Cooperative Diversity Technique in Mobile Communication

[1]Dr. S.S. Sreeja Mole, [2]S.Sandhya, [3]B. Ganapathy Ram

Professor & Head,Department of Electronics and Communication Engineering, Narayanaguru College of Engineering, Kanyakumari, Tamil Nadu, India.

Assistant Professor, Department of Electronics and Communication Engineering, Narayanaguru College of Engineering, Kanyakumari, Tamil Nad, India.

Assistant Professor Department of Electronics and Communication Engineering, Regional Centre, Anna University, Tirunelveli, TamilNadu, India.

Abstract

To effectively combat multipath fading across multiple protocol layers in mobile networks during transmission of multimedia components we develop an energy efficient transmission protocol called cooperative diversity which involves cooperation among terminals and which is created by antenna sharing and coordinated transmission by several distributed radios. A Cooperative diversity network with a sender, a destination and a third station acting as a relay is analyzed. The channels are modeled containing thermal noise, Rayleigh fading and path loss. After summarizing a model for the wireless channel we enhance the basic arrangement to a system with relay and receiver stations and we present various practical algorithms based on the relaying process that are Amplify and Forward and Decode and Forward. To combine the incoming signals the channel quality should be estimated as well as possible. Information about the average quality shows nice benefits and a rough approximation about the channel quality increases the performance even more. The combining techniques used here are Signal to Noise Ratio Combining and Enhanced Signal to Noise Ratio Combining. The Outage probability of the cooperative communication has been analyzed and compared in this paper.

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I. INTRODUCTION

Cooperative communication is one of the fastest growing areas of research, and it is likely to be a key enabling technology for efficient spectrum use in future. The key idea in cooperation is that of resource-sharing among multiple nodes in a network. The reason behind the exploration of user-cooperation is that willingness to share power and computation with neighboring nodes can lead to savings of overall network resources. Mesh networks provide an enormous application space for user-cooperation strategies to be implemented. Cooperative techniques can be applied within and across any communication layer. Many well known concepts and techniques in wireless communication can be described by using cooperative principles. In 3G wireless transmission the quality of multimedia signal suffers severe degradations due to effects like signal fading caused by multipath propagation. To reduce such effects, diversity is proposed that can be used to transfer the different samples of the same signal over essentially independent channels.

Diversity is a powerful technique transmitting the redundant signals over essentially independent channel realizations in conjunction with suitable receiver combining to average channel effects.

A. Spatial Diversity

Spatial diversity combats multipath fading by transmitting copies of original signals through uncorrelated paths to the receiver. Signals are combined at the receiver end and the individual channel effects are averaged in spatial diversity.

Antenna arrays are the most common way to achieve spatial diversity. But multiple antennas are not always available or the destination is just too far away to get good signal quality. So the cooperative diversity technique is necessary to overcome this problem

Spatial diversity employs multiple antennas, usually with the same characteristics, that are physically separated from one another. Depending upon the expected incidence of the incoming signal, sometimes a space on the order of a wavelength is sufficient. Other times much larger distances are needed. Cellularization or sectorization is a spatial diversity scheme that can have antennas or base stations miles apart. This is especially beneficial for the mobile communications industry since it allows multiple users to share a limited communication spectrum and avoid co-channel interference.

B. Cooperative Diversity

An energy efficient class of cross layer network algorithm called co-operative diversity that exploit the broad cast nature of the wireless medium and spatial diversity of the channel. Co-operative diversity is a fruitful technique which relies on the co-operation on multiple spatially distributed nodes, provides a useful alternative for fading mitigation.

Owing to the broadcast casting nature of the wireless medium transmission from the source node may be heard by the node in neighborhood. These neighborhood nodes may act as wireless relays and provide alternative communication routes that give raise to co-operative networks.

Cooperative diversity is a cooperative multiple antenna techniques which exploits user diversity by decoding the combined signal of the relayed signal and the direct signal in wireless multihop networks. A conventional single hop system uses direct transmission where a receiver decodes the information only based on the direct signal while regarding the relayed signal as interference, whereas the cooperative diversity considers the other signal as contribution. That is, cooperative diversity decodes the information from the combination of two signals.

