Combined HQAM and Hybrid Relay Selection for Error Resilience Transmission

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ABSTRACT

This paper is concerned with relay networks and hierarchical modulation for error resilience transmission. The advantage of Hierarchical QAM-based UEP is that a high performance of protection under the high-to-moderate noise conditions is obtained, without an increase in bandwidth, but at the same time decreases the overall quality at low noise conditions, On the other hand, it has been proven that hybrid relaying achieves excellent performance at low noise conditions. Therefore, a combination of the two methods can take advantages of both. This is the main motivation of this paper.

Through the means of combination, the combined scheme of UEP results in the overall quality improvement of transmitted data, especially under moderate-to-high SNR values. It has produced better BER and PSNR performance than the individual HQAM and HRSP UEP schemes.

Keywords: Hierarchical QAM, Hybrid Relay Selection, Error Resilience.

1. Introduction

In multimedia transmission over wireless networks, distortion of reconstructed data can be reduced if more important parts of these data are decoded reliably at the expense of less reliable detection of less important parts. This is referred to as the unequal error protection (UEP) technique. Many different techniques to implement UEP for data communications were proposed in the literature [1, 2, 3, 4, 5].

Cooperative relay communication has become a widely used technique in wireless communication systems to combat fading effects induced by multipath propagation. It is also used to improve the reliability of data transmission [6], Recently, an alternative relay selection scheme based on a hybrid relay protocol has received a lot of attention. The proposed algorithm divided the relays into two groups, which are AF and DF relay groups, and then exploits the merits of both relay groups. In this case, noise amplification in AF relay, and error propagation in DF relay, will be avoided [7, 8, 9, 10]. By incorporating relay selection with hybrid relaying protocol, its performance can be further improved. This process is known as hybrid relay selection [11, 12, 13, 14, 15, 16].

There exists of research work related to hierarchical modulation and cooperative communication systems [17, 18, 19, 20, 21, 22, 23]. Closely related to the proposed work in this paper are [24, 25, 26], where cooperative relays are exploited to achieve UEP. UEP scheme exploiting the DF cooperative relay networks was proposed in [26]. In this method, the most significant bitstreams is transmitted through the best relay, while the less important bitstreams is transmitted through other relays. The closed-form expressions of SEP and spectral efficiency were also derived. The authors in [24] proposed an UEP scheme based upon hierarchical modulation in a single-relay network. The relay transmits high and low protection data, or the most significant data, or remains silent in the second hop. In their system, each node was equipped with a single antenna. Furthermore, an extended work of [24] to a multiple-relay cooperative scenario was proposed in [25], where the best relay was selected for transmission.

The contributions of this paper are two-fold:

1. Hybrid relay selection and HQAM are investigated and combined together to improve system performance. The difference of this work, compared with those in [19, 27, 24, 25, 26, 22, 23], is the use of DF and AF relays together and the exploitation of the merits of both.

2. The performance analysis of the proposed hybrid relaying protocol is presented. Specifically, analytical expressions of the BER and outage probability of the SNR for indirect links are given in closed-form.

2. Proposed System

The proposed system is aimed to improve the overall system performance by jointly considering the hybrid relay selection and HQAM techniques. The idea is to jointly consider hybrid relay and HQAM as an error protection strategy in order to improve transmission reliability and error resilience in terms of protection against channel errors.

The block diagram of the proposed system is shown in Figure 1. A general two-hop relay network consists of one source node, denoted as S, one destination node denoted as D, and N relays, distributed between S and D. At the source node, the HP and LP data are encoded separately using H.264/AVC encoder. The encoded bitstreams are then protected unequally using 16-HQAM. Then, the output of 16-HQAM is transmitted through hybrid relay networks, where the HP and LP signals are transmitted over the best DF and the best AF relays, respectively. Each node in the proposed two hop multi-relay network is assumed to be equipped with a single antenna and the half-duplex transmission mode is considered.

The destination can simultaneously receive the signal from both AF and DF relays. Thus, this system is known as a hybrid relay system. At the destination, the complete channel state information (CSI) is known and the relay selection is conducted at the beginning of each transmitted block. This technique was proposed by [30, 31] and is adopted in this work. The proposed system assumes that the relays have the ability for perfect error-checking.

