IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 7, February 2017)

An Efficient Diversity Achievement by Opportunistic Relaying in Amplify and Decode and Forward Using ZF and MMSE Equalizers

Manish Sahajwani
msahajwanister@gmail.com

Dr. Alok Jain
alokjain6@rediffmail.com

Dr. R. S. Gamad
rsgamad@gmail.com

Abstract: **High data rates and large coverage area are key requirements of today's wireless communication systems. Diversity is considered to manage the probability that the transmitted signal, which travel through various independent paths is in fade, is made negligible. These facilities are provided by MIMO systems. However, implementing multiple antennas at handheld devices is not practical due to size, power, cost, and weight constraints. Virtual MIMO concept known as Cooperative Diversity was introduced. Frequency diversity, time diversity and space diversity are the basic techniques providing diversity to the communication systems. Virtual MIMO antenna systems have been considered as an efficient approach to address these demands by offering significant multiplexing and diversity gains over single antenna. In this paper we compare the relaying strategies of cooperative communication viz. Amplify and forward (AaF) and Decode and forward (DaF) under minimum mean square error (MMSE) and Zero-Forcing Equalizer (ZF) using Maximal Ratio Combining (MRC).We analyze the Symbol Error Rate (SER) performance of AaF and DaF using single relay selection. We show that DaF outperforms AaF with constant amplification gain.**

Keywords – **AaF, DaF, MIMO, MMSE, MRC, SER, SNR, ZF.**

I. Introduction

Wireless ad hoc communication is characterized by a network with distributed nodes which forms a temporary functional network and support seamless leaving or joining of nodes without any centralized controller or pre-established infrastructure. Application of such networks have been realized in military communication and have lot of potential for civilian applications, to include commercial and educational use, disaster management, road vehicle network etc. [1]. They are known by their low cost, rapid deployment and self-organization capability. With the rapid growth of multimedia services, future generations of wireless communications require higher data rates and a more reliable transmission link. In this respect, multiple input multiple-output (MIMO) antenna systems have been considered as an efficient approach to address these demands by offering significant multiplexing and diversity gains over single antenna systems without increasing requirements on radio resources such as bandwidth and power. The expected coverage and throughput benefits of a cooperative relaying approach with respect to conventional networks are sufficiently large to attract industrial interest.

The simplest cooperative relaying network consists of three nodes, namely source, destination, and a third node supporting the direct communication between source and destination denoted as relay. If the direct transmission of a message from source to destination is not (fully) successful, the overheard information from the source is forwarded by the relay to reach the destination via a different path. Since the two communications took a different path and take place one after another, this example implements the concept of space diversity and time diversity [2]. Diversity is a communication technique where the transmitted signal is managed to travel through various independent paths and as a result the probability that all the wireless paths are in fade is made negligible.

The basic relaying schemes, such as Amplify and Forward (AaF) or Decode and Forward (DaF), rely on the retransmission, performed by the relay, of the packets received from the source node [3-6]. In the former case, the received signal (including interference and noise) is simply amplified before retransmission, while in the latter the packet is first decoded, and the obtained symbols are then re-encoded and transmitted. Clearly, DaF requires additional complexity, but is also able to grant a higher benefit, since interference and noise amplification is avoided.

The aim of this paper is to compare relaying schemes of cooperative communications and relay technology & analyze the Symbol Error Rate (SER) performance of different cooperative communication protocols using MATLAB.

II. Role of Relay and its Selection

In Cooperative communication scenario, relay selection scheme determines how relays are assigned, in other words, how it is determined which users cooperate with each other, and how often relays are assigned. Generally relay selection mechanisms can be categorized into two main categories based on how the algorithms are implemented, centralized and distributed mechanisms. Systems such as cellular networks in which users communicate with a central base station offer the possibility of centralized relay selection. It means that a central base station collects and utilizes the required information to select one or more relays to each source-destination pair. In contrast, systems such as ad hoc networks which do not have centralized control require distributed protocol. In this category, each node individually determines whether to cooperate and who to cooperate with according to the information exchange between nodes. Here we have proposed an opportunistic AF and DF protocol which selects the "best" relay between the source and destination. This protocol has the following features.

—The protocol is distributed and each relay only makes local channel measurements.

—Relay selection is based on instantaneous channel conditions in slow fading wireless environments. No prior knowledge of topology or estimation of it is required.

