An Enhanced Relay Selection Scheme (ERS) for Cooperative Relaying in Mobile WiMAX Networks

M. Deva Priya, R.K. Shanmugapriya, M.L. Valarmathi

***Abstract* - WiMAX technology is an affordable solution for high speed 4G mobile broadband applications. It is a standard for long range wireless networking. Extending coverage is an interesting area of research. In WiMAX, cell coverage can be protracted by deploying Relay Stations (RSs) in which the Mobile Station (MS) routes traffic through intermediate RSs to the Base Station (BS). This work deals with providing a cooperative relaying based on an Enhanced Relay Selection (ERS) scheme. The ERS scheme not only uses fixed RSs, but also recruits femto BSs (fBSs) as new fixed relays and MSs as mobile relays showing pronounced performance cooperative gains. The "best" RS is selected based on the Channel State Information (CSI) of next hop node. CSI table is constructed with channel statistics and relay pairing schemes are used to pair the selected RS. The simulation results demonstrate that ERS yields better throughput, Packet Delivery Ratio (PDR) involving lesser delay, message drops and control overhead.**

***Index Terms* - Access Link, Relay Link, Relay Selection Factor (RSF), Relay Station, Relaying Capability Factor (RCF), WiMAX.**

I. INTRODUCTION

Worldwide Interoperability for Microwave Access (WiMAX), a Fourth Generation (4G) network, provides ubiquitous wireless access with high data rates, high mobility and wide coverage. IEEE 802.16m also known as Mobile WiMAX Release 2 has revised IEEE 802.16 Wireless Metropolitan Area Network - Orthogonal Frequency - Division Multiple Access (MAN - OFDMA) specification to provide an advanced air interface for operation in licensed bands [1]. IEEE 802.16m incorporates innovative communication technologies such as multi-user Multiple In - Multiple Out(MIMO), multicarrier operation and cooperative communications [2].

***Manuscript received April , 2014*.**

M. Deva Priya, *Assistant Professor, Department of Computer Science and Engineering, Sri Krishna College of Technology, Coimbatore, India*

M. L. Valarmathi, *Associate Professor, Department of Computer Science and Engineering, Government College of Technology, Coimbatore, India*

R. K. Shanmugapriya,*PG Scholar, Department of Computer Science and Engineering, Sri Krishna College of Technology, Coimbatore, India*

IEEE 802.16 standard was developed to compete with cable access networks. In the beginning, end users were immobile and had Line Of Sight (LOS) communication with the BS. But now, mobile Non-Line Of Sight (NLOS) communication is made possible with IEEE 802.16e and IEEE 802.16j. IEEE 802.16j standard, an amendment to IEEE 802.16e, is a Mobile Multihop Relay (MMR) specification for wireless networks.

As the MSs may access the high speed wireless networks anytime, anywhere, the BS allocates system resources to all the MSs in its coverage [3]. A relay network is a broad class of network topology commonly used in wireless networks, where the source and destination are interconnected by means of nodes [4].

As the distance between the source and destination is larger than the transmission range, they cannot communicate directly [5]. RS are used as intermediary node(s). They increase the coverage of nodes by multiple hopping.

A. Mobile Multihop Relay (MMR) networks

A standard Mobile Multihop Relay (MMR) system enables a MS to route through intermediate RSs to reach the BS or Destination. MMR system is used to provide higher system capacity and extended cell coverage. It reduces the loss of packets. This system involves both the fBSs and MSs as relays. Multihop Relay Station (M-RS) is an optional deployment that may be used to provide additional coverage or performance advantage in an access network. Relay nodes are equipped with multiple antennas while the destination nodes arefitted with a single antenna. The intermediate nodes in the network employ conventional schemes likeAmplify and Forward (AMF), selective Decode and Forward (DCF), Demodulation and Forward (DMF) to relay their input signals.

In a two hop connection, the two different levels of Channel State Information (CSI) considered at the RS are:

- **Access Link (AL)**: In a two hop connection, the radio link between the MS and the helpers is called an Access Link (AL).
- **Relay Link (RL):** The radio link between the helpers and the BS is called a Relay Link (RL).

A wireless network with multiple concurrent sources to destination transmission pairs is developed and the

ISSN: 2278 – 7798

potential interference and the CSI elevated from relays are considered in the proposed cooperative relaying network.