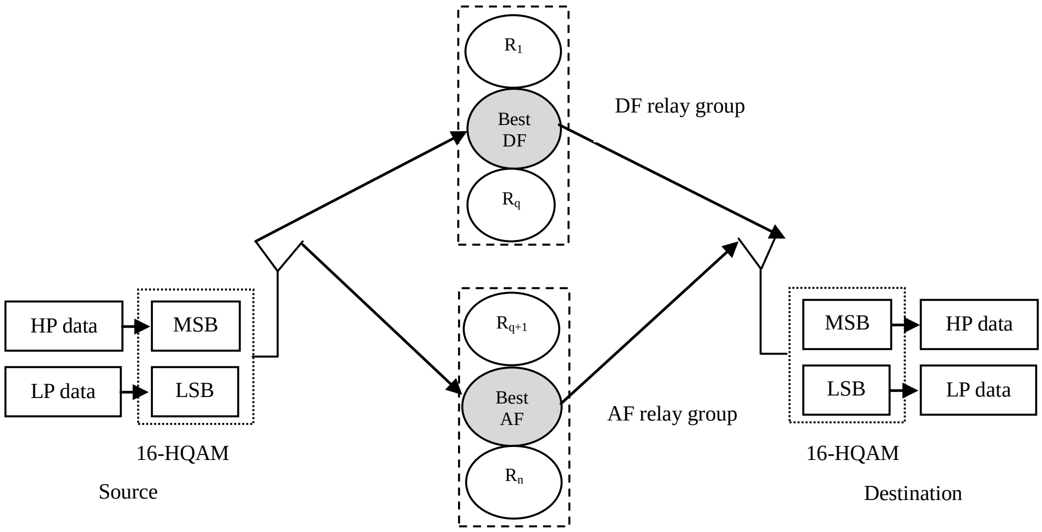

Figure 1. The proposed system model

Let $x_{r_i}(t)$ represent the transmitted signal from the relay i (DF or AF group) at time t. Then, the received signal at the destination at time t, represented by $y_{r_{i,d}}$ can be written as

$$y_{r_{i,d}}(t) = h_{r_{i,d}} x_{r_i}(t) + w_{r_{i,d}}(t) \tag{1}$$

where $h_{r_{i,d}}(t)$ is the channel fading between the relay i and the destination and $w_{r_{i,d}}(t)$ is the AWGN at the destination.

The overall received signal at destination after the selection of the two relays can be written as

$$y_d = \begin{cases} \sqrt{P_{r_{i,d}}} h_{r_{j,d}} s(t) + w_{r_{j,d}}, \\ \beta_i h_{r_{i,d}} \left(\sqrt{P_{s,r_i}} h_{s,r_i} \right) s(t) + \beta_i h_{r_{i,d}} w_{s,r_i} + w_{r_{i,d}}. \end{cases} \tag{2}$$

Then, the destination decodes the received signals from the best relay in AF and DF groups independently.

3. Performance Analysis

BER and outage probability of the proposed system over Rayleigh fading channels are calculated.

3.1 BER Performance

The closed-form expression of the error probability can be obtained as

$$P_b(e) = \frac{1}{2} \sum_{i=1}^{q} \sum_{j=q+1}^{n-q} \binom{q}{i} \binom{n-q}{j} (-1)^{i+j} \frac{ij}{j\gamma_{eq} - i\gamma_{rd}} \times \left[\left(1 - \sqrt{\frac{\gamma_{eq}}{i+\gamma_{eq}}} \right) - \left(1 - \sqrt{\frac{\gamma_{rd}}{j+\gamma_{rd}}} \right) \right] \tag{3}$$

3.2 Outage Probability Performance

The outage probability is defined as the probability that the end-to-end instantaneous SNR falls below a certain predefined threshold value, γ_{th}.

The outage probability P_{out} is given by

$$P_{out} = P_{r(\gamma_i < \gamma_{th})} = \int_0^{\gamma_{th}} f_{\gamma_i}(\gamma) dy \quad (4)$$

where $f_{\gamma_i}(\gamma)$ is the PDF of the end-to-end SNR.

Using the conditional error probability, then closed-form expression of the error probability can be obtained as

$$P_{out} = \sum_{i=1}^{q} \sum_{j=q+1}^{n-q} \binom{q}{i} \binom{n-q}{j} (-1)^{i+j} \frac{ij}{j\gamma_{eq} - i\gamma_{rd}} \left[\int_0^{\gamma_{th}} e^{-i\frac{\gamma}{\gamma_{eq}}} dy - \int_0^{\gamma_{th}} e^{-j\frac{\gamma}{\gamma_{rd}}} dy \right] \quad (5)$$

4. Simulation Results and Discussion

In this section, the performance of joint HQAM and HRSP for encoded bitstreams under various strategies of UEP is discussed. HQAM is applied using different values of β (β = 1.5 and 2.5). In the following subsections, the results of three different UEP strategies over Rayleigh fading channels are presented. Equations (3), (4) (5) are used to evaluate the performance of UEP based HQAM. Average PSNR is discussed to evaluate the UEP strategy with different values of β. Second, the UEP based HRSP is then discussed. Finally, the joint UEP strategy of these two previous techniques is presented. The performance of the BER and outage probability of the proposed system is shown.