Hence, it can be seen that cooperative diversity is an antenna diversity that uses distributed antennas belonging to each node in a wireless network. Note that user cooperation is another definition of cooperative diversity. User cooperation considers an additional fact that each user relays the other user's signal while cooperative diversity can be also achieved by multi-hop relay networking systems.

II. DIRECT TRANSMISSION MODEL

Today the 3G mobile communication is accomplished between the base station (source) and the mobile station (destination) via a direct line of sight path. The signals from other paths due to reflection, diffraction and scattering are regarded as interference and this causes fading. The data which is transferred from a sender to a receiver has to propagate through the wireless channel (i.e. air medium). The channel is assumed to have path loss and Rayleigh fading which are multiplicative components and Additive White Gaussian Noise (AWGN) which is additive.

The system model for a direct link transmission is given in figure 1.

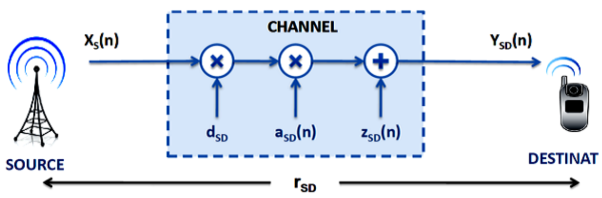

Figure 1: Block Diagram of Direct Transmission Model

In Figure 1, the term r_{SD} is the distance between source and destination, the term $X_S(n)$ is the signal transmitted by the source and the term $Y_{SD}(n)$ denotes the signal received by the destination. The transmitted multimedia signal $X_S(n)$ is attenuated by the path loss $d_{SD}(n)$ and is weaken by multipath Rayleigh fading $f_{SD}(n)$ and is corrupted by Additive white Gaussian noise $Z_{SD}(n)$.

Hence the destination mobile terminal receives the noisy version of the signal $Y_{SD}(n)$ which can be explicitly represented by

$$Y_{SD}(n) = d_{SD} f_{SD}(n) X_S(n) + Z_{SD}(n) \quad (1)$$

Path loss, the reduction in power density of a signal is inversely proportional to the square of the distance between the source (S) and the destination (D). It is given by

$$d_{SD} = \frac{1}{r_{SD}^2} \quad (2)$$

Radio waves propagate from a transmitting antenna, and travel through free space undergoes absorption, reflection, refraction, diffraction, and scattering. Due to this the transmitted signal arrives at the receiver via several paths. Therefore, a receiver at one location may have a signal that is much different from the signal at another location, only a short distance away, because of the change in the phase relationship among the incoming radio waves. This causes significant fluctuations in the signal amplitude. This phenomenon of random fluctuations in the received signal level is termed as fading. The fading coefficient $f_{SD}(n)$ in this paper is modeled as a Rayleigh distributed random variable. Rayleigh fading coefficients can be given by

$$f_{SD}(n) = \frac{n}{\sigma_{SD}^2} \exp\left\{-\frac{n^2}{2\sigma_{SD}^2}\right\} \quad (3)$$

In equation (3) the term σ_{SD}^2 is the variance of the Rayleigh distributed fading. The signal is attenuated mainly by the effects of free space path loss and fading. Therefore the attenuation coefficients $h_{SD}(n)$ is given by

$$h_{SD}(n) = d_{SD} f_{SD}(n) \quad (4)$$

The substitution of equations (2) and (3) in (4) yields the attenuation coefficients $h_{SD}(n)$ as follows

$$h_{SD}(n) = \frac{n}{(r_{SD}\sigma_{SD})^2} \exp\left\{-\frac{n^2}{2\sigma_{SD}^2}\right\} \quad (5)$$

The main sources of noise in a wireless network are interference and electronic components like amplifiers. If the latter dominates, thermal noise can be assumed, which can be characterized as additive complex Gaussian noise. The scalar $z_{S,D}(n)$ can then be simulated as the sum of a real and a imaginary noise vector, both Gaussian distributed, mutually independent and zero mean with variance σ_n^2. The total noise power can be denoted by $N_0 = 2\sigma_n^2$.

