A Survey on Relay Selection Strategies in Cooperative Wireless Network for Capacity Enhancement

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ABSTRACT
Cooperative communication can be considered as a promising technology to significantly increase the transmission rate along with the coverage area of a wireless network which aims to achieve spatial diversity via the cooperation of user terminals in transmission without requiring installation of multiple transceiver antennas. The user terminals which can be used for this purpose can be termed as relay nodes. However, most of the existing solutions on relay node assignment problem with multiple source-destination pairs are limited to assign each single pair at most one cooperative relay node. Therefore, this paper studies the cooperative relay node assignment problem in a network environment, where multiple source-destination pairs compete for the same pool of cooperative relay nodes and each pair can be allotted multiple cooperative relay nodes for cooperative communication to maximize the transmission rate and hence improves the performance among all communicating pairs. Without requiring multiple antennas on the same device, spatial diversity is achieved by exploiting the antennas on other nodes, i.e., relay nodes, in the network. Therefore, the selection of relay nodes has a significant impact on the achieved total capacity.

Keywords
Cooperative Communications, MIMO, Relay Selection, Spatial Diversity.

1. INTRODUCTION
Wireless networks are rapidly changing to provide connectivity to growing number of mobile devices. The requirement of the high data rate and enhanced capacity is definitely increased in order to meet the demands of new multimedia applications. Next generation wireless communication must employ new techniques to overcome wireless channel problems in meeting these requirements. The specialized network called multi input multi output (MIMO) network will be one of the noticeable technique to overcome some of the problems of wireless environment [1,7]. Installation of multiple transmit and receive antennas is a widely accepted solution for achieving the spatial diversity in wireless networks to clear the detrimental effects of wireless channel fading. In other words diversity provided by MIMO technique is one of the promising techniques of dealing with channel fading, which requires more than one antenna at the transmitter and receiver sides.

But this technique is not suitable in every case for example ad hoc and wireless sensor networks. Implementing the MIMO using multiple antennas in such cellular networks may not always be practical because of smaller size of the user terminals [1, 3] i.e. the spacing between antennas should be of the order of half the signal wavelength.

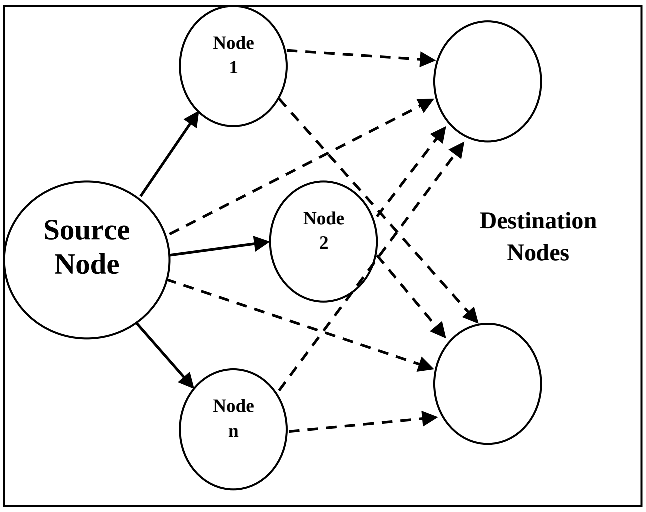

Fig. 1 A MIMO Communication System

Now a days, a new kind of distributed spatial diversity is invented which is based on the cooperation between wireless terminals, which is termed as a cooperative communication [2, 3]. In this new aspect of communication technique a promising scheme called wireless relay networking is proposed which shows the performance improvement in wireless cooperative networks and can provide the benefits of diversity without implementing multiple antennas per terminal [1, 2]. Relay networks can allow surrounding terminals to collaborate, acting as a virtual MIMO an antenna array. This type of cooperative communication [13] is practically more beneficial as each node needs only one antenna as a relay node or a communicating device as a relay node. Thus there forms a virtual antenna array through multiple relay nodes in the network. The basic idea of cooperative diversity network technology is that between the transmitter and receiver nodes, there can be another node, which can be used to provide diversity by forming a virtual multi-antenna system [10].