4.1 UEP Using 16-HQAM

First, the performance of the proposed system in which only HQAM is used to provide UEP to encoded bitstreams is shown. Figure 2 shows the quality of decoded bitstreams with UEP using 16-HQAM at different SNRs. The modulation parameter β is selected from the set β = 1.5 and 2.5. EEP is referred to equal error protection of 16-HQAM. From this figure, comparing EEP and UEP (β =1.5), an improvement in quality can be observed for SNR in the range 6 -17 dB.

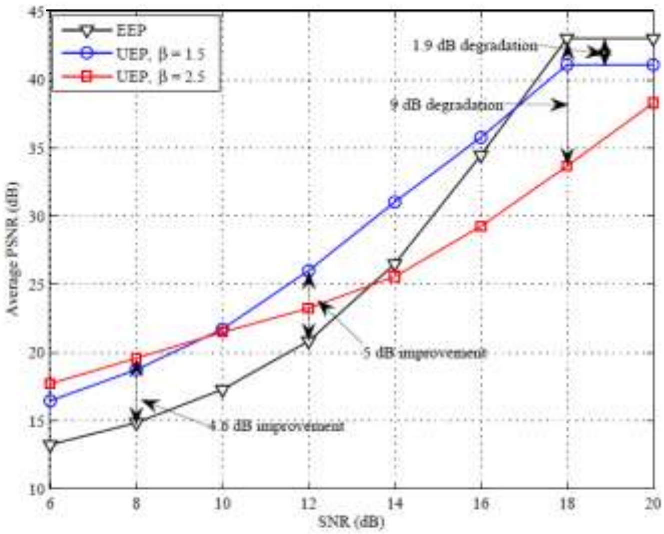

Figure 2: PSNR for different SNR using 16-HQAM.

4.2 UEP Using HRSP

Figure 3 shows the BER performance of the proposed HRSP discussed in Section 3 with different numbers of relays versus SNR. The BER performance of HP data outperforms the LP data because of the noise amplification of AF relay. Increasing the numbers of relays in each group results in increased performance of the system. For example, the HP data achieves a gain of about 2 dB compared with LP data in the case of single relay in each group. Increasing the number of relays in each group to 2 and 4 results in performance gains of 3 and 3.5 dB, respectively.

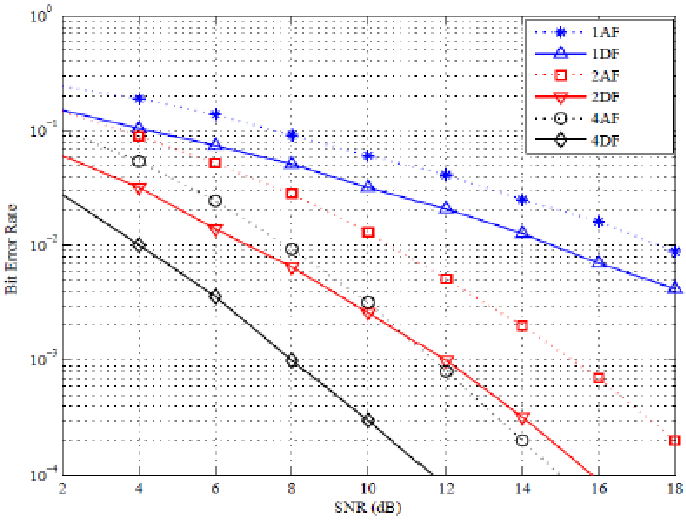

Figure 3: BER performance of HRSP with different numbers of relays.

4.3 UEP Combining HQAM and HRSP

Figures 4 compare the quality of reconstructed data obtained by 16- HQAM only, HRSP only, and the joint UEP scheme over a range of SNR noise conditions. The figure shows that the joint UEP scheme consistently outperforms UEP at individual techniques. The performance of combined UEP strategies results in a significant improvement especially at moderate-to-high SNRs. The proposed combined technique offers an improvement of about 5.9-13 dB over HRSP and 16-HQAM, respectively.

The reason for this improvement is that in the combined strategy, HP data are additionally protected by HRSP. In HRSP, the HP data are transmitted by using DF relay which forwards clean data to the destination and the LP data is transmitted using AF relay which forwards soft represented data to the destination. Furthermore, increasing the number of relays (M=2 and 4) leads to a performance improvement of almost 7 dB.

