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IMPROVING PERFORMANCE OF MULTIDESTINATION ARQ SCHEMES UNDER HIGH ERROR RATE CONDITIONS

Indexing terms: Data transmission, Information theory

The throughput efficiencies of a class of continuous multidestination ARQ schemes are evaluated. The operation of the proposed schemes is simpler than that of the schemes studied previously. Numerical results also show that the optimal proposed scheme offers a better throughput performance than the optimal one investigated previously.

Introduction: Because of the increasing demands of point-to-multipoint communication over a broadcast links such as file distribution or teleconferencing links, various multidestination automatic repeat request (MARQ) schemes have been recently proposed and evaluated.[1-4] For example, the performance of the Moeneclaey and Bruneel,[5] the Sastry[6] and Morris[7] schemes for multidestination environments were examined in Reference 4. It was found that the Morris scheme offers the best throughput performance of the three whereas the Moeneclaey and Bruneel scheme is the simplest to implement and provides almost the same throughput performance as the Morris scheme under very high error rate conditions. In Reference 8, a class of MARQ schemes which can achieve a better performance under high error rate conditions were proposed.

The class of MARQ schemes investigated in Reference 8, however, have to distinguish whether a data block is transmitted for the first time or is being retransmitted, resulting in a complicated operation. I propose another class of MARQ schemes with repeated transmissions which can improve the throughput performance and simplify the operation as well.

Investigated ARQ schemes: In the continuous ARQ schemes investigated here, each data block is transmitted with m or fewer copies contiguously to the receivers. At each receiver, an error detection procedure is performed on each received copy. A positive (ACK) or a negative acknowledgment (NAK) is sent back to the transmitter according to whether the copy is received successfully or erroneously. A data block is considered to be successfully delivered as long as each receiver receives successfully at least one of the transmitted copies. If at least one receiver detects all the m copies with error, then, just as in the go-back-N ARQ scheme, the transmitter goes back to and retransmits that data block against with at most m copies. This process is repeated until the data block is successfully delivered.

For convenience, the time to transmit a copy of a data block is called a slot. Consider the transmission of a particular data block. We assume for simplicity that the round-trip delay between the transmitter and any receiver is equal to N slots. As a result, if $m \leq N$, all the m copies of a data block have to be transmitted before any response can arrive at the transmitter. If $m > N$, then the transmitter may receive an ACK for the data block from each receiver before all the m copies are transmitted. When this occurs, the transmitter will start transmitting the next data block rather than continuing transmitting the rest copies. Therefore, the phrase 'or fewer' was used in the description of the operation of the investigated ARQ schemes.

It should be obvious that, given the round-trip delay N and the block error probability P_e, the optimal maximal allowed number of copies in each transmission depends on the number of unacknowledged receivers. In other words, to maximise the throughput efficiency, the maximal allowed number of copies should be adaptively adjusted according to the number of unacknowledged receivers. However, such adaptive protocols could be too complicated and thus may not be favoured from an implementational point of view. Therefore, the MARQ schemes proposed in this Letter are worth studying.

Throughput performance: Let K denote the number of receivers in the system. For simplicity, we assume that transmission errors between copies of data blocks occur independently at each receiver and the feedback channel is error-free.

Consider a particular value of m. Let η_m denote the throughput efficiency. Clearly, $\eta(m) = 1/L_m(K)$, where $L_m(K)$ represents the average number of transmissions required to successfully deliver a data block. To compute the value of $L_m(K)$, we have to consider three cases separately.

(i) *Case 1:* $m = \infty$.

The scheme when $m = \infty$ is actually the Moeneclaey and Bruneel scheme and has been examined in Reference 4. The result is

$$L_m(K) = S(P_e, K) + N - 1 \tag{1}$$

where

$$S(P_e, K) = \sum_{i=1}^{K} \binom{K}{i} \frac{(-1)^{i+1}}{1 - P_e^i} \tag{2}$$

represents the average number of copies transmitted until each of the K receivers receives at least one copy successfully.

(ii) *Case 2:* $1 \leq m \leq N$.

For this case, all the m copies are transmitted before the transmitter can receive any response. Therefore, $L_m(K)$ can be computed recursively by

$$L_m(K) = m + \sum_{i=0}^{K-1} \binom{K}{i} (1 - P_e^m)^i \times (P_e^m)^{K-i} [N - 1 + L_m(K - i)] \tag{3}$$

with

$$L_m(1) = \frac{m + P_e^m(N - 1)}{1 - P_e^m}$$

Notice that, to compute $L_m(K)$, the values of $L_m(1)$, $L_m(2)$, ..., and $L_m(K - 1)$ have to be determined first.

(iii) *Case 3:* $N < m < \infty$.