In this paradigm, individual wireless terminals intelligently share each other's antennas and form virtual antenna arrays, resembling to an extent the operation of a multiple input multiple-output system. Besides achieving diversity gain, cooperation can also help increase the coverage area in wireless networks which is particularly important for commercial service providers [13]. Most of the times in the wireless network an interference occurs due to overheard by some of the intermediate nodes while the information is being transmitted from the source node [3]. However, the information received at the intermediate nodes is essentially the same as that received at the destination. Intelligent relaying from some intermediate nodes can therefore help the source-destination pair to achieve spatial diversity since the intermediary nodes which can act as relays are spread over a (usually reasonable) geographic area.

The article is purely the survey based on the various means of relay node networking and cooperative communication established as a result of relaying. Along with that relay node, relay pairing scheme and the characteristics of relay network has also been discussed. A small overview on the optimal relay node selection algorithm is performed. In the later part of the article, the description and technicalities of most commonly used type of communication called MIMO is highlighted along with its types and requirements. Final part of the paper includes two of the most common means for implementing cooperation that is (1.) Amplify-and-Forward (AF) (2.) Decode-and-Forward (DF). AF is the simplest protocol in which the relay(s) simply amplifies and forwards the signal received from the source node, along with the noise [5, 6]. Whereas in DF, the selected relay(s) first decodes the received message and upon verifying the correct reception, relays the message to the destination [15]. The paper ends with considerable focus on the future scope and conclusion of the technologies that are discussed.

2. RELAY TECHNOLOGY

OFDMA that is frequency division multiple access being a popular standard for the communication between mobile users always demands the capacity and performance enhancement. For the sake of modernization of an orthogonal frequency division multiple access (OFDMA) IEEE 802.16e system [4], lot many efforts were done. All these efforts are now come to the discussion of enhancing performance and capacity of the 802.16e standard by extending the coverage area and enhancement of link throughput. For these modifications a new kind of technique has brought forward under the IEEE 802.16j standard which is relay based wireless access networks [7]. This IEEE 802.16j standard was published by the 802.16j task group *(IEEE Std 802.16-2009, 2009)*. The main difference between 802.16e and 802.16j is the existence of relay stations (RS) for data communication as shown in Figure 2. In the 802.16j system, a multi hop relay base station (BS) communicates with MS through multi hop wireless links by deploying RS between the BS and MS [9]. Thus, MS may communicate with the BS directly or with RS through multi hop wireless links without being aware of the existence of an intermediate RS.

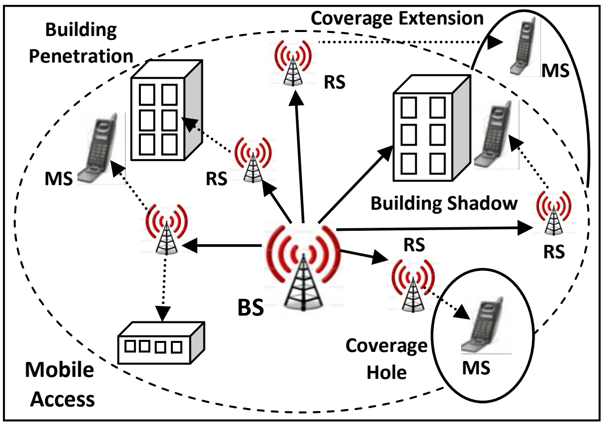

Fig. 2 802.16j Relay Based Wireless Access Networks (Cooperative Communication)

By deploying the relay stations [4] in lower signal to noise ration cell boundary area, the system capacity, throughput per user, and the system reliability can be enhance

2.1 Relay Pairing Scheme

To establish the collaboration between RS and BS the pairing schemes are developed. This will improve the coverage and throughput of the mobile multi hop relay (MMR) networks. There are two pairing schemes proposed, centralized pairing scheme and distributed pairing scheme. The other Relay pairing schemes are random relay pairing Schemes and opportunistic relay pairing schemes.

2.1.1 Centralized relay pairing schemes

In this scheme the BS is responsible for controlling the pairing decision by collecting the channel and location information from all the RSs and MSs. This information must be formed as a service set and periodically updated in the local BS to capture dynamic changes of MSs. This scheme requires more signalling over head, and can achieve better performance gains.

2.1.2 Distributed relay pairing schemes

In this scheme, RS collects the channel and location information from all the nearby MSs and then makes the pairing decision. First each RS identify its service set of neighbourhood MSs and also the channel conditions between its BS as well as its SS, those RS with single service set each randomly selects a time slot from the N- slots in the pairing scheme. If multiple RS choose the same time slot then collusion occurs and those RS will be trying again in the next pairing scheme.