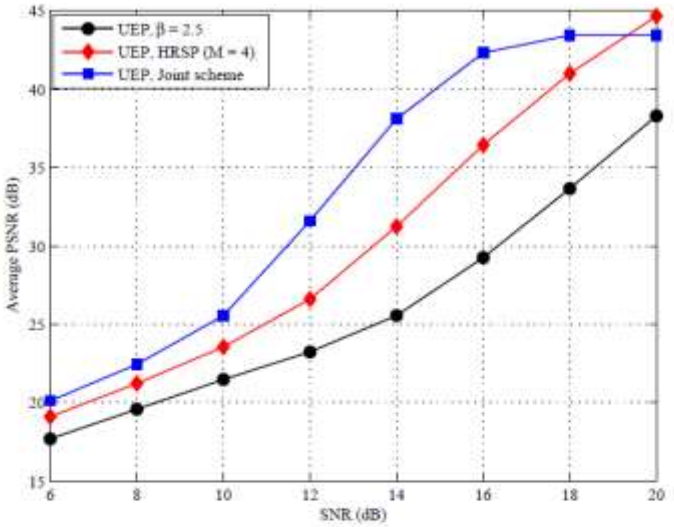

Figure 4: Comparisons of the proposed combined UEP scheme with 16-HQAM and HRSP.

5. Conclusions

A combined UEP scheme for bitstreams communication over wireless networks was proposed. Through the means of combination, the combined scheme of UEP results in the overall quality improvement of transmitted data, especially under moderate-to-high SNR values. It has produced better BER and PSNR performance than the individual HQAM and HRSP UEP schemes.

References

[1] A. S. Tan, A. Aksay, G. B. Akar, and E. Arikan, “Rate-distortion optimization for stereoscopic video streaming with unequal error protection,” *EURASIP J. Adv. Signal Process*., vol. 2009, pp. 1-14, Jan. 2009.

[2] B. Barmada, M. M. Ghandi, E. V. Jones, and M. Ghanbari, “Combined turbo coding and hierarchical QAM for unequal error protection of H.264 coded video,” *Signal Process. Image Commun.*, vol. 21, no. 5, pp. 390-395, Jan. 2006.

[3] M. M. Ghandi and M. Ghanbari, “Layered H.264 video transmission with hierarchical QAM,” Elsevier *J. Vis. Commun. and Image Represent.*, vol. 17, no. 2, pp. 451-466, Apr. 2006.

[4] C. Wu, C. Wang, and C. Chao, “UEP constructions of quasi-cyclic low-density parity-check via masking,” *Trans. Inf. Theory*, vol. 63, no. 10, pp. 6271-6294, Oct. 2017.

[5] M. Mhamdie, A. Zribi, C. Perrine, and Y. Pousset, “Efficient multiple concatenated codes with turbo-like decoding for UEP wireless transmission of scalable JPEG 2000 image,” *IEEE Access*, vol. 7, pp. 6327-6336, 2019.

[6] J. N. Laneman, D. N. C. Tse, and G. W. Wornell, “Cooperative diversity in wireless networks: efficient protocols and outage behavior,” *IEEE Trans. Inf. Theory*, vol. 50, no. 11, pp. 3062-3080, Dec. 2004.

[7] M. R. Souryal and B. R. Vojcic, “Performance of amplify-and-forward and decode-and-forward relaying in Rayleigh fading with turbo codes,” *in Proc. IEEE ICASSP'06*, Istanbul, Turkey, May 2006, pp. 681-684.

[8] M. Eslamifar, W. H. Chin, C. Yuen, and G. Y. Liang, “Performance analysis of two-way multiple-antenna relaying with network coding,” *in Proc. IEEE VTC 2009-Fall*, Anchorage, Alaska, USA, Sep. 2009, pp. 1-5.

[9] N. Hidayate, Suwadi and Wirawan "Performance of best relay selection in single relay selection scheme with network coding," *in Proc. 2nd International conference on Information Technology, Information systems and Electrical Engineering (ICITISEE)*, Yogyakarta, 2017, pp. 388-391.

[10] P. Puris, N. D. Chatzidiamantiz, P. Garg, M. Aggarwal and G. K. Karagiannidis "Two-way relay selection in multiple relayed FSO networks," *in IEEE wireless communications letters*, vol. 4, no. 5, pp. 485-488, Oct. 2015.

[11] T. Divya, K. K, gurrala, and S. Das, "Performance analysis of hybrid decode-amplify-forward (HDAF) relaying for improving security in cooperative wireless network," *in Proc. Global conference on communication technologies (GCCT),* Thuckalay, 2015, pp. 682-687.

