ISSN(Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 2, February 2015

Performance Analysis of Relay-Aided Cellular Networks

P.Mangayarkarasi [1], K.Sudha Selvarasi [2], Dr.S.Jayashri[3]

Assistant Professor, Department of ECE, Adhiparasakthi Engineering College, Melmaruvathur, Tamilnadu, India[1]

PG Scholar, Department of ECE, Adhiparasakthi Engineering College, Melmaruvathur, Tamilnadu, India[2]

Professor, Department of ECE, Adhiparasakthi Engineering College, Melmaruvathur, Tamilnadu, India[3]

ABSTRACT: Energy efficiency in cellular networks has been receiving significant attention in wireless communication, because of the importance in reducing the energy consumption and maintaining the profitability of networks, in addition it makes these networks "greener". In the traditional cellular architecture, the urban cell topography increases the capacity along with the coverage require the deployment of a large number of base stations (BSs). This approach is cost prohibitive and also increase the mobile station (MS) transmission power. An alternative, relaying techniques are expected to alleviate the coverage problem and reduce the MS transmission power. To propose a geometrical model for the energy efficient relay station (RS) placement that requires only a small number of characteristic distances and is to estimate the maximum cell coverage of a relay aided cell, given power constraints. This proposed method analyzes the path loss model based on RS to BS link and it compares both cell coverage and energy efficiency using Decode and Forward (DF) relaying schemes in line of sight conditions.

KEYWORDS: Relay aided cellular networks, Decode and Forward relaying, Energy efficiency, Coverage capacity.

I. INTRODUCTION

Relay aided transmissions provide significant coverage extension and energy gain in cellular networks. The cellular principle partitions a geographical area into cells containing each, a base station and a number of mobile terminals. The application of the relay concept to cellular networks, however, raises, many technical issues such as the best position of relay station (RS) placement, coverage extension, energy consumption etc. Relays have been introduced in the evolving cellular systems as a solution to improve the system coverage and increase the user capacity in cellular region. Multiple types of relaying methodologies have been proposed to achieve these goals. The notion of Relay Efficiency Area and a geometrical model for energy efficient relay placement, for both uplink and downlink transmissions, which allows meaningful performance analysis without the need for excessive simulations. The urban cell RS placement model is used to compare both the energy consumption and coverage capacity based on above rooftop model (relay to base station link based on distance).

Recently relay networks have been widely considered as supplementary technology in next generation wireless systems such as Fifth generation (5G), Third Generation Partnership project-Long Term Evolution (3GPP-LTE) and LTE-A is envisioned as part of future heterogeneous networks, along with macrocell, picocell, and femtocells [1]. Relaying in IEEE 802.16m is performed using a decode and forward paradigm. Both time division duplex (TDD) and frequency division duplex (FDD) modes are analyzed [2]. Heterogeneous networks based on different access technologies and challenges associated with the deployment of traditional macro base stations can be overcome by the utilization of base stations with lower transmit power was studied [3]. Resource allocation and relaying strategies in cooperative systems targeted to improving the cell capacity or spectral efficiency [4]. To compare the system capacity according to the throughput oriented and signal strength oriented relay selection rules, with considering the effect of relay location [5]. The proper planning of RS placements, the capacity of IEEE802.16j networks can be greatly enhanced by RSs, especially when hotspots are present [6]. To analyse different relaying strategies, amplify-forward, decode-forward and compress-forward, and compare their spectral efficiency [7]. The impact of relay station placement on the network performance in the IEEE 802.16j network was studied. Specifically, the throughput maximization relay station placement problem is mathematically formulated and its complexity was analysed [8]. Cross-layer resource allocation

IJIRSET

ISSN(Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

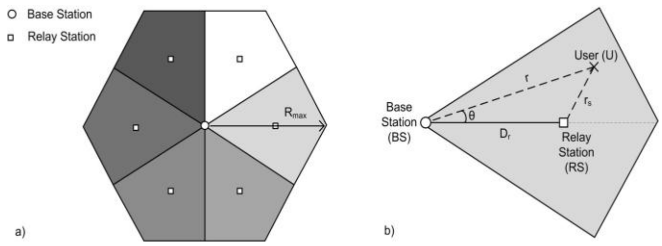
Vol. 4, Issue 2, February 2015

can efficiently support diverse QoS requirements over wireless relay networks. Both AF and DF relays shows significant superiorities over direct transmissions when the delay QoS constraints are stringent. [9]. The Mobile multi hop relay networks (MMR) to analyse the scalability of a wireless network is usually limited by the system radio bandwidth and channel interference. The radio resource management which target at addressing capacity enhancement have been extensively reported , and most of the research efforts at maximizing resource utilization [10]. Relay station (RS) provide less functionality compare than the BS can forward high data rates to remote areas of the cell while lowering infrastructure cost [11]. The synergy between OFDMA and relaying techniques offers a promising technology for providing high data rate to WSs everywhere, at anytime [12].