2.2 Characteristics of the Relay based Networks

Three main benefits provided from relay based architecture over single hop architecture are [12] throughput enhancement, coverage increase and deployment cost.

2.2.1 Throughput enhancement

It is expected to increase system capacity by deploying RSs in a manner that enables more aggressive spatial reuse.

2.2.2 Coverage enhancement/extension

The relay technology is established to enhance the coverage reliability in those geographic areas that are severely shadowed from the BS and to extend the range of that BS.

2.2.3 Cost reduction

Relay node is not always needed to be an antenna, deployment of which requires a large infrastructural implementation and cost. Relay node can be a single mobile device with an extended relaying facility which does not require an expensive installation procedure. Relay based systems have the potential to deliver cost gains over traditional single hop wireless access systems. Using RSs, an operator could deploy a network with wide coverage at a lower cost than using only (more) expensive BSs to provide good coverage and system capacity.

2.3 Relaying Techniques

The relaying techniques include the following traditional techniques [9]: i) *a time domain relaying*, ii) *a frequency domain relaying* and iii) *hybrid time/frequency domain relaying* and the current technique which is the primary attraction of the research community, iv) *cooperative technique*.

2.3.1 Time domain relaying

In this scheme, relays access the medium in time multiplex. The resources are further divided in time in either the downlink or uplink to allow the relay station to receive and transmit data.

2.3.2 Frequency domain relaying

Relays are operating on different frequency channels. The main advantage of this scheme is that relays can transmit and receive data simultaneously.

2.3.3 Hybrid time/frequency domain relaying

Relays are operating periodically on different frequency channels to forward data. The idea here is to switch between two frequencies in order to allow the BS to transmit to its client while the relay is forwarding data on another frequency.

2.3.4 Cooperative relaying techniques

These techniques significantly enhance the performance of relay based systems by multiple RSs cooperatively transmitting the same data to a SS or the BS. This scenario forms the resemblance with MIMO technique with transmit/receive diversity and spatial multiplexing.

2.3.5 Path management

Being cooperative nature, 802.16j network comprises multi-hop paths between the BS and MS [11], there needs a controlled path management mechanism. There defines two approaches for path management, embedded and explicit path management.

2.3.6 Relay path routing

The process of determining most suitable route to BS from source MS by considering constrains such as bandwidth available, radio resource, interference etc is nothing but the relay path routing. Again two types are there for this purpose. In *centralized path routing* path information is stored in the BS, but in *distributed path routing* path information is populated in RSs.

For reducing the access and transmit time (latency) and also for using the radio resource effectively, the distributed path routing is preferred over the centralized one. The BS using centralized path routing is not able to control whole networks. Throughput of a wireless link depends on both the bandwidth of the link and the PHY-layer loss rate, therefore the path selection method should take both the loss rate and the link bandwidth into account.

2.4 Relay Modes

The 802.16j standard defines two separate types [7] of relay nodes: a transparent RS and a non-transparent RS. The transparent RS is designed to increase the link capacity of the BS by covering coverage holes. Therefore, the transparent RS are located inside the coverage of the BS. On the other hand, the non-transparent RS is deployed at the edge of the coverage in low traffic areas to extend the coverage area of a BS.

2.4.1 Transparent relay mode

Transparent relay mode increases the throughput, and thus capacity increases within the base station coverage area. As it does not forward framing information to the base station, it does not support coverage extension. The transparent relay mode operates in two hop network topology and supports centralized scheduling which is done in Base Station [8]. It also uses the channel ID based forwarding scheme and supports embedded and explicit mode of path management. The transparent relay station does not transmit control message, permeable, FCH (frame control header) etc, as it only increases system throughput.

2.4.2 Non-Transparent relay mode

The IEEE 802.16j standard uses non-transparent relay stations to extend coverage area [8]. In this mode the relay station generates its own framing information and forwards it to the mobile stations or subscriber stations. Non transparent mode supports and operates on multi hops transfer and uses centralized or distributed scheduling mode, as scheduling is done in the base station and relay stations. The channel ID and tunnel based forwarding scheme is used to support the embedded and explicit mode of path management in non transparent relay mode. There are again two types of non-transparent relay modes, that is, the time-division transmit and receive relay mode (TTR) which can operate with one of two types of frame structures, a single-frame and/or multi frame structure, and the simultaneous transmit and receive relay mode (STR). The TTR and STR relay modes have recently been introduced in the 802.16j standard.

