Throughput of Nonbinary Type-II Hybrid ARQ with Adaptive Modulation

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I. INTRODUCTION

Hybrid Automatic-Repeat-reQuest (ARQ) combines the advantages of ARQ and Forward-Error-Control (FEC), and can achieve good throughput with very low bit error rate (BER) [1]. In this paper, nonbinary HARQ is proposed and analyzed in terms of throughput. Nonbinary HARQ is also applied in a cell with adaptive modulation and the average throughput is obtained.

II. NONBINARY TYPE-II HARQ

Type-II HARQ uses FEC for error correction, but only retransmits the necessary part, such as the information or parity check part, rather than the whole packet, as in type-I. The most widely used protocol is to combine 1/2-rate invertible codes with ARQ [2]. With invertible codes, all the information in the packet may be retrieved from the error-free parity check part.

In our nonbinary HARQ, half rate shortened Reed-Solomon (RS) code is used in the FEC subsystem instead of binary BCH codes. The latter has been used in Lin and Yu's original type-II HARQ [2]. The merits of using RS codes are obvious. For one thing, RS codes are suited to correct long-burst errors, which degrade transmission quality in wireless communications; for another, they belong to the class of Maximum-Distance-Separable (MDS) codes, and allows flexibility in adjusting the coding rate. In addition, RS codes can be easily combined with such bandwidth efficient modulation schemes as MPSK, or QAM, allowing the full use of the precious spectrum resource.

The throughput of nonbinary HARQ can be derived similarly as in [2]. Due to space limitations, the results will not be presented here.

III. HARQ WITH ADAPTIVE MODULATION

Assume that nonbinary HARQ is applied to a cell, which is divided into two circular regions, A_1 and A_2, with the transmission antenna at the center. Mobile terminals (MTs) in A_1 are near the antenna, and encounter better channel states in comparison with those MTs in A_2. Accordingly, high throughput HARQ should be used in A_1, and relatively low throughput HARQ, in A_2. HARQ schemes with different throughputs can be implemented by changing the size of the modulation constellation. Two MPSK schemes, QPSK and 8PSK, are considered in our research, for their wide use in current communication system. The two modulation schemes are switched according to the average SNR of the received signal, viz., the distance from the base station. 8PSK and QPSK are adopted in the near and far regions, respectively.

To evaluate different partitioning of a cell, we define the modulation assignment index

$$f = \frac{\sharp \text{ of MTs in } A_1}{\text{total } \sharp \text{ of MTs in the cell}}.$$

Assume the mean throughput of the user at distance r from the antenna to be $\eta_{MPSK|r}$, and the pdf of r to be $p(r)$, we average $\eta_{MPSK|r}$ over the whole cell, and get $\eta = \int_{A_1} \eta_{8PSK|r}p(r)dr + \int_{A_2} \eta_{QPSK|r}p(r)dr$.

IV. NUMERICAL RESULTS

Two nonbinary type-II HARQs are considered, RS (60, 30) code with 8PSK and QPSK, respectively. Let the roundtrip delay be 33 ms, data rate be 2 Mbps, radius of the cell be 1000 m, and operation frequency be 900 MHz. Slow, flat, Rician fading with a Rician parameter of 5 dB is included in the calculation.

Figure 1 shows a cluster of throughput curves with a parameter of γ_{d0}, SNR at reference distance d_0 from the antenna. It is easily observed that an optimum f exists, corresponding to the maximal value of the average throughput. From the calculation of the average throughput, we conclude that the optimal threshold of SNR is where the throughput curves of QPSK and 8PSK coincide.
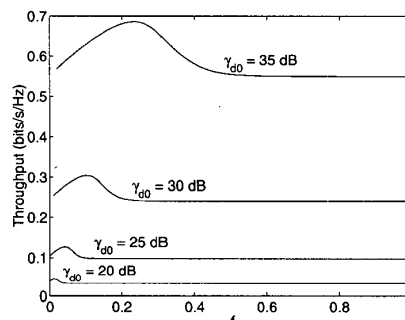

Figure 1: Throughput of HARQs with adaptive modulation as a function of f with error-correction capability $t = 5$ of shortened RS (60, 30) code.

Furthermore, type-II HARQ with adaptive modulation can achieve much higher throughput compared to the non-adaptive ones. Considering the case of $\gamma_{d_0} = 30$ dB, the maximal throughput exceeds 0.30 bits/s/Hz, while the corresponding throughputs of fixed 8PSK ($f = 1$) and QPSK ($f = 0$) are 0.24 and 0.25 bits/s/Hz, respectively. Over 25% throughput gain can be achieved with the adaptive scheme.

REFERENCES

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