II. SYSTEM MODEL

This system presents the cell and path loss models. There are two path loss models depending on the relay being below or above rooftop. This system model analyze the path loss model based on the relay to base station link (above rooftop model).

A. System model for relay placement analysis:



a)Hexagonal cell b)User location (rooftop mode

Fig1: System model for a 6-sector urban cell

Consider a 6-sector hexagonal cell. R_{cov} refers to the maximum radius in hexagonal cell, which includes the coverage extension provided by the relay station.

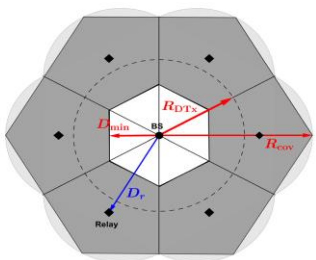


Fig2: A model for Relay Efficiency Area(REA)

The base station is located at the center of the cell and each sector is provided with a relay station, located at a distance D_r from the base station. The 16 users are placed in random manner in a given cell area. Consider the urban cell model, and H_B, H_R and H_U denotes the heights of the base station, the relay station and the user respectively and r_s refers to the distance from the user to relay . The multiple access strategy allows right-angled (orthogonality) between users, such that only one user is served for a given time and frequency resource. To assume the relay operates in the same frequency resource as the user it serves (in band relaying).

B. Channel model for half-duplex relaying:

The channel model for half duplex relaying performed in time division. Half duplex relays have one transceiver, so the relay transmits and receives on the same sub channel on two timeslots. In the first timeslot, the source sends the data to the receiver and the relay overhears (assuming cooperative relaying) the data. In the second timeslot, the relay resends the data after some processing to the receiver which then combines the received signals from the relay station as well as

ISSN(Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 2, February 2015

from the source through the direct link using some combination techniques, such as, Maximum Ratio Combining (MRC). Here, a transmission of unitary length is carried out in two phase of equal duration. And denote the transmitted code words X_1 and X_2 for the user at each phase respectively, and X_r for the relay. Y_r and Y_1 respectively are the received signals at the relay and destination at the end of phase 1, Y_2 is the received signal at the destination at the end of phase 2. Thus, the half duplex relay channel is written as follows:

$$Y_r = h_s X_1 + Z_r \,;\; Y_1 = h_d X_1 + Z_1;\; Y_2 = h_d X_2 + h_r X_r + Z_2 \qquad (1)$$

where Z_r, Z_1 ,Z_2 are independent additive white Gaussian Noises (AWGN) with equal variance N. This system respectively denotes h_d, h_s and h_r the channel from user to base station (direct link), from user to relay and from relay to base station. Consider the following path loss models: 1)Vicinity relay: The relay station is located below rooftop, implying that the user to relay link is generally strong but at the cost of a weaker relay to base station link 2) Base station like relay: The relay station is located above the rooftop, like a base station, the h_r(Base station to relay) link is very strong. In the system model for urban cell topography considers only in above rooftop model (Base station like relay) based on the BS-RS distance based link.

III. RELAYING SCHEMES AND POWER ALLOCATIONS FOR ENERGY EFFICIENCY

This system presents the full decode and forward coding scheme for half duplex time division relaying. For each coding scheme, the power allocation minimizes the energy consumption while maintaining a given user rate R. The user and the relay have individual power constraints over the two transmission phases within the same bandwidth, respectively denoted as P_U(max) and P_R(max).Relay aided uplink transmissions, two schemes are considered in full decode forward relaying scheme.Full decode and forward scheme: In the relay aided scheme, the user sends its message to the base station with rate 2R and power P_U. Then, the relay decodes the message, re-encodes it rate 2R and forwards it to the destination with power P_R . Two main decoding techniques are generally considered. 1)Two hop relaying: It is used in practical system, in which the base station only considers the signal received from the relay and thus the relay is merely a repeater. 2)Repetition coded decode and forward: The base station uses Maximum Ratio Combining (MRC) and combines the signals received from both the user and relay. The power allocation set(P_U,P_R) satisfies the following constrains:

$$\frac{1}{2} P_U \le P_U(\max) \text{ and } \frac{1}{2} P_R(\max) \qquad (2)$$

The allocation set which minimizes the energy consumption is

$$P_U = (2^{2R}-1)\frac{N}{|h_s|^2} \text{ and} \qquad (3)$$

$$P_R = (2^{2R}-1)\left(1-\alpha\left|\frac{h_d}{h_s}\right|^2\right)\frac{N}{|h_r|^2} \qquad (4)$$

In the urban cellular network relay aided transmission considering path loss only, combining the signals received from both the user and relay station as done in repetition coded full decode and forward only brings little energy gain compared to two hop relaying. The relay aided transmission is more energy efficient than the direct transmission is an out of range. Subsequently, to consider two hop relaying and repetition coded decode and forward as two variants of the same reference scheme, denoted as Full Decode-Forward (Full-DF).

Characterization of Efficient Relay Placement: The characterization of efficient relay placement define the relaying efficiency, both in terms of energy consumption and coverage extension. This system introduce the notion of Relay Efficiency Area (REA), and build our geometrical model based on the Relay for both uplink and downlink transmissions.

Analytical model for Relay Efficiency Area: A relay aided cell is characterized by the probability for a user to be served by the relay station and by the energy saved by using the relay. On the contrary, of the message is relayed, leading to sufficient energy gain to compensate for the shorter transmission duration. With regard to downlink, this relaying condition is relevant for the full decode and forward scheme, $|h_d|^2 \le |h_r|^2$, which is always satisfied since the relay to base station link is very strong. The area of a cell sector can be expressed as follows:

$$A_{sector} = \frac{\sqrt{3}}{4} Rcov^2$$

ISSN(Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 2, February 2015

Totally 16 users are placed in a cell. The center node is act as base station and the six green nodes are relay station. In this mobile nodes are placed in infeasible direct transmission to base station and it is placed in small characteristic distance from base station. In this mobile nodes are placed in feasible relay aided transmission to relay station. These characteristic distances, as defined above, allow the direct computation of the overall probability of relaying a communication, given that the user is randomly located in the cell, as well as the average consumed energy to successfully transmit data in the line of sight propagation mode.

IV A. ANALYSIS OF RELAY EFFICIENCY AREA (REA) FOR DECODE-FORWARD SCHEMES

The analysis of REA compute the sixteen characteristic distance (user position) for full decode and forward in relay aided transmission for both uplink and downlink transmission. These characteristic distances are derived from the channel condition. The common condition for relaying is expressed as follows,

$$R_{DTx} = \left(\frac{P_i}{K_d\, N(2^R - 1)}\right)^{10/Ad} \quad (5)$$

where A_d and K_d are given by path loss model constants dependent on the global location of the transmitter and receiver(rooftop model). $P_i = P_U(\max)$ for uplink and $P_i = P_R(\max)$ for downlink. Where R_{DTx} refers to relay-aided transmission.

Conditions for energy efficiency of full decode-forward (Full-DF):
First, this system model focus on energy efficiency and derive the conditions for which the energy consumption using full decode-forward (denoted E_{DTx}) relaying scheme. The energy efficient condition can be seen as the dual of the throughput oriented condition is expressed as follows,

$$\log 2\left(1 + \frac{P_s |h_d|^2}{N}\right) \leq \frac{1}{2}\log_2\left(1 + \frac{2P_S |h_s|^2}{N}\right) \quad (6)$$

$$E_{DTx} \geq E_{DF} \quad (7)$$

$$\Leftrightarrow \alpha K_s K_r D_r^{(Ar/10)} \leq K_d r^{(Ad/10)}\left[K_s - \left(\frac{2}{2^R+1} K_d r^{(Ad/10)} - K_r D_r^{(Ar/10)}\right)\frac{1}{r_s A_s/10}\right] \quad (8)$$