Table 1. Comparison between transparent and non transparent relay node.

Sr. No.	Transparent Node	Non Transparent Node
1.	Centralized scheduling is supported which is done at base station.	Distributed and centralized scheduling is supported as it is done in both base station and relay node.
2.	Uses two hops and lacks the coverage extension.	Uses two or more hops and provides base station coverage extension.
3.	Relay station cost is low.	Relay station cost is high.

3. OPTIMAL RELAY SELECTION

A principal problem of Relay Node Assignment in the co-operative communication in wireless network is solved up to the major extent by the algorithm called Optimal Relay Assignment Algorithm proposed by Sharma S. and Y. Thomas in [17]. The basic idea behind this algorithm is a “linear marking” mechanism, which offer a linear complexity at each iteration results in achieving polynomial time complexity. According to the authors of [17] this algorithm works regardless of the number of the relay nodes are less or more than the number of source or destination nodes. Starting with this initial assignment, ORA adjusts the assignment during each iteration, with the goal of increasing the objective function. Specifically, during each iteration, ORA identify the source node that corresponds to minimum capacity. Then, ORA help this source node to search a better relay such that this capacity can be increased.

The algorithm as proposed is based on the widely used objective for the cooperative communication which is capacity. Each source and destination pair will exhibit the different capacity after we apply the algorithm. The attempt in any way should be maximization of the capacity of the particular pair among all source-destination pair. It is not necessary that in every network there should be enough relay nodes available. Capacity enhancement of the source-destination pair should be the ultimate result of the relay node assignment. Again an important thing is that, an algorithm does not always assign the relay node to the pair. If the assignment of the relay node exhibits the smaller capacity as compared to the direct transmission, there will be no relay assignment.

Simplifying the working of the algorithm, it is always interested in maximizing the minimum capacity of the source destination pair. That means, the capacity with which the particular pair of source destination is performing the communication will always been tried to be maximized by assigning the suitable relay node, but if that relay node is ineffective i.e. not able to maximize the capacity up to desirable extent, then the relay will not be assigned to that source destination pair and the direct transmission will be carried out. Detailed description of the ORA algorithm is beyond the scope of this paper.

4. MULTIPLE INPUT MULTIPLE OUTPUT

To improve cell coverage and increase average number of users within the cell Multiple Input Multiple Output (MIMO) communication Multiple input multiple output techniques have been used which comes under IEEE 802.16d/e/j standard. Multiple inputs multiple output transmission is used to increase the data rate of communication between a given transmitter-receiver pair and/or improve the reliability of the link. With the use of multiple antennas and a given range of frequencies the achievable rates of data transfer and user's utilization of the network can be improved [10]. And as a result of which the MIMO technology is expected to be widely used for the all kinds of wireless communications as it will go mature.

Multiple input multiple output futures such as closed loop input multiple output will be included in future Worldwide interoperability for Microwave access; more specifically, it has been already decided to support closed loop multiple input multiple output using channel quality information, preceding matrix index, and rank feedback in future systems. Multiple input multiple output techniques includes following scenarios of communication

- Single user-multiple input multiple output
- Multi user-multiple input multiple output
- Cooperative multiple input multiple output.

The key multiple input multiple output techniques are open-loop transmit diversity in downlink, open-loop spatial multiplexing in downlink, open-loop transmit diversity in uplink, and open-loop spatial multiplexing in uplink. The acceptance of MIMO technique for any wireless communication demands the strong interactive bonding and integration between some of the higher layers of the IEEE 802.16j such as physical layer, medium access control layer etc.

For the next generation worldwide interoperability for microwave access which termed as WiMAX, a system is to support at least up to 8 transmit antennas at the base station, 4 streams, and space-time coding. The following features are included in releases 1.0 and 1.5 of worldwide interoperability for microwave (WiMAX) access forum.

- Collaborative spatial multiplexing in uplink
- Adaptive beam forming
- Closed-loop antenna grouping/selection
- Closed-loop codebook-based precoding.

Based on the full or partial availability of channel state information to receiver and transmitter single user-multiple input multiple output is classified into

- open loop- single user MIMO
- closed loop- single user MIMO

For the improvement of the cell spectral efficiency and average user experience both, MIMO techniques allows the main open-loop multiple input multiple output scheme. For the mobility applications the open loop-single user-multiple input multiple output systems are proved to be more reliable because they do not require channel state information as 802.16e support mobility of up to 120 km/h. Like the main open-loop multiple input multiple output scheme, 802.16e operates on the space time coding. Space-time coding is supported by both the uplink and downlink. The space-time coding option achieves low complexity decoding, while others are optimized for high complexity decoding. The multi cell multiple input multiple output system has the potential to eliminate dominant inter cell interferences, while offering multiplexing rate and diversity gain.

