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Outage Probability Analysis of Coded Cooperative Communication

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***Abstract*—**Cooperative communication was proposed for wireless networks such as cellular network and wireless ad-hoc networks to meet the rapid increase in the data rate. Coded cooperative communication is one of the co-operative system, in which cooperation is combined with the channel coding. Coded cooperation is a promising technology to improve the outage performance of the system.

***Keywords*—*Coded cooperative communication, Outage Probability*.**

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I. INTRODUCTION

Wireless transmission suffers from fading. Transmitting independent copies of the signal can generate diversity which is an effective technique to mitigate the effect of fading. Transmit diversity require multiple transmitting antennas. However most of the wireless devices are limited to one antenna due to their size, cost and hardware complexities. In phase of this limitation Cooperative communication was proposed [1] that enable a single antenna mobile in a multi user environment to share their antennas to create a virtual MIMO system. Cooperative communication is an effective technique to improve the reliability of wireless networks.

Cooperative communication draws from the ideas of using broadcast nature of wireless media. The communicating nodes help each other to implement the communication process in a distributed manner. Three terminal networks is the fundamental unit in user cooperation. The key idea behind the user cooperation is that of resource sharing among multiple nodes in the network [2]. User cooperation improve the system performance such as increase in spectral and power efficiency, network coverage area and reduced outage probability

Based on the way how the relay node forwards broadcasted signal to the destination, there are various relaying protocols such as Amplify and Forward (AF), Decode and Forward (DF), Compress and Forward (CF) and Coded Cooperation. In Coded Cooperation instead of repeating the code word each user tries to add some incremental redundancy for its partner. Coded Cooperation uses the same overall rate for coding and transmission; however the coded symbols are rearranged between the two users such that better diversity can attain [3].

II. CODED COOPERATIVE COMMUNICATION

Coded cooperative communication, one of the efficient co-operative technique in which cooperation is combined with channel coding. Limitations associated with repetition based methods can be overcome through the use of coded cooperation. In coded cooperation, instead of repeating the code word each user tries to add some incremental redundancy for its partner [3]. Coded cooperation framework is shown in figure 1 [1].

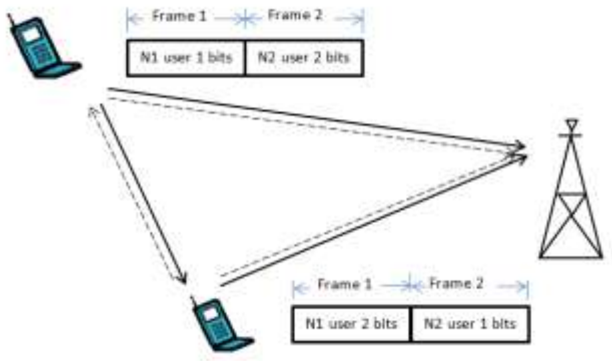

Figure 1: Coded Cooperative Communication

In coded cooperation, users split their code word into two. First part is transmitted by the user itself and the second part is transmitted by its cooperative partner. The user segments their source information into block and then added with cyclic redundancy check (CRC) codes. Each user has an N bit code word to send that is partitioned into N_1 bit N_2 bit code word. Data transmission period for each user is also divided into N_1 bit and N_2 bit interval, it is known as frame. In first frame, each user transmits N_1 bits code word of itself. Where N_1 bit code word is itself a valid code word. In this interval each user also tries to decode its partner's N_1 bits. If the decoding is successful, user calculate and transmits N_2 bit code word of its partner. If the decoding is failed, in second frame the user will transmits N_2 bits of itself. Thus each user always transmits an N bit per source block over two frames [3].

The level of cooperation α is defined as

$$\alpha = N_2 / N \quad (1)$$

α defines the percentage of the total bits per each source block that the user transmit for their partner [3].

Different channel coding methods can used with coded cooperation such as convolutional codes, block codes or combination of the two. Puncturing or product codes can be used to select the code word for the two frames.

The user act independently in the second frame with no knowledge of whether their first frame was correctly decoded or not [2]. As a result there is four cooperative cases has to be analyzed for the second frame transmission.