III. COOPERATIVE COMMUNICATION MODEL

To achieve cooperative diversity, an interesting approach might be to build a network using another mobile station as a relay. The model of such a system is illustrated in Figure 3 which consists of two hops. The sender S (base station), sends the data to the destination D (mobile terminal), while the relay station R is listening to this transmission. Then the relay forwards the received data burst after processing to the destination, where the two received signals are combined. As proposed in [2], orthogonal channels are used for the two transmissions. Without loss of generality, this can be achieved using time divided channels, which is done in all the simulations in this project work.

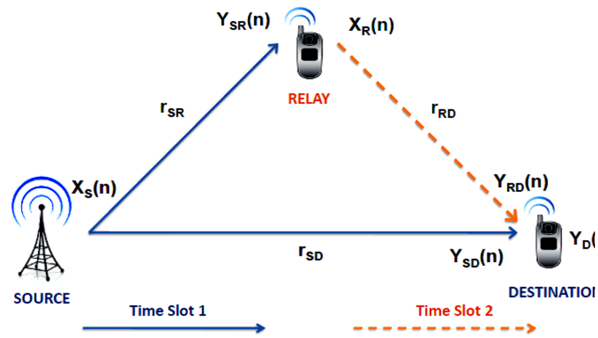

Figure 2: Cooperative Diversity – Block Diagram

In Figure 2 r_{SD} is the distance between source and destination, r_{SR} is the distance between source and relay, r_{RD} is the distance between relay and destination, $Y_{SD}(n)$ is the signal received by the relay from the source, $X_R(n)$ is the signal transmitted by relay and $Y_{R,D}(n)$ is the signal received by the destination from the relay

At time slot 1 the source sends its message to both the relay and destination that is the source broadcasts its message. Let $X_S(n)$ be the signal broadcasted by the base station (source) to both the relay mobile station and the destination mobile station. Signal received by the relay due to the transmission of the source is given by

$$Y_{SR}(n) = h_{SR}(n)X_S(n) + Z_{SR}(n) \quad (6)$$

In equation (6) the term $Z_{SR}(n)$ represents the AWGN present in the channel between source and relay. The attenuation $h_{SR}(n)$ is the product of path loss and fading coefficient of the channel between the source and relay, that is

$$h_{SR}(n) = d_{SR}\, a_{SR}(n) \quad (7)$$

Signal received by the destination due to the transmission of the source during the same time slot is given by

$$Y_{SD}(n) = h_{SD}(n)X_S(n) + Z_{SD}(n) \quad (8)$$

At time slot 2 the relay forwards the message to the destination with the help of the relaying protocols such as Amplify and Forward (AAF) and Decode and Forward (DAF). During the second time slot the signal received by the destination due to the transmission of the relay is given by

$$Y_{RD}(n) = h_{RD}(n)X_R(n) + Z_{RD}(n) \quad (9)$$

A. *Relaying Protocol*

Cooperative relaying allows single-antenna terminals to gain some benefits of transmit diversity without the need for physical antenna arrays. Cooperative relaying (with one relay) includes two phases where the first one is for the transmission of the source and the second for the relaying of the relay, thus significantly reducing spectral efficiency. The cooperative transmission protocols used in the relay station are Amplify and forward (AAF) and Decode and Forward (DAF) [1, 2].

1) *Amplify and Forward (AAF) Relaying*

The idea behind the AAF protocol is simple. The signal received by the relay was attenuated and needs to be amplified before it can be sent again. This method is often used when the relay has only limited computing time or power available or the time delay, caused by the relay to decode and encode the message, has to be minimized. In doing so the noise in the signal is amplified as well, this is the main downfall of this protocol.