5. RELAYING STRATEGIES

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5.1 Detect and Forward Method

This method is having a close resemblance with the traditional relay assignment method. User attempts to detect the bits of partner and retransmit them. It is possible that the partner, whose data bits are being retransmitted, may be assigned mutually with the base station. We considered two users for above scenario, but actually only important factor is that each user has a partner that provides a second (diversity) data path. It is easy to visualize this scenario using the pairs of mobile device or communication devices. The other partnership topologies that assign the mobile device as a relay are also effective and can also achieve the same effect. That may remove the strict constraint of pairing too. But Partner assignment is a rich topic whose details are beyond the scope of this introductory article.

5.2 Decode and Forward Method

Another simple cooperative signalling is the decode-and-forward method. We consider three different decode-and-forward strategies, and we call these

- Irregular encoding/successive decoding,
- Regular encoding/sliding-window decoding,
- Regular encoding/backward decoding.

In the [15] to describe the first strategy author used Markov superposition encoding, random partitioning (binning), and successive decoding. The encoding is performed with the codebooks of different size; hence the strategy is termed as irregular encoding. The other two strategies were developed in the context of the multi access channel with generalized feedback (MAC-GF). As described, it uses the three nodes just like the single relay channel, in which two of the nodes transmit messages to third node. King developed an achievable rate region for this channel. Although this region can be difficult to evaluate, there are several interesting features of the approach.

A example of decode-and-forward signalling can be viewed as analysis and a simple code-division multiple access (CDMA) implementation of decode-and-forward cooperative signalling which was particularly suggested by Sendonaris in [14]. Simplicity and adaptability to channel conditions are the most advantageous things about decode-and-forward signalling.

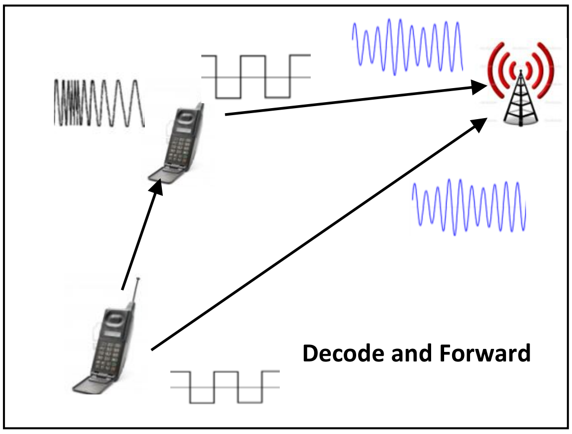

Fig. 3. Decode and Forward Cooperation

5.3 Amplify and Forward Method

Another simple cooperative signalling is the amplify-and-forward method. Every user in this cooperation first receives the signal with noise transmitted from its partner which is then retransmitted but after performing the amplification of that noisy signal [6] (Fig. 4). The base station combines the signals sent by the user and partner. 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. Laneman in [16] proposed this method.

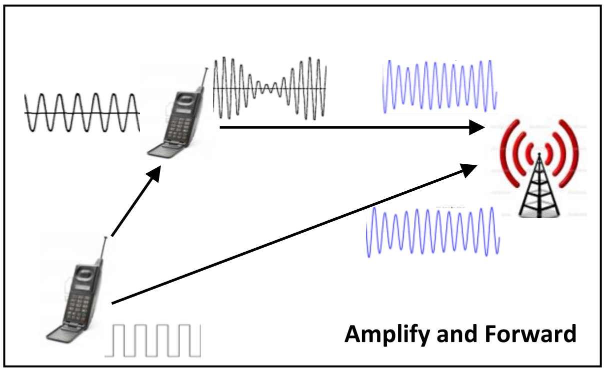

Fig. 4 Amplify and Forward Cooperation

In amplify-and-decoding, for the optimal decoding of the signal base station should have the inter user channel coefficient so some mechanism of exchanging or estimating this information must be incorporated into any implementation. Sampling, amplifying, and retransmitting analog values is technologically nontrivial. Nevertheless, amplify-and-forward is a simple method that lends itself to analysis, and thus has been very useful in furthering our understanding of cooperative communication systems. Detailed description of the relay strategies is beyond the scope of this paper.

