been developed. Simulations show that it can successfully suppress stationary additive and nonzero mean multiplicative noise with any PDF. It is also very practical since it has a low computational overhead.

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Difference threshold test for asynchronous BFSK frequency-hopped multiple access systems over Rician channels

Ing-Jiunn Su and Jingshown Wu

A new side information generating mechanism, the difference threshold test (DTT), is proposed to improve the capacity of asynchronous frequency-hopped multiple access systems with binary frequency shift keying (BFSK) signalling over Rician fading channels. By adjusting the threshold in the DTT decision logic, optimum capacity can be obtained. This technique has proven to be advantageous compared with the conventional hard decision technique. For systems with signal-to-noise ratio ranging from 10 to 13dB, this improvement can be >13%.

Introduction: Frequency-hopped multiple access (FHMA) techniques have attracted increasing interest in the application of wireless communications. However, simultaneously transmitted signals may collide in the same frequency band: such events are called hit events. The hit symbols would be liable to the wrong decision being made at the receiver using a hard decision scheme. If a side information generating mechanism can indicate that this event has occurred and inform the following decoder to erase these hit symbols, then the performance would be improved. Some schemes have been proposed to provide this side information in the FHMA system [1]. In this Letter, a new and simple scheme, called the difference threshold test (DTT), is proposed to generate effective side information. The DTT scheme just performs comparison operations in the decision logic, which is much simpler than that in the conventional side information generating mechanisms. We will investigate its effectiveness in an asynchronous binary frequency shift keying (BFSK) FHMA system with Rician channels. A noncoherent detection scheme is assumed in this Letter.

System description and analysis: We consider that K users are active in the FHMA system allocated with q available frequency slots. Each transmitter modulates information bits with a BFSK signalling scheme. The carrier frequency of each modulation symbol is changed with each random sequence from the available frequency slots. Without co-ordinating the user's hopping sequences, the transmitted symbols may collide with the other simultaneously transmitted signals. The probability that a symbol will collide with a specific user's signal in the asynchronous hopping system can be represented by

$$p_h \simeq \frac{2}{q} \qquad (1)$$

The receiver first removes the frequency hopping effect from the received signal according to the intended hopping pattern and directs it to the envelope detectors. Here we assume that the 0th user's signal is desired to be received. For BFSK signalling, two envelope outputs are generated for a decision and represented by [2]

$$r_i = \left| Z_i + \delta_{i0}\alpha_0 e^{j\theta_0} + \sum_{m=1}^{K-1} C_{im}\alpha_m x_m e^{j\theta_m} \right|, \quad i = 0,1 \qquad (2)$$

where δ_{i0} is Kronecker delta, Z_i is zero-mean complex Gaussian noise, the real and imaginary parts of which have the same variance $\sigma_0^2 = N_0/2$, N_0 is the one-sided power spectral density of noise, C_{im} is a binary-valued random variable which represents the presence or absence of the mth user's signal in the ith envelope output, α_m and θ_m are the amplitude and phase of the mth user's signal, and x_m is a random variable uniformly distributed over [0, 1) to reflect the partial collision nature in asynchronous hopping systems. For Rician channels, θ_m is uniformly distributed over [0, 2π) and $\{\alpha_m\}$ are modelled as independent and identically distributed (i.i.d.) Rician random variables with the average unfaded component a^2 and faded component $2\sigma_f^2$ by assuming the same average received power for all user's signals. $\Gamma(\equiv a^2/2\sigma_f^2)$ is an indicator of the degree of fading in the channel. $\Gamma = 0$ represents the Rayleigh channel. The probability function of C_{im} can be represented by

$$\Pr(C_{im}) = \begin{cases} \frac{p_h}{2} & C_{im} = 1 \\ 1 - \frac{p_h}{2} & C_{im} = 0 \end{cases} \qquad (3)$$