Case 1: Both partners correctly decode its partner's data. In the second frame both users transmit additional parity for their partner.

Case 2: In this case, neither user correctly decodes their partner's first frame. So each user will transmits additional parity bits of itself over the available channel .i.e., the system will automatically revert into non cooperative mode.

Case 3: User 2 correctly decodes User 1, but User 1 does not correctly decode User 2. In second frame, User 1 and User 2 both transmit additional parity bits for User 1. In this case there is no parity bits are transmitted for User 2.

Case 4: User 1 correctly decodes User 2, but Use 2 does not correctly decode User 1. In the second frame, both users transmit parity bits for User 2 while no parity bits are transmitted for User 1. This case is similar to Case 3, where the role of User 1 and User 2 was reversed.

A. *Outage probability of Coded Cooperation [3]*

With quasi static fading, the capacity conditioned on the channel realization, characterized by the instantaneous SNR is given by Shannon formula;

$$C(\gamma) = \log_2(1+\gamma) \text{ b/s/Hz} \tag{2}$$

If the capacity conditioned on the channel falls below a selected threshold rate R, then the channel is said to be in outage. Corresponding outage event is given by

$$C(\gamma) < R \tag{3}$$

The outage probability is given by

$$P_{out} = P_r(\gamma < 2^R - 1) = \int_0^{2^R-1} P_r(\gamma)\, d\gamma \tag{4}$$

For Rayleigh fading channel

$$P_{out} = \int_0^{2^R-1} \frac{1}{\Gamma}\exp\left(\frac{-\gamma}{\Gamma}\right) d\gamma \tag{5}$$

Where Γ denote the mean value of SNR. In coded cooperation, an overall information rate of R is allocated to each user. The user transmits over two frames. In the first frame each user transmits for a rate $R_1 = R/\alpha$ consisting of N_1 code symbols. For analyzing outage probability of coded cooperation, the four cooperative cases has to be considered. Over all outage probability for User 1 is given by;

$$\begin{aligned}
P_{out,1} = {} & P_r\left\{\gamma_{1,2} > 2^{R/\alpha} - 1\right\}.P_r\left\{\gamma_{2,1} > 2^{R/\alpha} - 1\right\} \\
& P_r\left\{(1+\gamma_{1,d})^{\alpha}(1+\gamma_{2,d})^{(1-\alpha)} < 2^R\right\} + \\
& P_r\left\{\gamma_{1,2} < 2^{R/\alpha} - 1\right\}.P_r\left\{\gamma_{2,1} < 2^{R/\alpha} - 1\right\} \\
& P_r\{\gamma_{1,d} < 2^R - 1\} + \\
& P_r\left\{\gamma_{1,2} > 2^{R/\alpha} - 1\right\}.P_r\left\{\gamma_{2,1} < 2^{R/\alpha} - 1\right\} \\
& P_r\left\{(1+\gamma_{1,d})^{\alpha}(1+\gamma_{1,d}+\gamma_{2,d})^{(1-\alpha)} < 2^R\right\} + \\
& P_r\left\{\gamma_{1,2} < 2^{R/\alpha} - 1\right\}.P_r\left\{\gamma_{2,1} > 2^{R/\alpha} - 1\right\} \\
& P_r\left\{\gamma_{1,d} < 2^{R/\alpha} - 1\right\}
\end{aligned} \tag{6}$$