$$\text{where } r_s{}^2 = D_r^{\,2} + r^2 - 2D_r r\cos(\theta)$$

In this above equation r_s represents distance from user to relay station. D_r represents distance from base station to relay station. K_d are given by path loss model constants dependent on the global location of the transmitter and receiver(rooftop model). K_s are given by path loss model constants dependent on the global location of the transmitter. K_r are given by path loss model constants dependent on the global location of the relay station and r represents distance from user to base station. Note that Eqn. (4) is symmetric in h_s and h_r, meaning that it is valid for both uplink and downlink. The solution of Eqn. (4) for $\alpha = 0$ is almost solution for $\alpha = 1$. α refers that path loss exponent. In above rooftop (relay to base station link) model to described the coverage capacity and energy efficiency based on the base station to relay station distance variation.

IV B. ESTIMATED PROBABILITY OF RELAYING AND AVERAGE ENERGY CONSUMPTION

The estimated probability of relaying for relay aided communication to assume that the user is randomly located in the cell and that the location distribution is uniform. Such distribution allows us to derive a simple expression of the probability of relaying. The probability of relaying, denoted P_{RTX} is obtained by the ratio of relaying area vs. total area and is expressed as follows for hexagonal cells,

$$P_{RTx} = 1 - \frac{8}{\sqrt{3R_{COV}\,2}}\left(\frac{D_{min}{}^2}{2}\tan(\varphi) + \frac{R^2{}_{DTx}}{2} + \frac{3}{8}R_{COV}{}^2\tan\left(\frac{\pi}{6} - \emptyset\right)\right) \quad (9)$$

Conditions on φ and ϕ are defined based on geometrical
principles of a cell sector angles in upper bound and lower bound depend on $D_{min} \leq x$ or (x,y)€ C(0, RDTx). D_{min} refers to as minimum distance (200 meters ie., relay to base station link is strong) in above rooftop model. The user is positioned is longer distance to base station. So the user to Base station strength is too weaker. Compute the relay energy consumption in full decode and forward relay scheme as follows,

ISSN(Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 2, February 2015

$$\check{E}[E_R(DF)]=(2^{2R}-1)\frac{N}{2}K_rD_r^{(Ar/10)} \quad (10)$$

Where D_r is the distance from relay to base station. Where K_r is the global location of the relay station in above rooftop model. Where A_{sector} and P_{RTx} are as defined in Eqn. (4) and Eqn. (9) respectively. These expressions for the user and relay consumptions conclude the analysis of Relay Efficiency Area.

V. EXPERIMENTAL RESULTS

The performance obtained by relay aided transmissions, highlight the energy efficient relay configuration (placement). In this below figure 3 shows base station (pink colour) is placed in centre position, black colour nodes denotes mobile users and green colour denotes energy efficient relay station. In this geometrical model for energy efficient relay placement provide better coverage to cell edge users based upon the above rooftop model (relay to base station strength based on distance).

Table I
Simulation Parameters

Carrier frequency	f_c= 2.6Ghz
Relay power	1Watts
User power	500 mW
Base station height	30m
User height	1.5m
Relay height	15m
User rate	Ɽ=3bits/s/Hz
R_{cov}(maximum radius)	2000m
No of base station	1
No of relay station	6

Table II
COVERAGE VERSUS ENERGY EFFICIENCY USING DECODE AND FORWARD SCHEMES

Distance (RS-BS) (meters)	Coverage Area (meters)	Energy Consumption (joules)	Energy Gain (joules)
200	1110	140.5	7.15
250	1120	143	7.55
300	1130	147.5	7.9
350	1140	149.5	8.3
400	1150	151	8.65
Distance (RS-BS) (meters)	Coverage Area (meters)	Energy Consumption (joules)	Energy Gain (joules)
450	1160	152	8.75
500	1170	153.5	8.82
550	1180	154	8.9
600	1190	154.5	8.99
650	1200	154.5	8.98
700	1210	154.5	8.97
750	1220	154.5	8.95
800	1230	154.5	8.93