—The amount of overhead involved in selecting the best relay is minimal. It is shown that there is a flexible tradeoff between the time incurred in the protocol and the resulting error probability [11].

III. System Model

Cooperative communication's concept can be applied to wireless LAN, Ad-hoc or sensor networks or any wireless system. The cellular scenario with two wireless users and a single base station is presented in Fig.1. Both the users are considered to have independent information represented as w_i, where i = 1, 2. For transmission of the message to the destination is assumed to take place in two phases. First phase is termed as broadcast phase, as in this phase, the users broadcast their information to the destination. While, in the second phase, the users access the destination simultaneously, hence the second phase is called as multiple-access phase of the transmission.

The transmitting users are considered to be in the close proximity of each other and both of the users along with the destination, receive these messages transmitted via each other. In the next phase, both of the cooperating users, decode the message received from each other and forward some refinement information, on behalf of each other, to the destination. In this way, it is expected that the information from both of the users has been received twice and with two statistically independent paths. First path is due to direct transmission of user's and second path is for partner. Both have same information and is based on signal received at the destination. As a result, the decision made on the received message will be more reliable as it would have been with one time reception of the signal.

A. *Amplify and Forward:*

In this method every single user receives a noisy form of the signal transmitted by its partner. As the name implies, the user then can amplify and retransmits this noisy form. The base station combines the information sent by the user and partner, and makes a terminating decision on the transmitted bit as shown in Fig.2. Although noise is amplified by cooperation, the base station receives two independently faded versions of the signal and can make better decisions on the detection of information.

In the first phase, the source broadcasts data to the destination and also to relay. In the second phase, the relay after receiving data amplifies the received data and retransmits it to the destination. The relay receives the information signal appended by the channel gain and noise. The amplified signal is sent to the destination. Now, the receiver can decode the combined signal using Maximal Ratio Combining (MRC) [7-8].

In the first phase, the source broadcasts its information with transmission power P to destination and relays

$$Y_{sr} = \sqrt{P}\, \mathrm{h_{sr}}\, x + n_{sr} \qquad (1)$$

$$Y_{sd} = \sqrt{P}\, \mathrm{h_{sd}}\, x + n_{sd} \qquad (2)$$

Then, all the relays will forward the scaled versions of the received signal to D in the matched phases. Thus, at the destination terminal, the received signals from the relay R can be written as:

$$Y_{rd} = \beta_k\, \mathrm{h_{rd}} Y_{sr} + n_{rd} \qquad (3)$$

Where, $\beta_k = \sqrt{}[P_k/P|h_{sr}|^2 + N_0]$ and P_k is the transmit power of any relay. The source-to-relay and the relay to destination paths are separately estimated [8].

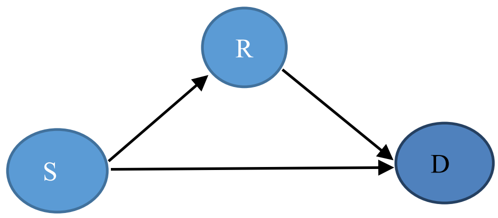

Fig.1 Amplify and Forward

B. *Decode and Forward*

This method is perhaps closest to the idea of a traditional relay. In this method a user needs to detect the partner's bits and then retransmits the detected bits as given in Fig.3. The partners may be assigned mutually by the base station, or via some other technique. Consider two users partnering with each other, but in practical the only important factor is that each user has a partner that provides a second (diversity) data path. The easiest method to visualize this is via pairs, but it is possible to achieve the same effect via other partnership topologies that remove the strict constraint of pairing.

The decoded signal at the relay may be incorrect. If an incorrect signal is forwarded to the destination, the decoding at the destination is meaningless. The received signal at the destination in Phase 2 can be modeled as with knowledge of the channel coefficients (between the source and the destination) and (between the relay and the destination), the destination decodes the transmitted symbols and the signals are received as from the source and from the relay. As shown in Fig.2 the decoding of signal occurs at R2. Here, the signal is decoded and checked for error if error=1 then the signal is transmitted by R3 to destination and if error=0 then the signal is re-encoded and transmitted through R1 to destination. The received signal at the destination in Phase 2 can be modelled as

$$Y_{sd} = \sqrt{P_2}\, \mathrm{h_{s,d}}\, x + n_{s,d} \qquad (4)$$

$$Y_{rd} = \sqrt{P_2}\, \mathrm{h_{r,d}}\, x + n_{r,d} \qquad (5)$$

With knowledge of the channel coefficients $\mathrm{h_{s,d}}$ (between the source and the destination) and $\mathrm{h_{r,d}}$ (between the relay and the destination), the destination decodes the transmitted symbols and the signals are received as Y_{sd} from the Y_{rd} source and from the relay.

IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 7, February 2017)

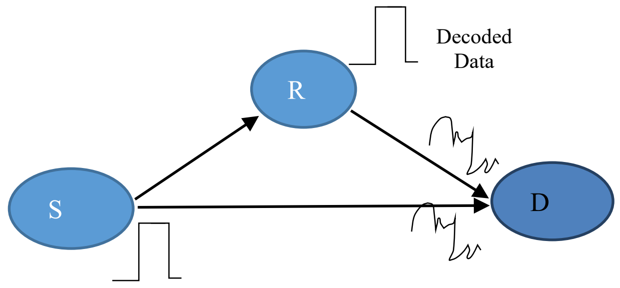

Fig.2. Detect and Forward

C. EQUALIZERS

The purpose of equalizers is to reduce intersymbol interference to allow recovery of the transmit symbols. It may be a simple linear filter or a complex algorithm. The following equalizer types are commonly used in digital communications:

MSME:-A minimum mean square error (MMSE) estimator is an estimation method which minimizes the mean square error (MSE) of the fitted values of a dependent variable, which is a common measure of estimator quality. Let x be an $n \times 1$ hidden random vector variable, and let y be a $m \times 1$ known random vector variable (the measurement or observation), both of them not necessarily of the same dimension. An estimator $\hat{x}(y)$ of x is any function of the measurement$y$. The estimation error vector is given by $e = \hat{x} - x$ and its mean squared error (MSE) is given by the trace of error covariance matrix.

$$MSE = tr\{E\{(\hat{x} - x)(\hat{x} - x)^T\} \qquad (6)$$

Where the expectation E is taken over both x and y. When x is a scalar variable, then MSE expression simplifies to $E\{(\hat{x} - x)^2\}$. Note that MSE can equivalently be defined in other ways, since

$$tr\{E\{ee^T\}\} = E\{tr\{ee^T\}\} = E\{e^T e\} = \sum_{i=1}^{n} E\{e_i^2\} \qquad (7)$$

The MMSE estimator is then defined as the estimator achieving minimal MSE.

ZF Equalizer:-The Zero-Forcing Equalizer applies the inverse of the channel frequency response to the received signal, to restore the signal after the channel [9].It has many useful applications. For example, it is studied heavily for IEEE 802.11n (MIMO) where knowing the channel allows recovery of the two or more streams which will be received on top of each other on each antenna. The name Zero Forcing corresponds to bringing down the intersymbol interference (ISI) to zero in a noise free case. This will be useful when ISI is significant compared to noise.

For a channel with frequency response $F(f)$the zero forcing equalizer $C(f)$is constructed by $C(f) = 1/F(f)$. Thus the combination of channel and equalizer gives a flat frequency response and linear phase $F(f)C(f) = 1$.

This second item is often the more limiting condition. These problems are addressed in the linear MMSE equalizer by making a small modification to the denominator of $C(f)$: $C(f) = 1/(F(f) + k$, where k is related to the channel response and the signal SNR.

D. Opportunistic Relaying

The performance of Amplify and Forward protocol and Decode and forward are analyzed and compared with full amplification and noisy ambience with single relay selection. Opportunistic relay scheme is used for single relay selection. According to opportunistic relaying, a single relay among a set of relay nodes is selected, depending on which relay provides for the “best” end-to-end path between source and destination (Figs. 1 and 2). The wireless channel between source and each relay, as well as the channel between relay Source transmits to destination and neighboring nodes overhear the communication. “Best” relay node among M nodes is selected to relay the information, through a distributed mechanism and based on instantaneous end-to-end channel conditions. The wireless channel between source and relay, and relay and destination changes over time according to Doppler shift which is inversely proportional to coherence time. Opportunistic selection of the “best” available relay involves the discovery of the most appropriate relay, in a distributed and “quick” fashion, well before the channel changes again. In this scheme the relay node monitor the instantaneous channel conditions and decides which one has the strongest path for relaying the information, before the change in channel characteristics. Hence topological information is not needed in this scheme.