$$\begin{aligned}
P_{out,1} = {} & \exp\left(\frac{1-2^{R/\alpha}}{\Gamma_{1,2}}\right).\exp\left(\frac{1-2^{R/\alpha}}{\Gamma_{2,1}}\right) \\
& \iint_A \phi(\gamma_{1,d},\gamma_{2,d},\Gamma_{1,d},\Gamma_{2,d})\, d\gamma_{1,d}\, d\gamma_{2,d} + \\
& \left[1-\exp\left(\frac{1-2^{R/\alpha}}{\Gamma_{1,2}}\right)\right]\left[1-\exp\left(\frac{1-2^{R/\alpha}}{\Gamma_{2,1}}\right)\right] \\
& \left[1-\exp\left(\frac{1-2^{R}}{\Gamma_{1,d}}\right)\right] + \\
& \exp\left(\frac{1-2^{R/\alpha}}{\Gamma_{1,2}}\right)\left[1-\exp\left(\frac{1-2^{R/\alpha}}{\Gamma_{2,1}}\right)\right] \\
& \iint_B \phi(\gamma_{1,d},\gamma_{2,d},\Gamma_{1,d},\Gamma_{2,d})\, d\gamma_{1,d}\, d\gamma_{2,d} + \\
& \left[1-\exp\left(\frac{1-2^{R/\alpha}}{\Gamma_{1,2}}\right)\right]\exp\left(\frac{1-2^{R/\alpha}}{\Gamma_{2,1}}\right) \\
& \left[1-\exp\left(\frac{1-2^{R}}{\Gamma_{1,d}}\right)\right]
\end{aligned} \tag{7}$$

$$A \equiv \left\{(\gamma_{1,d},\gamma_{2,d}) : (1+\gamma_{1,d})^{\alpha}(1+\gamma_{2,d})^{1-\alpha} < 2^R\right\}$$
$$B \equiv \left\{(\gamma_{1,d},\gamma_{2,d}) : (1+\gamma_{1,d})^{\alpha}(1+\gamma_{1,d}+\gamma_{2,d})^{1-\alpha} < 2^R\right\}$$
$$\phi(\gamma_{1,d},\gamma_{2,d},\Gamma_{1,d},\Gamma_{2,d}) = \frac{1}{\Gamma_{1,d}}\exp\left(\frac{-\gamma_{1,d}}{\Gamma_{1,d}}\right)\frac{1}{\Gamma_{2,d}}\exp\left(\frac{-\gamma_{2,d}}{\Gamma_{2,d}}\right)$$

We can simplify the result as

$$\begin{aligned}
P_{out,1} = {} & \exp\left(\frac{1-2^{R/\alpha}}{\Gamma_{2,1}}\right) \\
& \left[1-\exp\left(\frac{1-2^{R/\alpha}}{\Gamma_{1,d}}\right)-\exp\left(\frac{1-2^{R/\alpha}}{\Gamma_{1,2}}\right).\Psi_1(\Gamma_{1,d},\Gamma_{2,d},R,\alpha)\right] + \\
& \left[1-\exp\left(\frac{1-2^{R/\alpha}}{\Gamma_{2,1}}\right)\right]
\end{aligned} \tag{8}$$

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$$\left[1 - exp\left(\frac{1-2^{R/\propto}}{\Gamma_{1,d}}\right) - \exp\left(\frac{1-2^{R/\propto}}{\Gamma_{1,2}}\right).\Psi_2(\Gamma_{1,d},\Gamma_{2,d},R,\propto)\right]$$

Where

$$\Psi_1(\Gamma_{1,d},\Gamma_{2,d},R,\propto) = \int_0^{2^{R/\propto}-1} \frac{1}{\Gamma_{1,d}} \exp\left(-\frac{\gamma_{1,d}}{\Gamma_{1,d}} - \frac{a}{\Gamma_{2,d}}\right) d\gamma_{1,d}$$

$$\Psi_2(\Gamma_{1,d},\Gamma_{2,d},R,\propto) = \int_0^{2^{R}-1} \frac{1}{\Gamma_{1,d}} \exp\left(-\frac{\gamma_{1,d}}{\Gamma_{1,d}} - \frac{b}{\Gamma_{2,d}}\right) d\gamma_{1,d}$$

$$a = \frac{2^{R/(1-\propto)}}{(1+\gamma_{1,d})^{\propto/(1-\propto)}} - 1$$

$$b = \frac{2^{R/(1-\propto)}}{(1+\gamma_{1,d})^{\propto/(1-\propto)}} - 1 - \gamma_{1,d}$$

