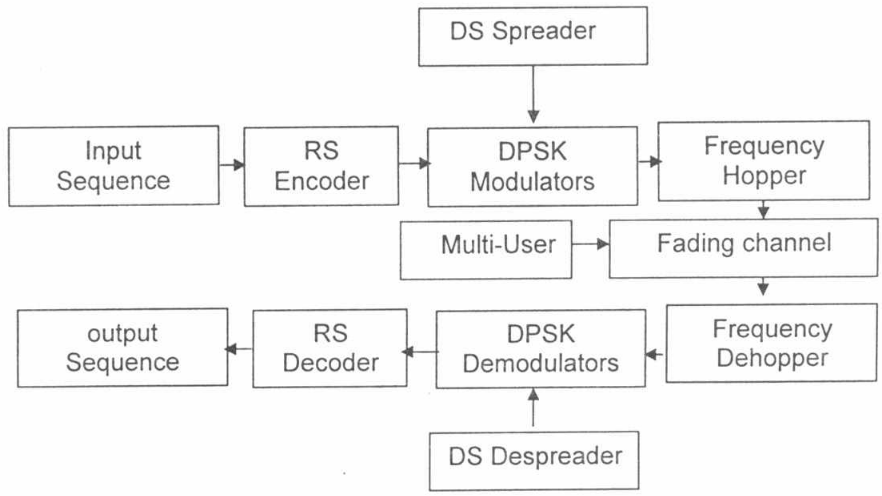

Fig. 1 Simplified system block diagram

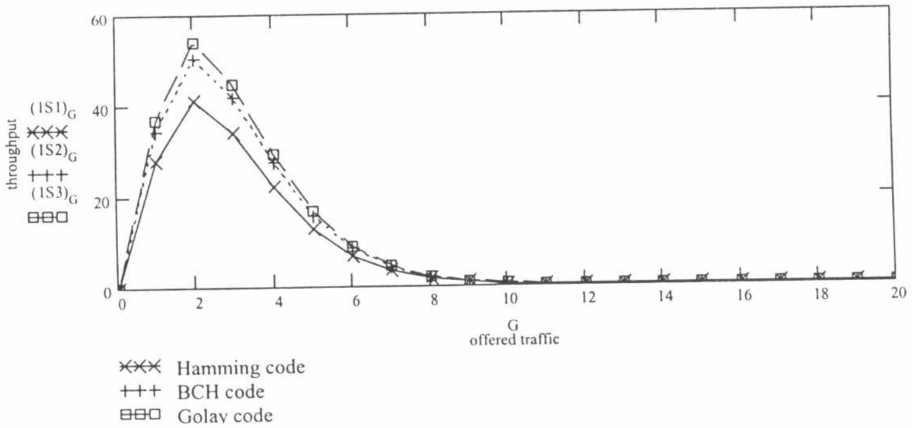

Fig. 2 Performance of the system throughput as a function of the offered traffic for the Hamming code, BCH code, and Golay coded hybrid SFH/DS SSMA over Rician fading channel.

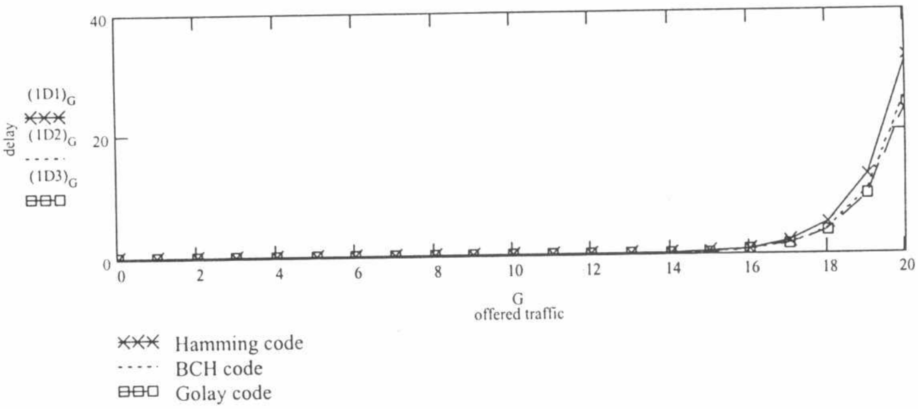

Fig.3 Performance of the system Delay as a function of the offered traffic for the Hamming code, BCH code, and Golay coded hybrid SFH/DS SSMA over Rician fading channel.