6. CONCLUSION AND FUTURE SCOPE

The Relay selection plays a vital role in maximizing the diversity gain achieved in wireless cooperative communication systems, and hence it has duly attracted attention of many research groups over the last few years. Different relay selection schemes are designed with different focus and objectives. In this paper, we discussed a literature survey on some of the most representative areas of relay selection/assignment domain in cooperative networks along with various types of relaying strategies and techniques.

Designing the reliable relay assignment scheme can be a principle working area in wireless cooperative networks. The implementation of the relay nodes with intelligence to perform some parametric operations (such as compress, demodulate, amplify etc.) on the incoming signals and brings out the advantageous manipulations in their behaviour in the cooperative environment can become vital research area. We also focused on the optimal relay assignment algorithm which provides the optimal solution to allocate the relay node for enhancing the capacity. In a later part of the article, a ray of light on the MIMO technology shows the inevitability of this technology in the area of cooperative communication in relaying network.

7. REFERENCES

[1] R. Pabst, B. Walke, and D. Schultz, "Relay-Based Deployment Concepts for Wireless and Mobile Broadband Radio," IEEE Commun. Mag., Sept. 2005. Assignment Scheme for Cooperative Networks," in Proc. IEEE 2012 .

[2] Gang Liu, Liusheng Huang, and Hongli Xu "Cooperative Relay Assignment in Wireless Networks " IEEE 2011

[3] Xuehua Zhang, Mazen Hasna and Ali Ghrayeb "Performance Analysis of Relay Assignment Schemes for Cooperative Networks with Multiple Source Destination Pairs," in Proc. IEEE 2012 .

[4] Thulasiraman P, Shen X, "Interference aware subcarrier assignment for throughput maximization in OFDMA wireless relay mesh networks". IEEE 2009

[5] Chengliang Huang Xiao-Ping Zhang "Performances of Amplify-and-Forward Cooperative Relay Networks with Different Topologies" Springer 2012

[6] Cai J, Shen X, Mark JW, Alfa AS. Semi-distributed user relaying algorithm for amplify-and-forward wireless relay networks. IEEE Transactions on Wireless Communications 2008;7(4):1348–57.

[7] Genc V, Murphy S, Yu Y,Murphy J (2008) , "IEEE 802.16j relay-based wireless access networks: an overview." IEEE Wireless Communication

[8] So-In C, Jain R, Al-Tamimi A, "Capacity evaluation for IEEE 802.16e Mobile WiMAX. J. Comput. Syst. Networks and Commun., 2010."

[9] Berezdivin R, Breinig R, Topp R (2002), " Next-generation wireless communications concepts and technologies.", IEEE Communication Mag.

[10] Fallah YP, Agharebparast F, Minhas MR, Alnuweiri HM, Leung CM, "Analytical modeling of contention-based bandwidth request mechanism in IEEE 802.16

wireless networks". IEEE Transactions on Vehicular Technology 2008

[11] Gang Liu, Liusheng Huang, "Cooperative Relay Assignment in Wireless Networks" IEEE 2011.

[12] Pabst R, et al. Relay-based deployment concepts for wireless and mobile broad- band radio. IEEE Communications Magazine 2004.

[13] A. K. Sadek, Z. Han, and K. J. R. Liu, "Distributed relay-assignment protocols for coverage expansion in cooperative wireless networks," IEEE Trans. on Mob. Computing, vol. 9, no. 4, April 201

[14] Andrew Sendonaris , Member, IEEE , Elza Erkip , Member, IEEE , and Behnaam Aazhang , Fellow, IEEE, "User Cooperation Diversity Part I and II " 2003

[15] J. Luo, R. S. Blum, L. J. Cimini, L. J. Greenstein, A. M. Haimovich,"Decode-and-Forward Cooperative Diversity with Power Allocation in Wireless Networks."

[16] J. N. Laneman, G. W. Wornell, and D. N. C. Tse, "An Efficient Protocol for Realizing Cooperative Diversity in Wireless Networks," Proc. IEEE ISIT , Washington, DC, June 2001.

[17] Yi Shi, Sushant Sharma, Y. Thomas Hou, " Optimal Relay Assignment for Cooperative Communications", Mobi Hoc 08, May 26–30, 2008, Hong Kong SAR, China.