II. COOPEREATIVE RELAYING

Cooperative relaying is principally a distributed MIMO system in multihop environments as shown in Fig. I. Multiple RSs work collaboratively as a virtual array to improve the signal quality or data rate owing to spatial diversity or multiplexing [6]. Furthermore, cooperative relaying potentially simplifies handoff between RSs.

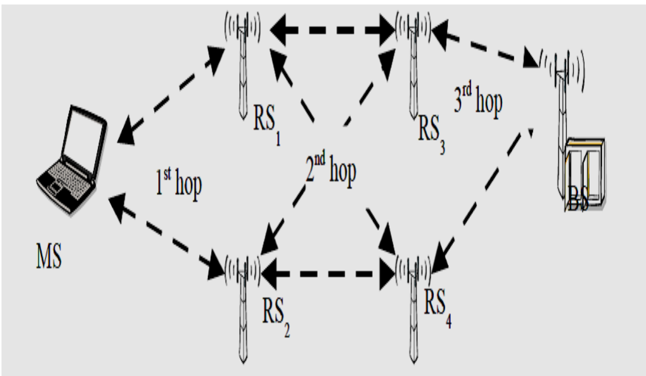

FIG. I COOPERATIVE RELAYING

Some of the relay transmission schemes [7] that are used to establish two hop communication between a BS and a MS through a RS are listed below.

A. *Amplify and Forward*

Initially, a RS receives the signal from the MS. It amplifies the received signal and forwards it to the BS in the second phase. This scheme is very simple and involves less delay, but amplifies noise [8].

B. *Selective Decode and Forward (DCF)*

The RS decodes (channel decoding) the received signal from the MS. Cyclic Redundancy Check (CRC) is computed to ensure correctness of the decode data. If the decoded data is right, then the RS performs channel coding and forwards the new signal to the BS. This scheme effectively avoids error propagation through the RS, but the processing delay is quite high [9].

C. *Demodulation and Forward (DMF)*

The RS demodulates the received signal from the MS and makes a hard decision (without decoding the received signal). Then it modulates and forwards the new signal to the BS. This scheme is simple and involves less processing delay [10].

III. RELATED WORK

In a WiMAX network, the BS cannot afford to provide service to all the users. So RSs can be employed to support users by extending the area of coverage of the BS where more number of RSs increase the system performance [11].

Cooperative relaying protocol used in [12] enhances the performance of wireless networks via relays. Selecting relays to obtain optimal performance is a key issue.

In [13], Quality of service (QoS) aware optimal relay selection scheme is proposed. To improve the diversity gain, RSs are selected based on the total power consumed in the network.

In [14], interference from a RS to its non-intended destinations and the interference level at any destination are jointly affected by relay selections of all Source-Destination (S-D) pairs. So the upper and lower bounds of the twohop transmission rate are derived and the joint impact of interference from multiple RSs is decoupled to each S-D pair. Based on these bounds, an interference-aware relay selection metric for each S-D pair is proposed.

In [15], a transmit beam forming design for MIMO is designed for Decode-and-Forward (DF) half-duplex two-hop relay channels with a direct source-destination link. Based on the unique properties of the beamforming vector, a low-complexity explicit expression for the optimal beamforming vectors is formulated for the selection of RSs. As the properties may vary according to the scenarios, the computational complexity is high.

In[16], the Signal to Interference Noise Ratio (SINR) of the serving BS is dynamically obtained and a list of cells are scanned. Based on the probability of relaying, the RSs are selected.

In [17], the CSI of the AL and RL are determined. Based on the available transmission power at the RS, the selection decision is made.

In [18], an interference aware relay selection scheme is proposed based on the upper and lower bounds of interference involved during transmission.

The rate of a relay-to-destination link depends on multiple interfering relays. The interference rate goes high, when more number of RSs is selected as helpers. By using fixed RSs, there may be chancesfor message drops [19].

In this work, an efficient relay selection scheme is proposed for IEEE 802.16m networks based on the total interference in the network. A Threshold (τ) is set and the number of RSs selected is always less than or equal to 10.

IV. COOPMAX PROTOCOL

CoopMAX protocol is a MAC layer protocol designed to incorporate both Distributed Space Time Coding (DSTC) and Randomized-DSTC (R-DSTC) based cooperative relaying into the current framework of the IEEE 802.16 system. The functionalities of the MAC layer design constitute a full range of signaling and helper

ISSN: 2278 – 7798

recruitment strategies.