ISSN(Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 2, February 2015

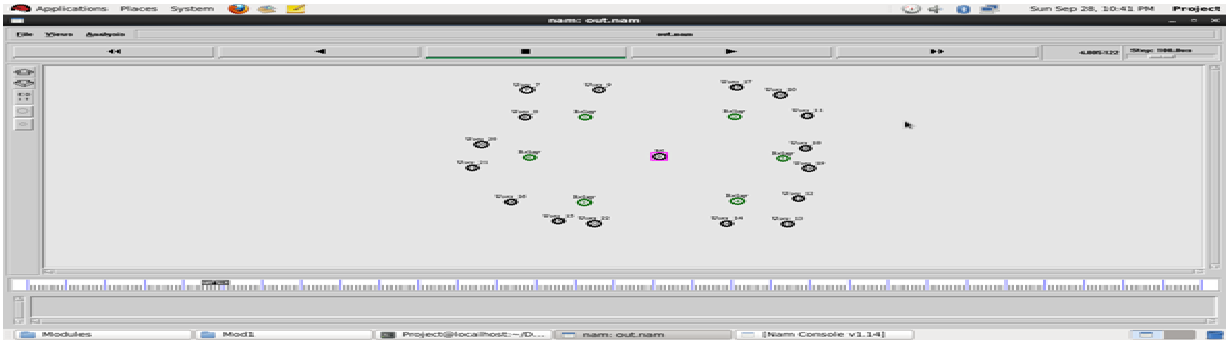


Fig3: Relay placement model in urban cell topography

In the above figure 3 shows the geometrical model for energy efficient relay placement position in the urban cell. In the relay placement model, six relays are placed in fixed position in a cell. The base station covers the all areas in a cellular region with the help of relay station in lower power consumption. So the mobile user does not need high power to transmit the data to destination and also the cell edge users are connect effectively to base station without packet loss or avoid path loss in the (transmission range distance is larger between source to destination) longer distance. In the below figure 4 shows the data transmission in the propagation environment.

Fig4:Data transmission from source to destination

The packet is forwarding from source to destination with the help of relay station as illustrated in figure 4.The performance analysis based on the relay to base station distance is varied from 200m to 800m it covers 55% area in minimum distance. (relay to base station distance) in the above rooftop model as illustrated in figure 5. To increase the relay to base station distance from 200m to 800m at the time the link capacity between base station to relay station is reduces.

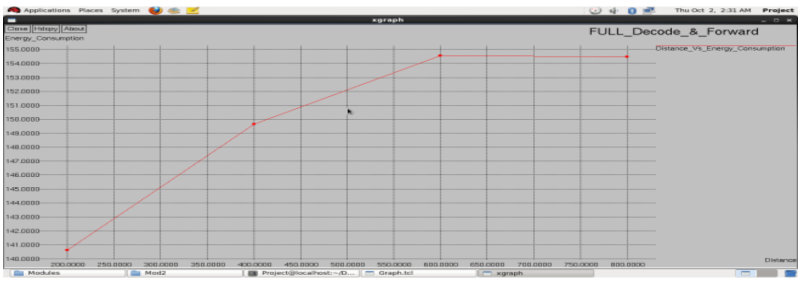


Fig5:Energy consumption vs distance (relay station-base station)

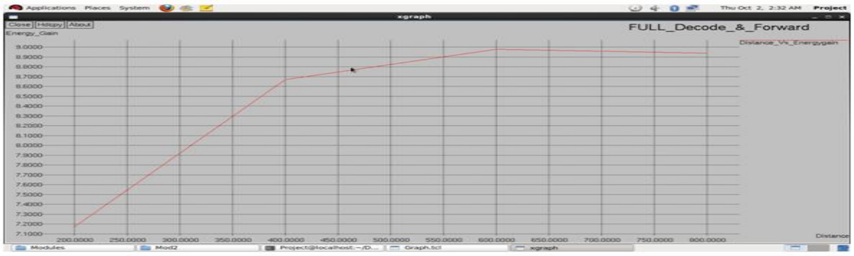


Fig6:Energy gain vs distance(relay to base station)

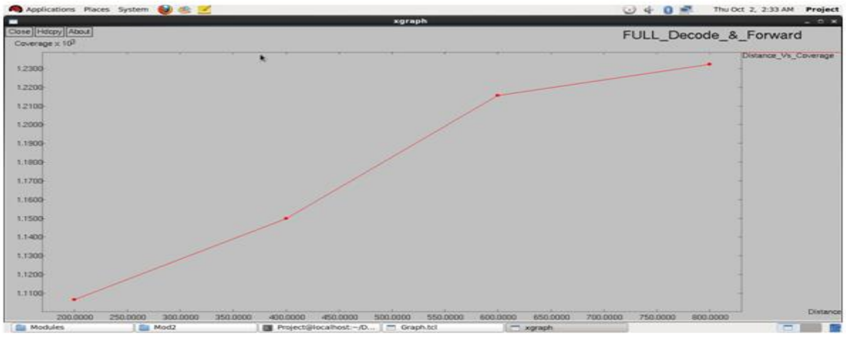


Fig7: coverage vs distance(base station-relay station) using full decode and forward relaying

