Performance Analysis of Relay Enhanced in LTE-Advanced Cellular Networks

Suhada Alias
Faculty of Electrical Engineering
Universiti Teknologi MARA
Shah Alam, Selangor, Malaysia
suhada.alias@gmail.com

***Abstract*— Relaying technology was introduced in Long Term Evolution (LTE) Release 10 to enhance coverage and throughput especially at cell edge area. It has been considered as one of feasible solutions for extending the coverage and improving network capacity due to its easy deployment with a comparatively low cost of installation and maintenance. This paper presents the performance of relay involving several scenarios within the LTE network. Each scenario undergone evaluations with several relay deployment environments to determine their performance impact on Symbol Error Rate (SER) and Signal to Noise Ratio (SNR). The evaluations are performed using Matlab simulation which is integrated with the Wireless World Initiative New Radio Phase 2 (WINNER II) channel model. This study has demonstrated enhancement in the network performance by transmitting signal through relay node than conventional transmission. Indirectly, it has also enhanced the spectral efficiency gain and quality of service by increasing the handover success rate and reducing transmission interruption.**

***Index Terms*—Relay, LTE-Advanced, SNR, SER.** *(key words)*

I. INTRODUCTION

Over the last decades, the mobile communication technology has undergone many changes including transition from analogue to digital transmission as early 1905[2]. It was followed by the evolution from 2G to 3G which offered better system capacity and provided higher quality of service at the time. The telecommunication industry has never stopped growing. Later, the fourth generation, LTE was introduced to provide access to wide range of advanced services with new level of user experience at anywhere and anytime. The increase numbers of mobile broadband penetration and mobile subscribers have catalyzed the high usage of data, which is projected to keep growing for the foreseeable future. This is no exception for high demand in unfavorable radio propagation environment such as dense urban, rural area and indoor area [3].

The Third Generation Partnership Program also known as 3GPP has come up with a standard for mobile broadband access to meet the throughput and coverage requirements of a fourth generation cellular technology. The main objectives of this standard are to provide higher data rate, better spectrum efficiency, improved coverage and reduced latency. So, to ensure these objectives are being met, 3GPP has identified radio relay system as one of promising technological solutions in LTE-Advanced Release 10 [5]. Relaying technology is seen capable of meeting the growing demand for equitable access to the network coverage everywhere.

By having an intermediate relay node (RN) in between a base station (eNB) and user equipment (UE), the radio link is divided into two links. The link between eNB and RN is denoted as backhaul link, while the link between RN and UE is denoted as access link [7]. Both links shall have better propagation conditions in contrast to the direct link from eNB to the UE. Example of relay deployment is shown as in Figure 1 below

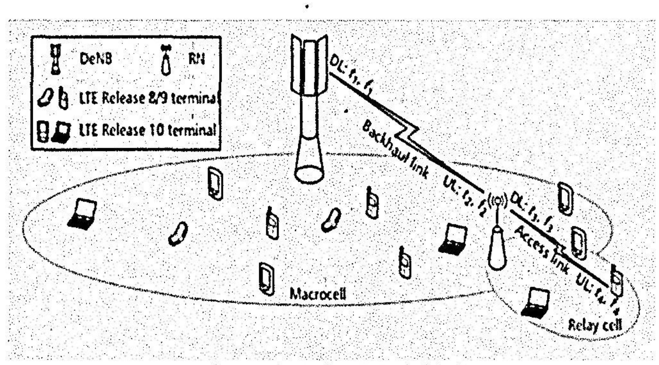

Figure 1: Relay Model [7]

RN reduces the distance of communication between eNB and UE and thus improving system capacity and end-to-end performance. Total of data transmitted or received by the eNB/UE increase over shorter distance as faster data rate can be delivered. Besides that, relay is a low cost solution for extending the coverage and improving the throughput of wireless network [5]. Saving substantial cost with deploying relay makes it one of the options considerable.

In the following sections, this article briefly explains on several relay deployment scenarios within the LTE network. Next, it examines the analysis of relay performance in each scenario. Later in the paper, conclusions and recommendation of future work related to this study are put forward.

II. MODELING OF RELAY DEPLOYMENT

A. System Model

Relay nodes (RNs) are defined as devices which are wirelessly connected to the radio-access network via a donor cell. It works as intermediary nodes and communicates with both their controller eNB and their controlled User Equipment (UE). There are several types of relay transmissions in communication; however this study is focused to a single type of RN, which is amplify-and-forward (AF) operation on the processed signals. The AF type of relay performs its function by amplifying the received signal and then retransmitting the amplified signal to the target destination [5].

In this paper, radio channel from the Winner Phase 2 (WINNER II) model has been selected for the performance analysis because it represents real-life radio channels with exceptional accuracy [4]. It has built-in with 17 propagation scenarios and follows a geometry-based and stochastic modeling element. Nevertheless, only four (4) different types of deployment scenarios are studied in the analyses namely, outdoor to indoor, typical urban microcell, bad urban microcell and indoor hotspot. Each scenario has been simulated to work in three (3) different environments as the following list;-

- without relay node;
- one relay with cooperative environment; and
- one relay without cooperative environment.

Figure 2 illustrates how environment without relay node works. It just considers one direct way of communication which is from eNB to UE.