The steps involved in the CoopMAX protocol are:

- **Helper Discovery**- When a MS enters the MMR network, the set of nodes that have relaying capability are identified. Thesecapable MSs are considered as helpers.
- **Synchronization** - Each helper sends periodic ranging signals to estimate the time offset from the BS and achieves time synchronization with the resolution of a Fast Fourier Transform (FFT) sampling interval. At the same time, frequency synchronization is achieved by using pilot channels and exchanging frequency offset information.
- **Channel Estimation**- The channel statistics are obtained from AL and RL. From the obtained values rate adaptation is performed.
- **Helper Recruitment** - The BS performs the relay selection based on the channel statistics.

A. *Relay Pairing Schemes*

Pairing scheme is developed for having collaboration between RSs and BS during data transmission. This improves the coverage and throughput of the MMRnetworks. There are two pairing schemes namely, Centralized Relay Pairing Scheme (CRPS) and Distributed RelayPairing Scheme (DRPS).

- *Centralized Relay Pairing Scheme (CRPS)*

In this scheme, the BS acts as a control node and collects the channel and location information from all the RSs and SSs and makes pairing decision. This information is formed as a service set and periodically updated in the local BS to capture dynamic changes of SSs. This scheme involves more signaling overhead but achieves better performance gains.

- *Distributed Relay Pairing Scheme (DRPS)*

In this scheme, RS collects the channel and location information from all the nearby MSs and then makes the pairing decision. Each RS identifies its service set of neighborhood MSs and the channel conditions between its BS and MS. RSs with single service set, randomly select a time slot from the N- slots in the pairing scheme. If multiple RSs choose the same time slot,interference occurs and they try again in the next pairing scheme.

V. ENHANCED RELAY SELECTION (ERS) SCHEME

The Enhanced Relay Selection (ERS) scheme considers the cooperative relay networks with multiple Source Destination pairs, each assisted by a relay selected from the candidates. The ERS scheme is used to select the MSs that can act as an RS.

Initially the MS transmits a MS Basic Capability REQuest (MBC-REQ) message. Based on the received MBC-REQ message, the BS can determine whether the MS supports cooperative functionality or not. The MBC-REQ message involves a cooperative capability field to inform whether the specific MS is able to serve as a helper or RS.

The BS in turn sends a MS Basic Capability ReSPonse (MBC-RSP) message as an acknowledgment. Based on the response messages, channel estimation is done on both RL as well as AL. When the MS or femto BS (fBS) requests for cooperative relaying, the MS or fBS is selected as RS based on the CSI.

The following PHYsical layer parameters are considered:

- ✓ Average Carrier to Interference plus Noise Ratio (CINR)
- ✓ Received Signal Strength Indicator (RSSI)
- ✓ Residual Energy (RE)
- ✓ Relaying Capacity (RC)
- ✓ Threshold (τ) – Approximately 10 RSs.

The following steps are followed for CSI determination.

- ✓ Entry of MS into the network.
- ✓ Initialization of Relay ID (Rid) to each node.
- ✓ Verification of relaying capability.
- ✓ Checking for the available bandwidth.
- ✓ Channel sounding - Each MS is assigned a specific sounding bandwidth to transmit a given sounding sequence that the BS can hear for channel measurement.
- ✓ Determining the pair of nodes for relaying based on the CSI using either CRPS or DRPS.

The Selection process is done by either the BS or the Gateway. The BS regulates the following factors for the selection of helpers.

- ✓ The Relay Selection Factor (RSF) is determined by,

$$\mathrm{RSF} = \frac{1}{\mathrm{CINR}} + \mathrm{RSSI} + \mathrm{RE} \quad (1)$$

- ✓ The Relaying Capability Factor (RCF) is determined by

$$\mathrm{RCF} = \frac{\text{Number of Messages Send}}{\text{Number of Messages Received}} \quad (2)$$

Using the above factors, the RS is weighted and the selection parameter is enabled. The Information Message Factor (IMF) is considered for selection. It contains the first bit of the message to be transmitted and the size of the message. Here the PHYsical layer statistics are verified to check whether the RS is capable of transmitting the message. The CSI table that is considered for RS selection is shown in Table I.For relay selection, based on the RSF and RCF values, the BS chooses the optimal RSs for

ISSN: 2278 – 7798

transmission. The CSI table includes parameters like CINR, RSSI, RE, RCF, IMF and RSF. By considering the CSI values from the AL and RL, the values are categorized as Very High, High, Moderate, Low and Very Low. The decision is based on the values in the fields and the message is formulated as Six bit information. Finally the number of RSs selected is compared with the Threshold (τ).