More specifically, the relays overhear a single transmission of a ready-to-send (RTS) packet and a clear-to-send (CTS) packet from the destination. From these packets, the relays evaluate how appropriate each of them is for relaying the source’s signal. The instantaneous channel condition between source and each relay is determined by the transmission of RTS packets. (Fig. 3).

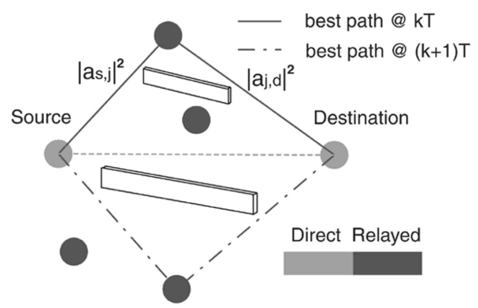

Fig.3: Opportunistic Relaying

Similarly, the transmission of CTS from the destination allows for the estimation of the instantaneous wireless channel between relay and destination at each relay according to the reciprocity theorem [10]. The source does not need to listen to the CTS packet from the destination. To minimize overall inrush from all the relays a time based method is chosen: as soon as each relay receives the CTS packet, it starts a timer from a parameter h_i based on the instantaneous channel measurements, α_{si}, α_{id}. The timer of the relay with the best end-to-end channel conditions will cease soon. A short duration flag packet is transmitted by that relay, signaling its presence. While other relays will wait to expire their timer and they will be in listening condition. As the flag packet is detected by the relays in listening mode they will back off. The relays can listen source and destination transmission but they are hidden from each other. The best relay notifies the destination with flag message while destination node uses a short duration broadcast packet to grant the permission. For each relay I the channel condition between source relay and destination is defined by channel estimates α_{si} α_{id} . During both hopes each relay should calculate its suitability as an active relay, using a function that involves the link quality of both hops. Two functions are: under Policy I, the minimum of the two is selected, while under Policy II, the harmonic mean of the two is used [11]. Policy I selects the "bottleneck" of the two paths while Policy II balances the two link strengths and it is a smoother version of the first one.

• Under Policy I

$$h_i = \min\{|\alpha_{si}|^2 |\alpha_{id}|^2\} \quad (6)$$

• Under Policy

$$h_i = \frac{2}{\frac{1}{|\alpha_{si}|^2}+\frac{1}{|\alpha_{id}|^2}} = \frac{2|\alpha_{si}|^2|\alpha_{id}|^2}{|\alpha_{si}|^2+|\alpha_{id}|^2} \quad (7)$$

The relay that maximizes function $h_i$is the one with the "best" end-to-end path between initial source and destination. Each relay will start its own timer after receiving the CTS packet, with an initial valueT_i, which is inversely proportional to the end-to-end channel quality h_i, according to the following equation:

$$T = \lambda / h_i \quad (8)$$

Here, λ is a constant. The units of λ depend on the units of h_i. Since h_i is a scalar, λ has the units of time.

$$h_b = \max\{h_i\} \Leftrightarrow \quad (9)$$

$$T_b = \min\{T_i\}, \quad i \in [1 \ldots\ldots M]. \quad (10)$$

Therefore, the "best" relay has its timer reduced to zero first [since it started from a smaller initial value, according to eq. (8)–(10)]. This is the relay b that participates in forwarding information from the source. And all the other relays will back off after listening to Flag packet.