The corresponding characteristic functions of the two envelope outputs can be expressed as [3, 4]

$$\phi_i(\rho) = e^{-\frac{\sigma_0^2\rho^2}{2}} \phi(\delta_{i0}\rho) \prod_{m=1}^{K-1} I(C_{im}\rho) \qquad (4)$$

where $\phi(\rho) = e^{-\frac{(\sigma_f^2\rho^2)}{2}} J_0(a\rho)$ is the characteristic function of the user's signal, $I(C_{im}\rho) = \int_0^1 \phi(C_{im}\rho)dx$ is the characteristic function by taking the expectation with x_m, and $J_0(\cdot)$ is the 0th order Bessel function. If K goes infinity with user density $\lambda(\equiv K/q)$ held constant, a Poisson approximation can be applied to C_{im} and the average characteristic functions can be determined as follows [5]:

$$\hat{\phi}_i(\rho) = e^{-\frac{\sigma_0^2\rho^2}{2}} \phi(\delta_{i0}\rho) e^{\lambda[I(\rho)-1]} \qquad (5)$$

By inverse transformation, the probability density functions $f_i(r)$ and cumulative distribution functions $F_i(r)$ can be obtained to evaluate the performance.

For the DTT decision scheme, a threshold d is preset to estimate the reliability of the received symbol. If the difference between two envelope outputs is smaller than this threshold, erasure side information is issued to indicate unreliable reception. Otherwise, the decision logic chooses the largest output as the estimated symbol. More erasure side information would be generated for a larger threshold. If the threshold is set to zero, no side information can be generated and the decision scheme degenerates to make a hard decision. According to this decision rule, the correct decision occurs when the non-desired envelope output r_1 is less than $r_0 - d$ and its probability is determined by $P_c = \int_0^\infty F_1(r - d) f_0(r)dr$, if the desired signal presented in r_0. Similarly, the error probability can expressed as $P_e = \int_0^\infty F_0(r - d) f_1(r)dr$.

For the symmetric binary erasure and error channel model, the total channel capacity, in terms of the number of bits per channel use, can be derived as follows:

$$C = \left\{ P_c \log_2 \frac{2P_c}{1 - P_x} + P_e \log_2 \frac{2P_e}{1 - P_x} \right\} \lambda q \qquad (6)$$

where $P_x = 1 - P_c - P_e$ is the erasure probability.

Numerical results: Since the threshold affects the generation of side information, the system performance would vary with the threshold setting. Although more erasure side information can be generated for larger d, the excess erasure would be wasteful and reduce the system capacity. Therefore, there exists an optimum threshold. With a numerical search, we can find this optimum threshold for each user density.

Fig. 1 presents the maximum capacity and optimum thresholds over the Rayleigh channels (i.e. $\Gamma = 0$) for $E_b/N_0 = 10$dB and $E_b/N_0 = 13$dB, where $E_b = a^2 + 2\sigma_f^2$ is the average bit energy. Here the threshold is normalised to $\sqrt{E_b}$. Intuitively, the threshold should be increased for higher user density due to the increased number of collisions. The results for a hard decision ($d = 0$) are also presented to illustrate the effectiveness of the side information. In general, a system with large E_b/N_0 would have more capacity regardless of the decision scheme. Moreover, it is found that the capacity obtained with optimum threshold in a DTT decision scheme can be significantly improved over that in a scheme using hard decisions. A >13% improvement in maximum attainable capacity can be obtained. Similarly, Fig. 2 also shows this advantage for $\Gamma = 10$. However, in contrast to the trend over Rayleigh channels, the optimum threshold does not increase with user density due to the more reliable unfaded component in the received signal over that for less faded channels.