TABLE I. CSI TABLE

CATEGORY	CINR	RSSI	RE	RCF	IMF	RSF
VERY HIGH	Yes	Yes	Yes	Yes	Yes	Yes
	No	No	No	No	No	No
HIGH	Yes	Yes	Yes	Yes	Yes	Yes
	No	No	No	No	No	No
MODERATE	Yes	Yes	Yes	Yes	Yes	Yes
	No	No	No	No	No	No
LOW	Yes	Yes	Yes	Yes	Yes	Yes
	No	No	No	No	No	No
VERY LOW	Yes	Yes	Yes	Yes	Yes	Yes
	No	No	No	No	No	No

The frequent helpers of the marginal bandwidth header are examined for transmitting signals. The message contains transmission parameters like CINR, RSSI, RE, RCF, IMF and RSF, each of size one bit.

Modulation and coding levels of each MS in the current frame for the Downlink (DL) and Uplink (UL) are sent at a rate that can be correctly received by all the nodes. To enable transmission via cooperative relaying, the decision is made by the Gateway.

After selecting the RSs, the information to be transmitted is encoded based on the CSI. The information code is mapped with the coding table and the codeword is obtained. The codeword is forwarded to the next hop node. The information is retrieved by decoding the codeword.

VI. IMPLEMENTATION

In this section, the results obtained after simulation are discussed. It is assumed that a MS entering the network routes the traffic to the BS through the selected RSs and forwards the packets to the destination.

The traffic in the network is classified into UGS, rtPS, nrtPS and BE and scheduled. The PHY layer performance metrics and the simulation parameters for the implementation are shown in Table II.

The delay, message drop, Packet Delivery Ratio (PDR), throughput, slot reuse and control overhead for the two schemes are shown in the following graphs.

TABLE II. SIMULATION PARAMETERS

Parameters	Value
MAC	802.16m
Routing Protocol	AODV
Queue type	Queue/Droptail/ PriQueue
Queue Size	50
Transmit Power (RS and MS)	200 mW
WiMAX frame size	5 ms
WiMAX spectrum bandwidth	5 MHz
Cooperative field size in network entry message	1 byte
Number of (OFDMA symbols, subcarriers)	(48, 512)
CINR field size in REP-REQ/REP-RSP	1 byte
CID size in REP-REQ/REP-RSP	2 byte
Modulation and Coding for CoopMAX Signaling Messages	16QAM ¾
UL/DL Bandwidth Ratio	1:3
Maximum number of helpers per MS	10

ERS scheme yields 15.48% greater throughput when compared to CoopMAX protocol (Fig. II).

ISSN: 2278 – 7798

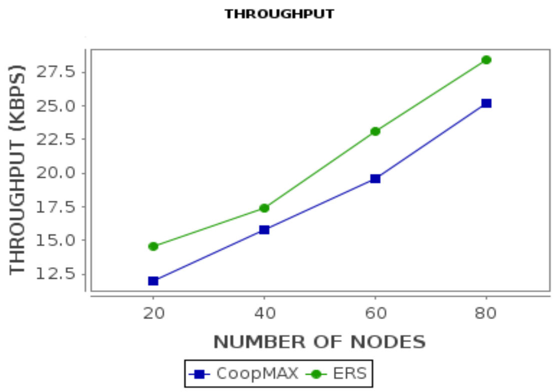

FIG. II THROUGHPUT

CoopMAX protocol offers 26.08% lesser PDR when compared to the ERS scheme (Fig. III).

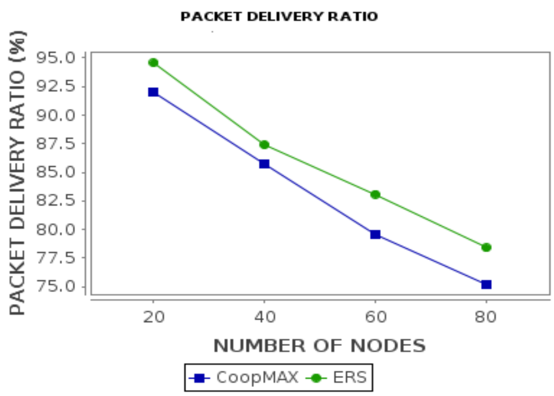

FIG. III PACKET DELIVERY RATIO

ERS scheme involves 29.47% lesser delay when compared to the CoopMAX protocol (Fig. IV).