In the case of $(\gamma_{1,2} = \gamma_{2,1})$ ie., reciprocal inter user channel, the equation can be further simplified to

$$P_{out,1} = P_r\{\gamma_{1,2} > 2^{R/\propto} - 1\} P_r\left\{(1+\gamma_{1,d})^{\propto}(1+\gamma_{2,d})^{1-\propto} < 2^R\right\} + P_r\{\gamma_{1,2} < 2^{R/\propto} - 1\} P_r\{\gamma_{1,d} < 2^R - 1\} \quad (9)$$

$$P_{out,1} = \exp\left(\frac{1-2^{R/\propto}}{\Gamma_{1,2}}\right) \left[1 - \exp\left(\frac{1-2^{R/\propto}}{\Gamma_{1,2}}\right) - \Psi_1(\Gamma_{1,d},\Gamma_{2,d}R,\propto)\right] + \left[1 - \exp\left(\frac{1-2^{R/\propto}}{\Gamma_{1,2}}\right)\right]\left[1 - \exp\left(\frac{1-2^{R}}{\Gamma_{1,d}}\right)\right] \quad (10)$$

Where $\Psi_1(\Gamma_{1,d},\Gamma_{2,d}R,\propto)$ is same.

In coded cooperation outage probability is a function of the mean channel SNR values $\{\Gamma_{1,2},\Gamma_{2,1},\Gamma_{1,d},\Gamma_{2,d}\}$, allocated rate and the level of cooperation α. Out of these α is a free parameter that can be optimized to optimize the performance.

III. SIMULATION RESULTS

In this chapter simulation and numerical results for the performance and optimization of coded cooperative communication are presented. Simulations are performed by using MATLAB R2013a.

Coded cooperative communication is one of the cooperative system where cooperation is combined with channel coding. It gain the inherent benefits of spatial diversity and added advantages of channel coding. Coded cooperation can achieve significant performance gain for variety of channel conditions, and it allow different code rates and partitions. Coded cooperation provide a great degree of flexibility to adapt to channel conditions.

Coded cooperation shows a better performance than repetition based methods, in which relay node repeat the source transmission. In coded cooperation codeword of each user is partitioned into two set, one partition is transmitted by the user and the other by the partner.i.e, instead of repeating the codeword each user tries to add some incremental redundancy for its partner. Whenever that is not possible the user automatically revert back into non cooperative mode.

In this work outage probability analysis of coded cooperation is done. Outage probability is a measure of robustness of transmission to fading. From the analysis it is clear that outage probability of coded cooperation depends upon three parameters such as, SNR (γ),Rate(R),and level of cooperation α. In which SNR and Rate are constrained parameters, i.e. they are constrained by the channel conditions. Level of cooperation α is a free parameter, that can be optimized to optimize the outage probability of coded cooperation.

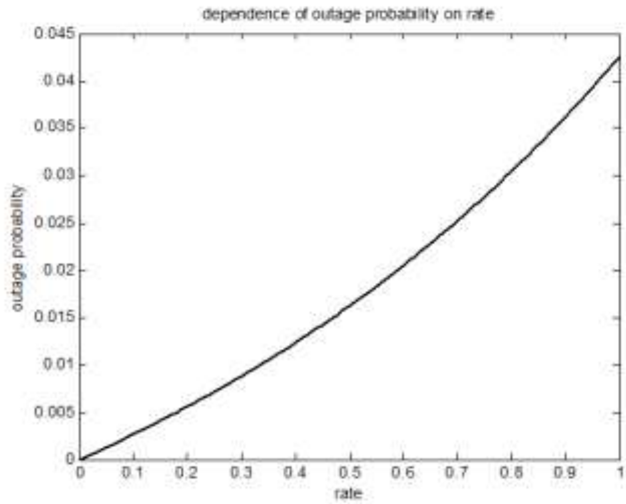

Figure 6.1 shows a graph between outage probability vs rate. In this analysis it is assumed that all channels have equal SNR.From the graph it is clear that outage probability increases exponentially with increase in rate. At the higher rate there is a high probability for the system in outage. So only low rate values (R < 1b=s=Hz) are considered for the analysis. Rate can be considered as a con- strained parameter due to the channel conditions. At higher rate outage probability will be high, it will degrade the coded cooperation performance.