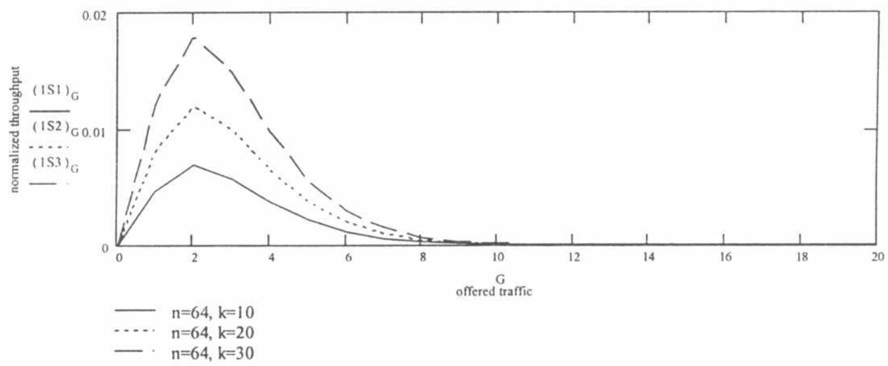

Fig. 4 Performance of the normalized system throughput as a function of the offered traffic for the RS coded hybrid SFH/DS SSMA over Rician fading channel for different RS (n,k) values.

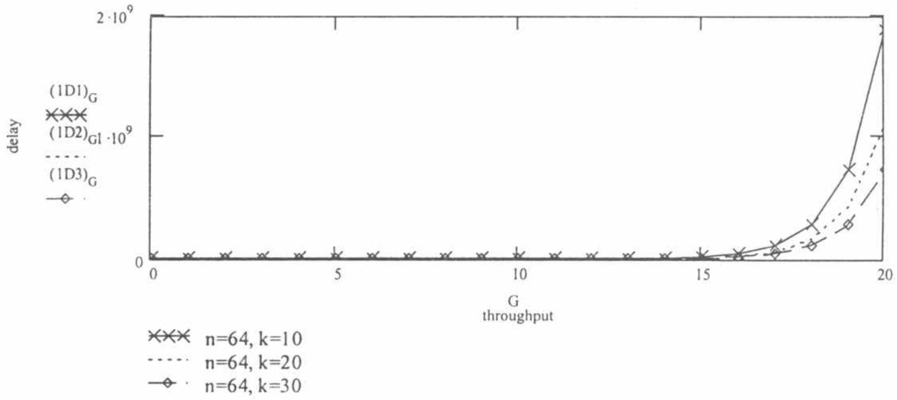

Fig.5 Performance of the system delay as a function of the offered traffic for the RS coded hybrid SFH/DS SSMA over Rician fading channel for different RS (n,k) values.

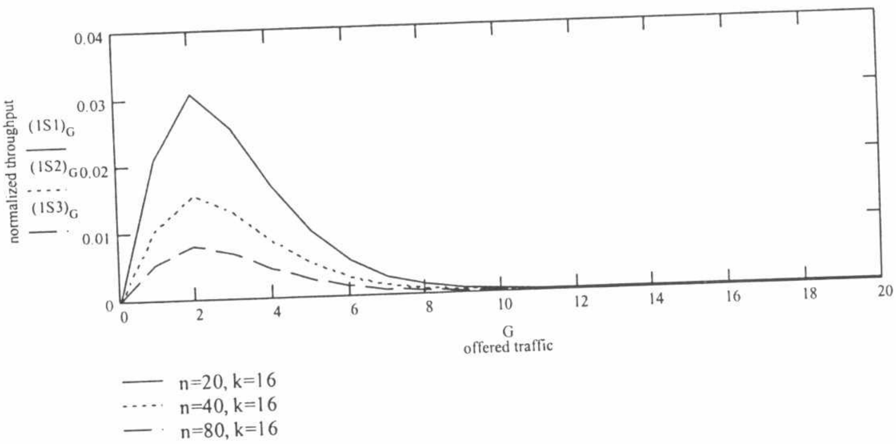

Fig. 6 Performance of the normalized system throughput as a function of the offered traffic for the RS coded hybrid SFH/DS SSMA over Rician fading channel for different RS (n,k) values.