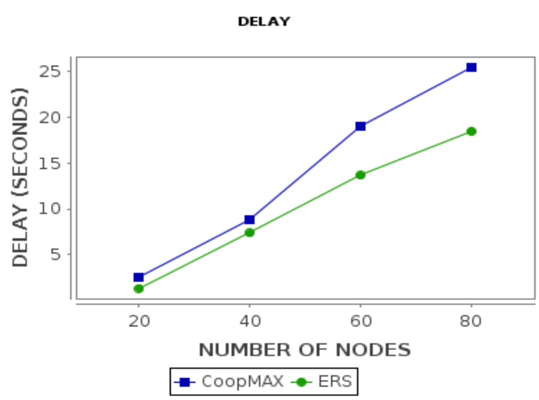

FIG. IV DELAY

CoopMAX protocol involves 19.15% more message drops when compared to the ERS scheme (Fig. V).

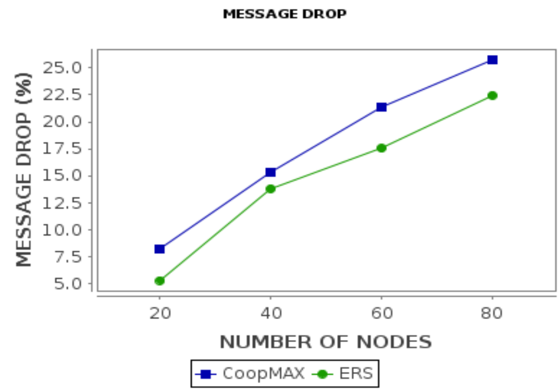

FIG. V MESSAGE DROP

ERS scheme offers 3.4% more number of slots for reuse when compared to the CoopMAX protocol (Fig. VI).

FIG. VI SLOTS REUSED

ERS scheme involves 26.08 % lesser control overhead when compared to the CoopMAX protocol (Fig. VII).

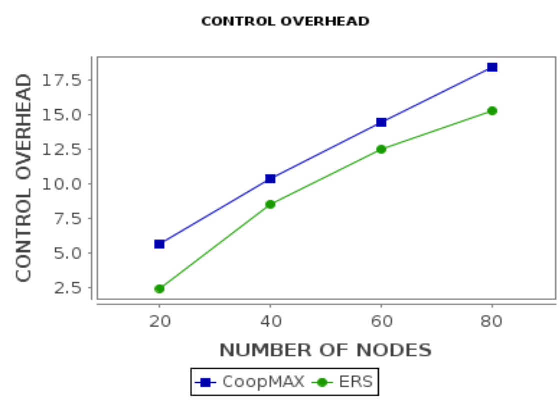

FIG. VII CONTROL OVERHEAD

The performance results are discussed in the Performance Analysis table (Table III).

ISSN: 2278 – 7798

TABLE III. PERFORMANCE ANALYSIS

PERFORMANCE ANALYSIS		NUMBER OF NODES				Performance (%)
		20	40	60	80	
Control Overhead	**CM**	5.65	10.38	14.42	18.39	**26.08**
	ERS	2.47	8.54	12.49	15.28	
Delay (Seconds)	**CM**	2.49	8.79	19.07	25.43	**29.47**
	ERS	1.34	7.38	13.67	18.48	
Message Drop (%)	**CM**	8.29	15.38	21.41	25.72	**19.15**
	ERS	5.32	13.82	17.56	22.47	
Packet Delivery Ratio (%)	**CM**	92.02	85.76	79.57	75.23	**3.32**
	ERS	94.56	87.38	83.09	78.39	
Number of Slots Reused	**CM**	92	85	79	75	**3.40**
	ERS	94	87	83	78	
Throughput (KB)	**CM**	12.02	15.76	19.57	25.23	**15.48**
	ERS	14.56	17.38	23.09	28.39	

VII. CONCLUSION

The Enhanced Relay Selection (ERS) scheme provides an efficient support for seamless packet transmission and selects optimal RSs. The MAC layer performance is measured in terms of net aggregated throughput, control overhead of sounding zone, channel estimation and cooperation control. This scheme provides an efficient cooperative relaying. The relay selection based on CSI offers high performance, yielding high throughput and low computational complexity. Further, by choosing appropriate RSs, more number of slots is reused.