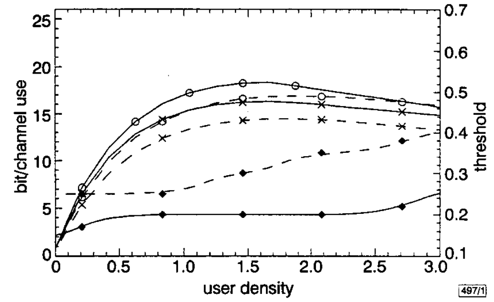

Fig. 1 *Capacity and optimum threshold for* $\Gamma = 0$ *and* $q = 48$

O optimum capacity
× capacity for hard decision
● optimum threshold
——— $E_b/N_0 = 13$dB
- - - - $E_b/N_0 = 10$dB

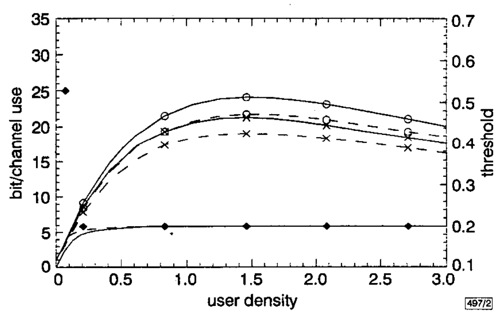

Fig. 2 *Capacity and optimum threshold for* $\Gamma = 10$ *and* $q = 48$

O optimum capacity
× capacity for hard decision
● optimum threshold
——— $Eb/N_0 = 13$dB
- - - - $E_b/N_0 = 10$dB

Conclusion: A new DTT decision scheme has been proposed for generating erasure side information in asynchronous BFSK FHMA systems over Rician fading channels. This scheme simplifies the decision logic and reduces the complexity of implementation. By optimising the threshold of the DTT decision logic, the generated side information can effectively improve the system performance. Compared with that in hard decision systems, the maximum attainable capacity for the DTT decision systems can be improved by >13% when the signal-to-noise ratio ranges from 10 to 13dB. It is also revealed that the optimum threshold should be increased for larger user density for severe fading channels.

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Differentiated services TCP algorithm for the Internet

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A new concept of the slow-start threshold hopping coefficient in the TCP Reno algorithm is proposed. A modified TCP algorithm is devised for implementing differentiated services over the Internet. A theoretical analysis and simulations are presented to validate the effectiveness of the algorithm.

Introduction: The Internet is evolving from a single service architecture to a differentiated services architecture. Modifying the distributed TCP (transmission control protocol) algorithm to provide end-to-end mechanisms for differentiated services has significant prospects. In this Letter we propose a modified TCP algorithm, called differentiated services-TCP (DS-TCP, in short), by introducing a slow-start threshold hopping coefficient into the TCP Reno slow-start and congestion avoidance algorithm [1]. We then theoretically analyse the differentiation effect of the connections' average throughput in a widely used fluid-flow model. The simulation results have confirmed the validity of the DS-TCP algorithm. It is expected that DS-TCP can achieve better results when combined with scheduling and queue management mechanisms in the router.

DS-TCP algorithm: In the TCP Reno slow-start and congestion avoidance algorithm, the connection's sending rate is determined by the minimum of the congestion window (*cwnd*) and the receiver's advertised window (*rwnd*). In this Letter, it is assumed that *rwnd* does not constrain the sending rate. Modifications to the fast recovery and fast retransmit algorithms are not considered.

The integrated slow-start and congestion avoidance algorithm in DS-TCP is described as follows:

every *ACK* do
  if $cwnd < ssthresh$ then $cwnd = cwnd + 1$ (slow-start phase)
  else $cwnd = cwnd + 1/cwnd$ (congestion avoidance phase)
every *Time-Out* do
  $ssthresh = \gamma \cdot cwnd$
  $cwnd = 1$

We call γ the slow-start threshold hopping coefficient (hopping coefficient, in short). It is typically set to 0.5 in the TCP Reno algorithm. Suppose that γ is set to be different when the bandwidth requirement from a class of elastic applications is different. We have proven that such a differentiation of the hopping coefficients can result in the differentiation of each connection's average throughput. The differentiated services can be achieved in this simple way.

Analysis model: A widely used fluid flow analysis model is introduced here [2]. Owing to the exponential increase of the window size, the slow-start phase is very short compared to the congestion avoidance phase and can be neglected in the evaluation of long-range performance criteria. Consider N connections that share the