IV. EXPERIMENTS AND RESULTS

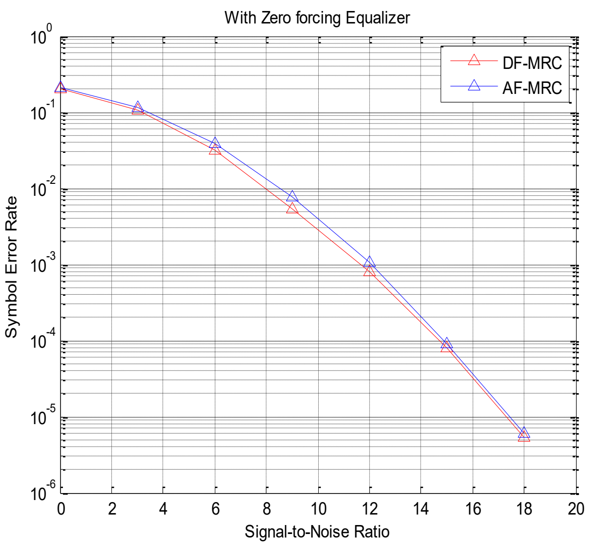

Fig.4: SER (symbol error rate) response with respect variable SNR

Simulation is done on Amplify forward and decode forward system model. Maximal ratio combing technique is used for data combing form different relay. SER plots shows the receiver response under zero forcing equalizer .With full amplification gain amplify forward and decode and forward perform nearly similar .As SNR increased i.e. signal power is increasing then there is decrease in SER accordingly. At SNR 20 dB the results of both system is same. Normally decode and forward outperform then amplify and forward under noisy ambience.

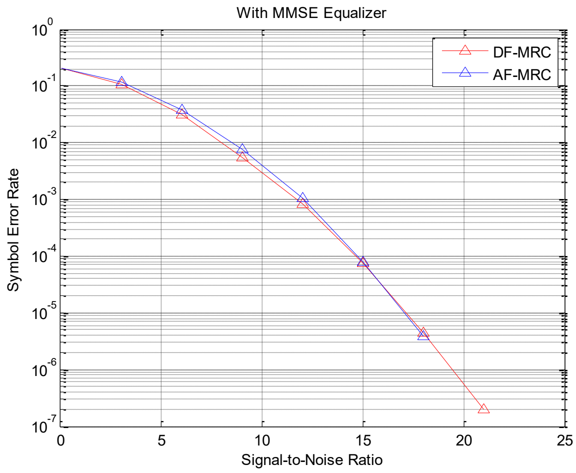

Fig.5: SER (symbol error rate) response with respect variable SNR

The above SER plots shows the receiver response under MMSE equalizer .With full amplification gain amplify forward and decode and forward perform nearly similar. As SNR increased i.e. signal power is increasing then there is decrease in SER accordingly. At SNR 20 dB the results of both system is same. Decode and forward outperform then amplify and forward under noisy ambience. The above results shows the better performance of MMSE equalizer which give better SER at 23 dB, as compared to zero forcing equalizer in above graph.

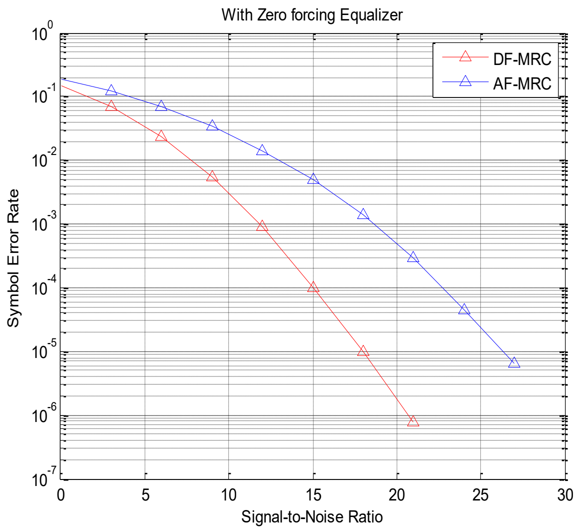

Fig.6: SER (symbol error rate) response with respect variable SNR

The above SER plots shows the receiver response under zero forcing equalizer. With noisier ambiance decode and forward outperform then amplify and forward. As SNR increased i.e. signal power is increasing then there is decrease in SER accordingly. At SNR 20 dB the results of both system is same. Decode and forward outperform then amplify and forward

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 7, February 2017)

under noisy ambience. The above results shows the better performance of MMSE equalizer which give better SER at 23db, as compared to zero forcing equalizer in above graph.