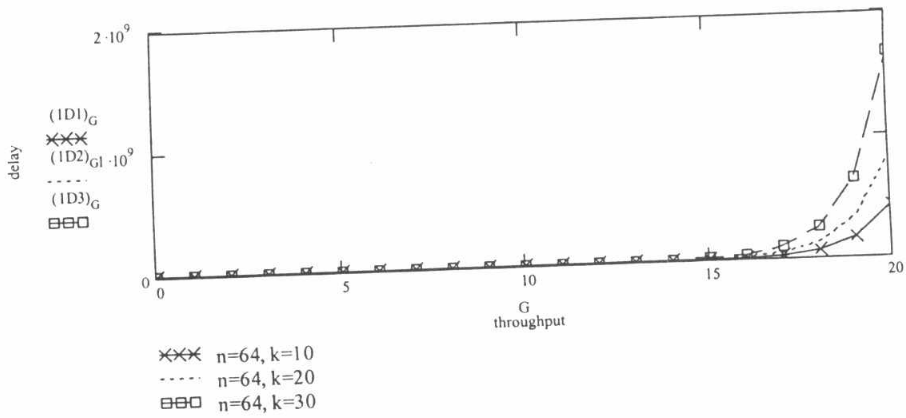

Fig. 7 Performance of the system delay as a function of the offered traffic for the RS coded hybrid SFH/DS SSMA over Rician fading channel with different values of the RS (n,k).

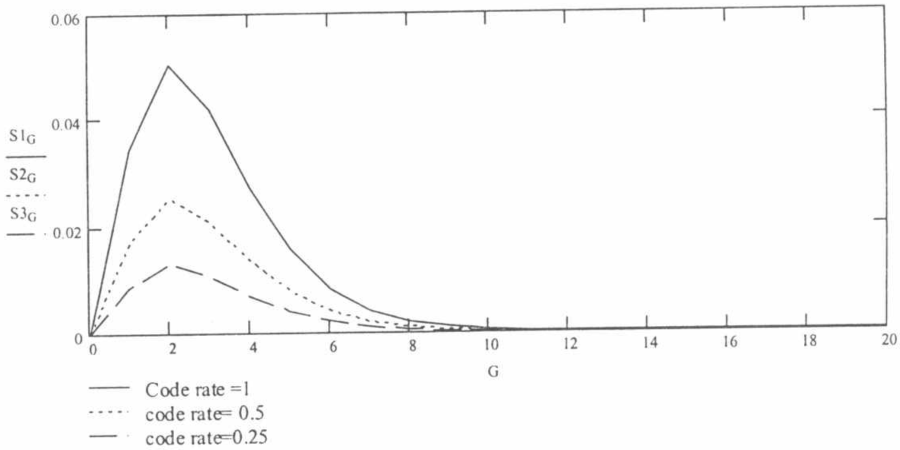

Fig. 8 Performance of the normalized system throughput as a function of the offered traffic for the RS coded hybrid SFH/DS SSMA over Rician fading channel for different code rate

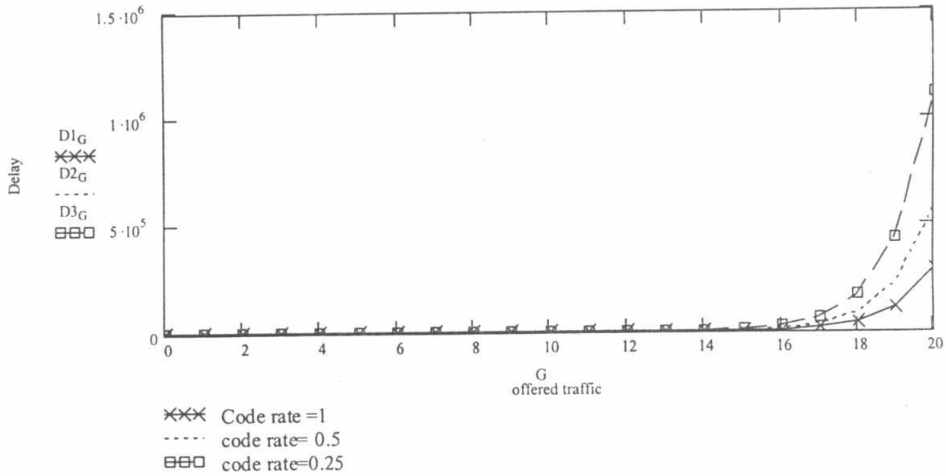

Fig. 9 Performance of the system throughput as a function of the offered traffic for the RS coded hybrid SFH/DS SSMA over Rician fading channel with different values of the code rate.