When $m > N$, the transmitter may receive an ACK from each receiver before all the m copies are transmitted. Let $Q_j(K)$ denote the probability that all the K receivers receive successfully the data block in j copies, i.e.

$$Q_j(K) = (1 - P_e^j)^K \tag{4}$$

Furthermore, let $R_j(K)$ denote the probability that the K receive the data block successfully exactly at the jth copy, i.e.

$$R_j(K) = Q_j(K) - Q_{j-1}(K) \tag{5}$$

Then $L_m(K)$ can be evaluated recursively by

$$L_m(K) = \sum_{j=1}^{m-N} R_j(K)(j + N - 1) + m \sum_{j=m-N+1}^{m} R_j(K) + \sum_{i=0}^{K-1} \binom{K}{i} (1 - P_e^m)^i \times (P_e^m)^{K-i} [m + N - 1 + L_m(K - i)] \tag{6}$$

Again, the values of $L_m(1)$, $L_m(2)$, ..., and $L_m(K-1)$ have to be determined before $L_m(K)$ can be computed.

Numerical results and discussions: Fig. 1 shows the throughput efficiencies of the multidestination selective repeat (MSR), the multidestination go-back-N (MGBN), the optimal scheme studied in Reference 8 (labelled as SUBOPT), and the optimal scheme investigated here (labelled as OPT) against P_e for $N = 5$ and $K = 5$. The throughput efficiencies of the MSR and MGBN schemes are equal to $1/S(P_e, K)$ and $1/[1 - N + NS(P_e, K)]$, respectively. We can see that OPT is consistently greater than SUBOPT. The percentage of improvement is about 12·3% at $P_e = 0{\cdot}15$. Fig. 2 shows similar results for $N = 5$ and $K = 20$. Again, the optimal proposed scheme offers a net increase in throughput efficiency with respect to that studied in Reference 8. According to numerical results, the percentage of improvement decreases as K increases. Fig. 3 illustrates the optimal maximal allowed number of copies m^* against P_e. We can see that m^* is an increasing function of P_e and tends to be larger as K becomes larger.

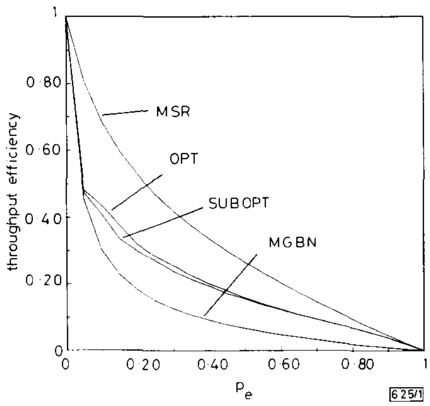

Fig. 1 *Throughput efficiency against P_e for $N = 5$ and $K = 5$*

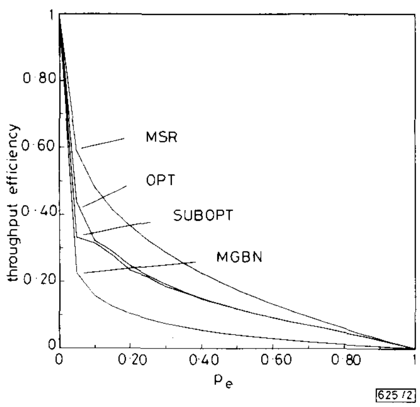

Fig. 2 *Throughput efficiency against P_e for $N = 5$ and $K = 20$*

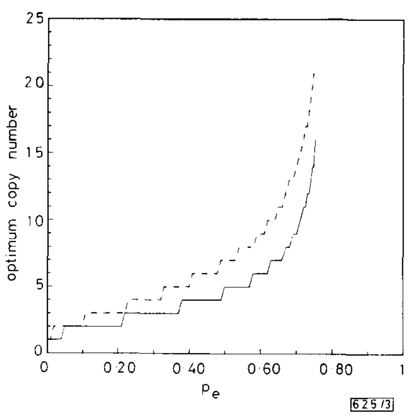

Fig. 3 *Optimal maximal allowed number of copies against P_e*

- - - - $N = 5$ $K = 20$
—— $N = 5$ $K = 5$

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26th November 1990

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FREQUENCY ASSIGNMENT FOR SATELLITE MULTILEVEL SCPC SYSTEMS

Indexing terms: Satellite links, Algorithms

A rule-based strategic search method for frequency assignment for satellite multilevel SCPC systems is presented. The quality of solutions improves significantly on published results. In addition, little computation time is required.

Introduction: In a recent communication,[1] a fast method for searching for the frequency assignment for satellite equal carrier SCPC systems is proposed. It suggests that a carrier be deleted and inserted alternately until no change results in the assignment. In brief, the carrier in a slot containing the largest amount of intermodulation (IM) products is deleted while a carrier is inserted in an unoccupied slot which contains the least amount of IM products. By adding a few practical strategies, the method is extended for the case of multilevel SCPC systems.

To evaluate the effect of IM noise in satellite communication systems, only third order IM products are considered because the third order IM product dominates the IM power spectrum.[2] There are two kinds of third order IM product, triple product, $(A + B - C)$, and double product, $(2A - B)$. In the search for quasioptimum assignments, only the triple product is taken into account. This is because there are many more triple than double products and because the triple product is 6dB higher than the double product in power level.[3,4]

In multilevel SCPC systems, $C/(N + IM)$ is to be maximised during system design. As N is known and constant, maximisation of C/IM is sufficient in this Letter. To assess the quality of an assignment, a parameter (C/IM advantage) is defined.[5] The C/IM advantage is defined as the ratio of the