[12] Q. Huo, T. Liu, L. Song, and B. Jiao, "All-participate hybrid forward cooperative communications with multiple relays," *in Proc. IEEE International Conf. Wireless Commun. Signal Process*., Marina Bay, Singapore, Oct. 2010, pp. 1-6.

[13] L. Song, Y. Li, M. Tao, and A. V. Vasilakos, "A hybrid relay selection scheme using differential modulation," *in Proc. IEEE WCNC'09*, Budapest, Hungary, Apr. 2009, pp. 1-6.

[14] U. Khair, Suwadi and Wirawan, "Performance of hybrid relay selection in cooperative communication system," *in Proc. 2nd International conference on Information Technology, Information systems and Electrical Engineering (ICITISEE)*, Yogyakarta, 2017, pp. 402-405.

[15] Y. Li, B. Vucetic, Z. Chen, and J. Yuan, "An improved relay selection scheme with hybrid relaying protocols," *in Proc. IEEE GLOBECOM'07*, Washington, DC, USA, Nov. 2007, pp. 3704-3708.

[16] X. Song, M. Zhang, W. Liu and F. Liu, "Threshold-based hybrid relay selection scheme," *in Proc. 12th world congress on intelligent control and automation (WCICA),* Guilin, 2016, pp. 222-227.

[17] C. Hausl and J. Hagenauer, "Relay communication with hierarchical modulation," *IEEE Commun. Lett*., vol. 11, no. 1, pp. 64-66, Jan. 2007.

[18] P. K. Singya, N. Kumar, V. Bhatia and M. Alouini, "On the performance of Hexagonal, cross, and rectangular QAM for Multi-Relay systems," *IEEE Access*., vol. 7, pp. 60602-60616, 2019.

[19] R. J. Whang, S. Malik, I. Hwang, and H. Liu, "Cooperative multiuser relay communications employing hierarchical modulation," *Wireless Pers. Commun.*, vol. 63, no. 4, pp. 1-17, Apr. 2012.

[20] R. J. Whang, H. Liu, and E. K. Hong, "Multiuser cooperative relay communication employing hierarchical modulation," i*n Proc. IEEE VTC Spring*, Taipei, May 2010, pp. 1-5.

[21] M. Peng, Y. Liu, D. Wei, W. Wang, and H.-H. Chen, "Hierarchical cooperative relay based heterogeneous networks," *IEEE Wirel. Commun.*, vol. 18, no. 3, pp. 48-56, June 2011.

[22] M. K. Chang and S. Y. Lee, "Performance analysis of cooperative communication system with hierarchical modulation over Rayleigh fading channel," *IEEE Trans. Wireless Commun*., vol. 8, no. 6, pp. 2848-2852, June 2009.

[23] W. Maham, T. sadaf, A. Rizwan, K. Adnan, A. Muhammed and A. Wagas, "Network coding and hierarchical modulation for energy efficient cooperative WBAN," *International journal of distributed systems and technologies*., vol. 10, pp. 90-111, Jul. 2019.

[24] H. X. Nguyen, H. H. Nguyen, and T. L. Ngoc, "Signal transmission with unequal error protection in wireless relay networks," *IEEE Trans. Veh. Technol*., vol. 59, no. 5, pp. 2166-2178, June 2010.

[25] H. X. Nguyen, H. H. Nguyen, and T. L. Ngoc, "Signal transmission with unequal error protection in relay selection networks," *IET Commun*., vol. 4, no. 13, pp. 1624-1635, Sep. 2010.

[26] T. Q. Duong, U. Engelke, and H.-J. Zepernick, "Unequal error protection for wireless multimedia transmission in decode-and-forward relay networks," *in Proc. IEEE Radio and Wireless Symposium (RWS'09)*, San Diego, Jan. 2009, pp. 703-706.

[27] H. Son, J. Park, and S. Lee, "Hierarchical modulation-based cooperation utilizing relay-assistant full-duplex diversity," *Wireless Netw*., vol. 17, no. 3, pp. 583-595, Apr. 2011.

[28] A. Bletsas, H. Shin, M. Z. Win, and A. Lippman, "A simple cooperative diversity method based on network path selection," *IEEE J. Sel. Areas Commun*., vol. 24, no. 3, pp. 659-672, Mar. 2006.

[29] Z. Yi and I.-M. Kim, "Decode-and-forward cooperative networks with relay selection," *in Proc. IEEE VTC 2007*-Fall, Baltimore, MD, USA, Oct. 2007, pp. 1167-1171.