REFERENCES

[1] IEEE 802.16 Working Group, "IEEE Standard for Local and Metropolitan Area Networks. Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems. Amendment 3: Management Plane Procedures and Services," IEEE Standard, 802, 2006.

[2] S. Ahmadi, "Mobile WiMAX: A systems approach to understanding IEEE 802.16m radio access technology," Academic Press, 2010.

[3] W. Ni, G. Shen, and S. Jin, "Cooperative relay approaches in IEEE 802.16j," IEEE C802.16j-07/258r1, IEEE 802.16 Broadband Wireless Access Working Group, Apr. 2007.

[4] C. Nie, P. Liu, T. Korakis, E. Erkip, and S. S. Panwar, "Cooperative Relaying in Next-Generation Mobile WiMAX Networks," IEEE Trans. Vehicular Technology, vol. 62, no. 3, pp. 1399-1405, 2013.

[5] C. Bettstetter, "Mobility modeling in wireless networks: categorization, smooth movement, and border effects," ACM SIGMOBILE Mobile Computing and Communications Review, vol. 5, no. 3, pp. 55-66, 2001.

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

[7] Y. Yang, H. Hu, J. Xu, and G. Mao, "Relay technologies for WiMAX and LTE-advanced mobile systems," IEEE Communications Magazine, vol. 47, no. 10, pp. 100-105, 2009.

[8] Z. Zhang, T. Lv, and S. Yang, "Round-robin relaying with diversity in amplify-and-forward multisource cooperative communications," IEEE Trans. Vehicular Technology, vol. 62, no. 3, pp. 1251-1266, 2013.

[9] R. Mesleh, and S. S. Ikki, "Performance analysis of spatial modulation with multiple decode and forward relays," IEEE Trans. Wireless Communications Letters, vol. 2, no. 4, pp. 423-426, 2013.

[10] H. M. Alazemi, and M. F. Uddin, "Fair resource allocation and DF relay selection for multiuser OFDMA-based cooperative networks," IEEE trans. Wireless networks, vol. 19, no. 6, pp. 1485-1496, 2013.

[11] J. M. Chang, W. T. Hsiao, J. L. Chen, H. C. Chao, and J. H. Park, "Navigation-based self-optimization handover mechanism for mobile relay stations in WiMAX networks," Telecommunication Systems, pp. 1-8, 2013.

[12] J. Liu, X. Lei, H. Cao and M. Jin, "Optimal relay allocation strategy based on maximum rate in two-user multi-relay system," Journal of Modern Transportation, vol. 21, no. 1, pp. 66-71, 2013.

[13] M. Alam, J. Mark, and X. U. E. M. I. N. Shen, "Relay selection and resource allocation for multi-user cooperative OFDMA networks," pp. 1-13, 2013.

ISSN: 2278 – 7798

[14] A. P. Subramanian, M. M. Buddhikot, and S. Miller, "Interference aware routing in multi-radio wireless mesh networks," 2nd IEEE Workshop on Wireless Mesh Networks, IEEE WiMesh 2006, pp. 55-63, Sep. 2006.
[15] Y. Zhao, R. Adve, and T. Lim, "Beamforming with limited feedback in amplify-and-forward cooperative networks," IEEE Trans. Wireless Communications, vol. 7, no. 12, pp. 5145-5149, 2008.
[16] Z. Becvar, P. Mach, and M. Vondra, "Optimization of SINR-based Neighbor Cell List for networks with small cells," IEEE 24th International Symposium on Personal Indoor and Mobile Radio Communications (PIMRC), pp. 2346-2351, Sep, 2013.
[17] O. Munoz-Medina, J. Vidal, and A. Agustín, "Linear transceiver design in nonregenerative relays with channel state information," IEEE Trans. Signal Processing, vol. 55, no. 6, pp. 2593-2604, 2007.
[18] S. Zhou, J. Xu, and Z. Niu, "Interference-Aware Relay Selection Scheme for Two-Hop Relay Networks with Multiple Source-Destination Pairs," vol. 1, no. 1, 2013.
[19] S. W. Peters, and R. W. Heath, "The future of WiMAX: multihop relaying with IEEE 802.16 j," IEEE Communications Magazine, vol. 47, no. 1, pp. 104-111, 2009.

ISSN: 2278 – 7798