The performance analysis based on the link capacity in the relay aided transmission obtained the energy gain 35% in the BS-RS link (minimum distance) is strong (link capacity strength is high). And it is obtained energy gain 11% only in BS-RS link (maximum distance) is weak (link capacity strength is low) as illustrated in figure 6. In this simulation result, figure 7 shows RS-BS distance based coverage. The RS-BS minimum distance covered 1110m. The RS-BS maximum distance covered 1230m. To investigated relay placement for noise limited urban cells. The urban cell coverage capacity and energy gain are analyzes based on the relay base station link (vary the distance between relay to base station) using full decode and forward relaying scheme is shown in figure 5,6 and 7.

VI. CONCLUSION

Analyze the geometrical model for evaluating energy efficiency and coverage extension, and highlighted that a trade-off exists between them. Two options can be deduced from this work to efficiently deploy relays in a cell and use two hop routing. In this case, attention has to be paid carefully positioning the relay station, so as to provide close to the optimal coverage and energy gain. With regards to heterogeneous networks, the relay should be deployed in proper position such that increasing the cell coverage has a minimal impact on energy efficiency.

REFERENCES

[1] A. Ghosh, R. Ratasuk, B. Mondal, et al., “LTE-advanced: next generation wireless broadband technology [Invited Paper],” IEEE Wireless Commun., vol. 17, no. 3, pp. 10–22, 2010.

[2] K.Loa, C.-C.Wu, S.-T.Sheu et al., “IMT-advanced relay standards [WiMAX/LTE update],” IEEE Commun. Mag., vol. 48, no. 8, pp. 40–48, 2010.

[3] A.Damnjanovic, J. Montojo, Y. Wei, et al., “A survey on 3GPP heterogeneous networks,” IEEE Wireless Commun., vol. 18, no. 3, pp.10–21, 2011.

[4] B. Lin, P. Ho, L. Xie, and X. Shen, “Optimal relay station placement in IEEE 802.16 j networks,” in Proc. 2007 ACM Int. Conf. Wireless Commun. Mobile Comput. Proc., pp. 25–30.

[5] L.-C. Wang, W.-S. Su, J.-H.Huang, et al., “Optimal relay location in multi-hop cellular systems,” in Proc. 2008 IEEE Wireless Commun. and Netw. Conf., pp. 1306–1310.

[6] J. Huang, L. Wang, C. Chang, and W. Su, “Design of optimal relay location in two-hop cellular systems,” Wireless Netw., vol. 16, no. 8, pp. 2179–2189, 2010.

[7] H.-C. Lu, W. Liao, and F. Lin, “Relay station placement strategy in IEEE 802.16j WiMAX networks,” IEEE Trans. Commun., vol. 59, no. 1, pp.151–158, Jan. 2011.

ISSN(Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 2, February 2015

[8] K. Sambale and B. Walke, "Decode-and-forward relay placement for maximum cell spectral efficiency," in Proc. 2012 European Wireless Conf. pp. 1-6.
[9] M.Alasti, B. Neekzad, J. Hui, and R. Vannithamby, "Quality of service in WiMAX and LTE networks," IEEE Commun. Mag., vol. 48, no. 5, pp. 104–111, May 2010.
[10] B. Lin, P.-H. Ho, L.-L. Xie, et al., "Optimal relay station placement in broadband wireless access networks," IEEE Trans. Mobile Comput., vol. 9, no. 2, pp. 259–269, Feb. 2010.
[11] G. Joshi and A. Karandikar, "Optimal relay placement for cellular coverage extension," in Proc. 2011 National Conf. Commun., pp. 1–5.
[12] R. Youssef, M. Helard, M. Crussiere, and J. Helard, "Effect of relaying on coverage in realistic deployment scenarios," in Proc. 2012 International Conf. Telecommun., pp. 1–5.

.