The received signal power at the relay due to the transmission of the source can be calculated as follows

$$P_R = E[|Y_R|^2] = E[|h_{SR}|^2]E[|X_S|^2] + E[|Z_{SR}|^2] \quad (10)$$

$$P_R = |h_{SR}|^2 P_S + 2\sigma_{SR}^2 \quad (11)$$

The Power Gain of the relay node is given by

$$\text{Power Gain} = \sqrt{\frac{\text{Power transmitted}}{\text{Power received}}} \quad (12)$$

$$\beta = \sqrt{\frac{P_S}{P_R}}$$

$$= \sqrt{\frac{P_S}{|h_{SR}|^2 P_S + 2\sigma_{SR}^2}} \quad (13)$$

Hence the signal forwarded by the relay using AAF is given by

$$X_R(n) = \beta Y_{SR}(n)$$

$$X_R(n) = \beta[h_{SR}(n)X_S(n) + Z_{SR}(n)] \quad (14)$$

2) *Decode and Forward (DAF) Relaying*

Decode and Forward technique is most often the preferred method to process the data in the relay. The received signal is first decoded and then encoded. But it is not always possible to fully decode the source message. The additional delay occurs due to the decoding process. The signal forwarded by the relay using DAF protocol can be written as

$$X_R(n) = \hat{X}_S(n-k) \quad (15)$$

In equation (15) $\hat{X}_S(n-k)$ is the estimate of the transmitted source signal and the term k is the delay due to decoding process

B. *Combining Technique at Destination Mobile Station*

As soon as there is more than one incoming transmission with the same burst of data, the incoming signals have to be combined. The signals are combined only with the current information of the signal and channel. The two combining methods used are Signal to Noise ratio and Enhanced Signal to noise ratio [1, 4, and 6].

1) *Signal to Noise Ratio Combining (SNRC):*

An even better performance can be achieved when precise information about the current state of the different channels is known. An often used value to characterize the quality of a link is the SNR, which is used to weight the received signals.

The estimation of the SNR of a multi-hop link using AAF or a direct link can be performed by sending a known symbol sequence in every block. This sequence is used to estimate the phase shift as well. If the multi-hop link is using a DAF protocol the receiver can only see the channel quality of the last hop. It is assumed that the relay sends some additional information about the quality of the unseen hops to the destination, so the SNR of the multi-hop link can be estimated. The channel quality for every single block is sufficient in contrast to the SNRC, which needs exact information of the channel quality for every single block, this is a surprising result. It means that the transferred signal in an AAF system contains some information that allows correcting a small difference in the channel quality.

The performance of the combining methods, which have precise information about every single block, is just about one decibel better in SNR which has just average knowledge of the channel quality. Hence using the AAF protocol, there is no point in wasting a lot of computing power and bandwidth to get exact channel information.

General equation of SNR combining method

$$Y_D(n) = \sum_{i=1}^{k} SNR_i \, Y_{iD}(n) \quad (16)$$

Equation representing the SNR combining method for using one relay

$$Y_D(n) = SNR_{SD}\, Y_{SD}(n) + SNR_{RD}\, Y_{RD}(n) \quad (17)$$

Using AAF method the signal received by the destination from the relay is given by

$$Y_{RD}(n) = h_{RD}(n) X_R(n) + Z_{RD}(n)$$

$$Y_{RD}(n) = h_{RD}(n)\beta[h_{SR}(n) X_S(n) + Z_{SR}(n)] + Z_{RD}(n) \quad (18)$$

The received signal power is given by

$$E[|Y_{RD}|^2] = \beta^2 |h_{RD}|^2 (|h_{SR}|^2 \varepsilon + 2\sigma_{SR}^2) + 2\sigma_{RD}^2 \quad (19)$$

The signal to noise ratio is given by

$$SNR = \frac{\beta^2 |h_{R,D}|^2 |h_{s,R}|^2 \varepsilon}{\beta^2 |h_{R,D}|^2 2\sigma_{S,R}^2 + 2\sigma_{R,D}^2} \quad (20)$$

To calculate the SNR of a multi-hop link using DAF, the BER of the link is calculated which can then be translated to an equivalent SNR. The BER over a one relay multi-hop link can then be calculated as

$$BER = BER_{SR}(1 - BER_{RD}) + (1 - BER_{SR}) BER_{RD} \quad (21)$$

For a BPSK modulated and Rayleigh faded signal SNR will be

$$SNR = \frac{1}{2}[Q^{-1}(BER)]^2 \quad (22)$$

Where $Q^{-1}(.)$ is the inverse error function.