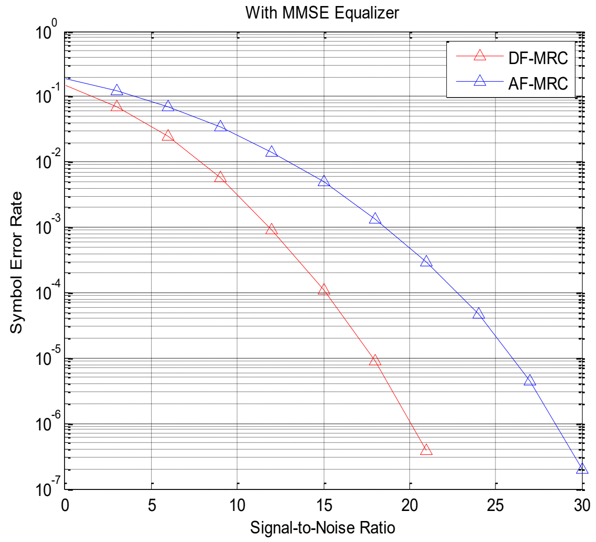

Fig.7: SER (symbol error rate) response with respect variable SNR

Simulation is done on Amplify forward and decode forward system model. Maximal ratio combing technique is used for data combing form different relay. SER plots shows the receiver response under MMSE equalizer. With noisier ambiance decode and forward outperform then amplify and forward. As SNR increased i.e. signal power is increasing then there is decrease in SER accordingly. At SNR 20 dB the results of both system is same. Decode and forward outperform then amplify and forward under noisy ambience. The above results shows the better performance of MMSE equalizer which give better SER at 23 dB, as compared to zero forcing equalizer in above graph.

V. Conclusion

We have compared the relaying strategies i.e. Amplify and forward (AaF) and Decode and forward (DaF) under minimum mean square error (MMSE) and Zero-Forcing Equalizer(ZF) using Maximal Ratio Combining (MRC).Opportunistic relaying scheme is used for attaining maximum diversity gain. It has shown that Symbol Error Rate (SER) performance of DaF outperforms AaF in the noisy environment and when the power is increased than only AaF performs almost as DaF.

VI. References

[1] M. Eriksson, A. Mahmud, "Dynamic Single Frequency Networks in Wireless Multihop Networks - Energy aware routing algorithms with performance analysis", 2010 IEEE International Conference on Computer and Information Technology, CIT'10, Bradford, UK, June 2010.

[2] W. Elmenreich, N. Marchenko, H. Adam, C. Hofbauer, G. Brandner, C. Bettstetter, and M. Huemer (2008). "Building blocks of cooperative relaying in wireless systems". e & i, Springer **125** (10): 353–359. doi:10.1007/s00502-008-0571-7.

[3] J. N. Laneman, D. N. C. Tse, and G. Wornell, "Cooperative diversity in wireless networks: Efficient protocols and outage behavior,"IEEE Trans. Inform. Theory, vol. 50, no. 12, pp. 3062–3080, Dec. 2004.

[4] G. Kramer, M. Gastpar, and P. Gupta, "Cooperative strategies and capacity theorems for relay networks,"IEEE Trans. Inform.Theory, vol. 51, no. 9, pp. 3037–3063, Sept. 2005.

[5] A. Høst-Madsen, "Capacity bounds for cooperative diversity,"IEEE Trans. Inform. Theory, vol. 52, no. 4, pp. 1522–1544, Apr.2006.

[6] H. Høst-Madsen, "Capacity bounds and power allocation for wireless relay channel,"IEEE Trans. Inform. Theory, vol. 51, no. 6,pp. 2020–2040, June 2005.

[7] Mischa Dohler, Yonghui, "Cooperative communication Hardware, Channel and Phy", John wiley and sons, Unversty of Sydney, Jan 2010.

[8] Rahat Al Khan, Muhammad Abdul Aleem, Asad Ali Shaikh, "Performance Analyss of Cooperative Communcation Protocols", JETCIS, vol.3,No.7, July 2012.

[9] Jon Mark and Weihua Zhuang (2003). "Ch. 4". Wireless Communications and Networking. Prentice Hall. p. 139.

[10] T. S. Rappaport, *Wireless Communications: Principles and Practice*. Upper Saddle River, NJ: Prentice Hall, 1996.

[11] A. Bletsas, A. Lippman, and D. P. Reed, "A simple distributed method for relay selection in cooperative diversity wireless networks based on reciprocity and channel measurements," in *Proc. 61st IEEE Semiannu. Vech. Technol. Conf*, vol. 3, Stockholm, Sweden, May 30–Jun, 1 2005, pp. 1484–1488.