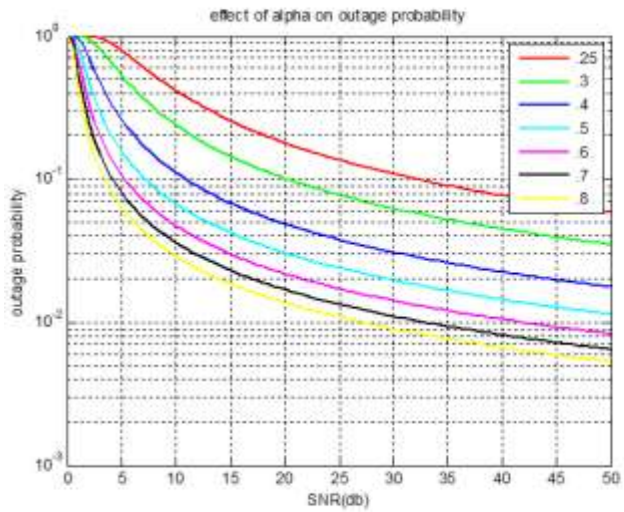

Figure 6.2 illustrate outage probability analysis for various values of level of cooperation α. plot is between Outage probability and SNR for various values of α .From the graph we can infer that outage probability decreases with increase in α. α = 0.25, .3, .4, .5, .6; .7, .8 are considered. For higher values of α lower will be the outage probability.

IV. CONCLUSION

Cooperation between wireless users has been proposed as a mechanism by which the users can achieve spatial diversity in applications where the users can only support a single transmit antenna. Recently, a new framework, called coded cooperation was proposed, where cooperation is integrated with channel coding. In this framework, a user transmits addition parity symbols for its partner according to some overall coding scheme, instead of repeating the symbols initially transmitted by the partner. Bit and block-error rate analysis has been performed for coded cooperation, and examples with specific coding schemes show significant improvement over non cooperative transmission.

To understand coded cooperation in a more general context that is independent of any particular coding scheme, we examine the outage probability of coded cooperation. From the outage probability analysis of coded cooperation it is clear that outage probability depend upon three parameters. The SNR γ, Rate R and Level of Cooperation α. Out of these SNR and Rate are constrained parameters, and α is a free parameters.

References

[1] Nosratinia, Aria, Todd E. Hunter, and Ahmadreza Hedayat. "Cooperative communication in wireless networks." *IEEE communications Magazine* 42.10 (2004): 74-80.

[2] Hunter, Todd E., and Aria Nosratinia. "Performance analysis of coded cooperation diversity." *Communications, 2003. ICC'03. IEEE International Conference on*. Vol. 4. IEEE, 2003.

[3] Hunter, Todd E., Shahab Sanayei, and Aria Nosratinia. "Outage analysis of coded cooperation." *IEEE Transactions on Information Theory* 52.2 (2006): 375-391.

[4] Janani, Mohammad, et al. "Coded cooperation in wireless communications: space-time transmission and iterative decoding." *IEEE Transactions on Signal Processing* 52.2 (2004): 362-371.

[5] Laneman, J. Nicholas, David NC Tse, and Gregory W. Wornell. "Cooperative diversity in wireless networks: Efficient protocols and outage behavior." *IEEE Transactions on Information theory* 50.12 (2004): 3062-3080.

[6] Hunter, Todd E., and Aria Nosratinia. "Distributed protocols for user cooperation in multi-user wireless networks." *Global Telecommunications Conference, 2004. GLOBECOM'04. IEEE*. Vol. 6. IEEE, 2004.

[7] Hunter, Todd E., and Aria Nosratinia. "Diversity through coded cooperation." *IEEE transactions on wireless communications* 5.2 (2006): 283-289.

[8] Bansal, Ankur, and Parul Garg. "An analytical approach to outage analysis and critical cooperation ratio in coded cooperation." *Wireless personal communications* 69.2 (2013): 721-733.

[9] Fitzek, Frank HP, and Marcos D. Katz. *Cooperation in wireless networks: principles and applications*. New York: Springer, 2006.