2) *Enhanced Signal to Noise Ratio Combining (ESNRC):*

Another plausible combining method is to ignore an incoming signal when the data from the other incoming channels have a much better quality. If the channels have more or less the same channel quality the incoming signals are rationed equally. The received signal using ESNRC method can be expressed as

$$Y_D(n) = \begin{cases} Y_{SD}(n) & , \quad \frac{SNR_{SD}}{SNR_{RD}} > 10 \\ Y_{SD}(n) + Y_{RD}(n), & 0.1 \le \frac{SNR_{SD}}{SNR_{RD}} \le 10 \\ Y_{SRD}(n) & , \quad \frac{SNR_{SD}}{SNR_{RD}} < 0.1 \end{cases} \quad (23)$$

Using this combining method, the receiver does not have to know the channel characteristic exactly. An approximation of the channel quality is enough to combine the signals.

IV. OUTAGE BEHAVIOUR ANALYSIS

A telecommunications system service condition in which a user is completely deprived of service by the system is called outage. Outage probability is the probability that an outage will occur within a specified time period. In a fading radio channel, it is likely that a transmitted signal will suffer deep fades that can lead a complete loss of the signal or outage of the signal. The outage probability is a measure of the quality of the transmission in a mobile radio channel. Outage is said to occur when the received signal power goes below a certain threshold level [3, 4]. It can be calculated as the integral of the received signal power p(t) as

$$P_{out} = \int_0^{P_{th}} p(t)dt \quad (24)$$

The procedure to find the outage probability is as follows:

1. Calculate the received signal power.
2. Set a threshold power level for the received signal relative to the average signal power.
3. Count the number of times in the sample interval that the received signal power goes below this threshold.
4. Using the basic concept of probability, the outage is then calculated by taking the ratio of the count in step 3 to the total number of samples.

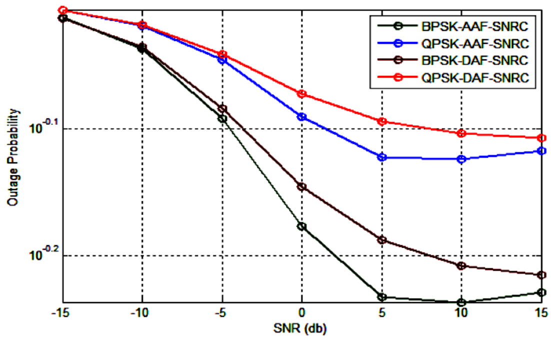

Figure (3) Outage Probability Curve for SNRC combining

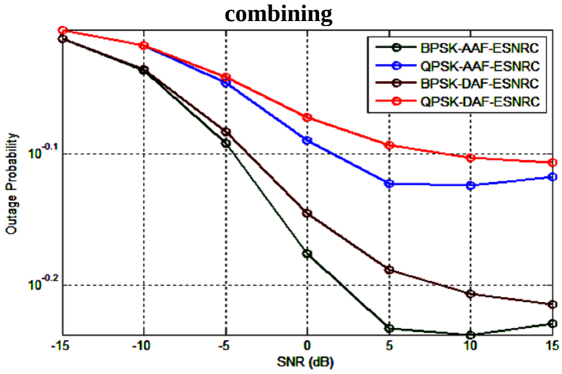

Figure (4) Outage Probability Curve for ESNRC combining

Figures (3) and (4) depict the outage probability curves for the SNRC and ESNRC methods respectively. From these figures it is revealed that AAF has better outage probability.

V. CONCLUSION

This thesis has shown the possible benefits of a wireless transmission using cooperative diversity to increase the performance. The data is sent directly from the base to the mobile or via the relay station. Such a system has been simulated to see the performance of various relaying protocols and various combining methods. The outage probability and capacity of the direct link and cooperative communication is found with respect to SNR when transmitting an image through a cooperative channel having Rayleigh fading and Gaussian noise. AAF relaying protocol has better outage probability over DAF relaying protocol for both SNRC and ESNRC combining techniques as it amplifies signal power.

REFERENCES

[1] Ahsan Haroon, (2011), ‘Wireless Imaging Using Cooperative Diversity of Relay Networks’, Project at Blekinage Institute of Technology, Sweden.

[2] Alamouti. S, (1998), ‘A Simple transmit Diversity Technique for Wireless communications’, IEEE Journal on Selected areas in Communications, Vol. 16, No.8, pp. 1451-1458.

[3] Aria Nosratinia, Todd E. Hunter, and Ahmadreza Hedayat, (2004), ‘Cooperative Communication in Wireless Networks’, IEEE Communication Magazine.

[4] Behrouz Maham and Are Hjorungnes, (2009), ‘Asymptotic Performance Analysis of Amplify and Forward Cooperative Networks in a Nakagami-m Fading Environment’, IEEE Communication Letters, Vol.13, No.5, PP. 300-302.

[5] Frank H.P. Fitzek and Markoz D. Katz, (2006), ‘Cooperation in Wireless Networks: Principles and Applications, Real Egoistic Behavior is to cooperate’, Springer.

[6] Herhold. P, E. Zimmermann and G. Fettweis, (2004), ‘On the Performance of Cooperative Amplify-and-Forward Relay Networks’, 5th International ITG Conference on Source and Channel Coding (SCC), Erlangen, Germany.

[7] John G. Proakis, (2001), ‘Digital Communications’, McGraw-Hill, 4th edition.

[8] Laneman J. N., Tse D. N. C., and Wornell G. W., (2004) ‘Cooperative Diversity in Wireless Networks: Efficient Protocols and Outage Behavior’, IEEE Transaction on Information Theory, vol. 50, no. 12, pp. 3062-3080.

[9] Sallama Ikki and Mohammed H. Ahmed, (2008), ‘Performance Analysis of Incremental Relaying Cooperative Diversity Networks over Rayleigh Fading Channels’, IEEE Communication Society WCNC Proceedings, pp. 1311-1315.

[10] Sallama Ikki and Mohammed H. Ahmed, (2009), ‘Performance Analysis of Decode-and-Forward Incremental Relaying Cooperative-Diversity Networks over Rayleigh Fading Channels’, IEEE Vehicular Society Conference Proceedings, VTC Spring.

[11] Sangkook Lee, Weifeng Su and Stella Batalama, (2010) ‘Cooperative Decode-and-Forward ARQ Relaying: Performance Analysis and Power Optimization’, IEEE Transactions on Wireless Communications, vol. 9, No. 8, pp. 2632-2642.

[12] Sendonaris. A, E. Erkip, and B. Aazhang, (2003), ‘User Cooperation Diversity Part I and Part II’, IEEE Trans. Commun.., vol. 51, no. 11, pp. 1927–48.

[13] Simon Haykin (2005), ‘Communication Systems’, Jhon Wiley & sons.

[14] Thanongsak Himsoon, W. Pam Siriwongpairat and K. J. Ray Liu, (2008) ‘Differential Modulations for Multinode Cooperative Communications’, IEEE Transactions on Signal Processing”, vol. 56, No. 7, pp. 3062-3080.

[15] Vicky Zhao. H and Weifeng Su, (2010), ‘Cooperative Wireless Multicast: Performance Analysis and Power/Location Optimization’, IEEE Transactions on Wireless Communication, vol. 9, No. 6, pp. 2088-2100.