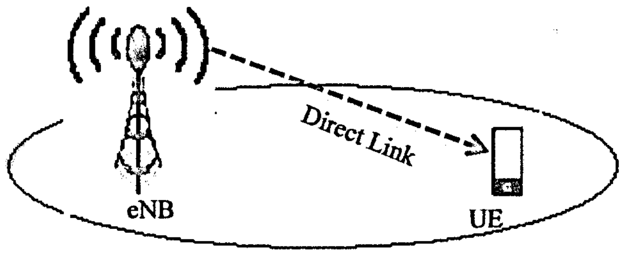

Figure 2: Without relay node. Only direct link is considered

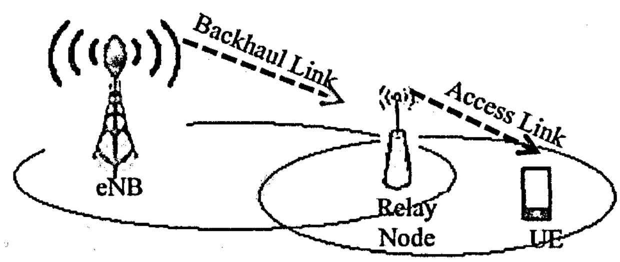

Figure 3: One relay in non-cooperative environment.

The setup of non-cooperative environment is, however quite different. Two hops of communications are designed with two separate radio link identified, as depicted in Figure 3 above which are backhaul link and access link. During the communication, signal is transmitted through a backhaul from eNB to UE first before it is transmitted from RN to UE via an access link.

Meanwhile, the cooperative environment is illustrated in Figure 4. *It implies a combination of both environments* mentioned earlier. First path is using the direct communication between eNB – UE whereas the second path is using the two hop communication via both backhaul and access link.

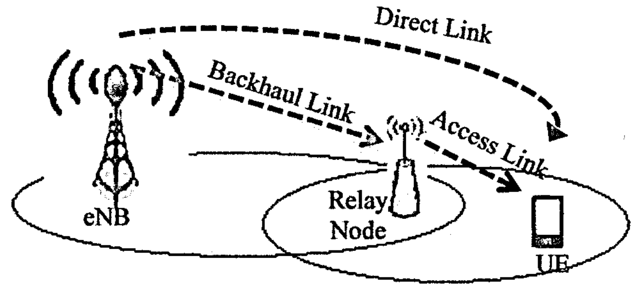

Figure 4: One relay in cooperative environment.

B. Simulation Scenarios

Based on Matlab documentation of Winner model [4], the propagation models are briefly described as follows:

B.1 Indoor to outdoor

The height of MS and BS antenna are measured just above the floor height. In this scenario, it is assumed to be at 1-2m and 2-2.5 m respectively. The calculation of the path loss for indoor-to-outdoor propagation scenario is given in equation (1) below.

$$PL_{NOS} = \left(10log_{10}(d) + 9.45 - 17.3log_{10}(h_{BS}) - 17.3log_{10}(h_{UE}) + 2.7log_{10}\left(\frac{f_c}{5}\right)\right) \times d + 14(15(1 - \cos\theta))^2 + 0.5d \quad (1)$$

B.2 Urban microcell

Both MS and BS antenna in the urban microcell model is assumed to be located at outdoors and lower than the tops of surrounding building. However, the BS is presumed to have a clear view, line-of-sight (LOS) from all location of the street. For this type of scenario, the path loss prediction is analyzed in the simulation using formulas as in equation (2) and (3) below.

$$PL_{LOS} = \left(40log_{10}(d) + 9.45 - 17.3log_{10}(h_{BS}) - -17.3log_{10}(h_{UE}) + 2.7log_{10}\left(\frac{f_c}{5}\right)\right) \quad (2)$$

$$PL_{NOS} = \left(P_{LOS} + 20 - 12.5n_j + 10n_j log_{10}(d) + 3log_{10}\left(\frac{f_c}{5}\right)\right) \quad (3)$$

B.3 Bad urban microcell

Bad urban microcell model has similar layout and path loss formula to previously mentioned scenario but different kind of shadowfading standard, which is 4dBm. Unlike typical urban microcell model, the multipath energy of distant object in the scenario can be received at several locations.

B.4Indoor hotspot

This model represents typical indoor coverage with low mobility but high traffic density such as in conference hall According to the Winner II channel specification, the dimensions of indoor hotspot could range from 20m × 20m up to more than 100m in length and width and up to 20m in height. The path lost equation for the model is in equation (4) below.

$$PL_{LOS} = \left(13.9log_{10}(d) + 64.4 + 20log_{10}(\frac{f_c}{5})\right) \quad (4)$$

where,

d = distance between transmitter and receiver (m)
h_{BS} = base station height (m)
h_{UE} = mobile station height (m)
f_c = carrier frequency (GHz)
θ = antenna aperture angle
n_j = max (2.8-0.0024d)

In addition to that, eNBs and UEs are distributed randomly with minimum distance as listed in simulation assumptions in Table 1. To further simplify the simulation, the relays are classified as normal amplify-and-forward (AF) relay as it works best in noise limited system.

Table 1: Simulation assumptions

Parameters	Values
Carrier frequency	2 GHz
Frequency bandwidth	20 MHz
Number of iteration	1000
Number of Relays	Without relay = 0; non-cooperative = 1; cooperative = 1
Height of eNB	30 m
Relay node transmitter power	40 W; 46 dBm
eNB power	1W; 30 dBm
Path loss	LOS / NOS
Data modulation format	QPSK
Channel model	Winner Phase 2
Minimum distance	eNB - relay node: 1000m
	UE – eNB: 2000m
	UE – relay node: 1000m
Power control	-56dBm, alpha = 0.6
Shadowfading std	Indoor-to-outdoor (7dB), urban microcell (3dB), bad urban microcell (4dB), indoor hotspot (3dB)

III. SIMULATION RESULTS

A Matlab-based system level simulation has been designed according to the 3GPP standard to analyze the performance of relay in the aforementioned scenarios. The process flow of the Matlab simulation is illustrated in Figure 5 [5].

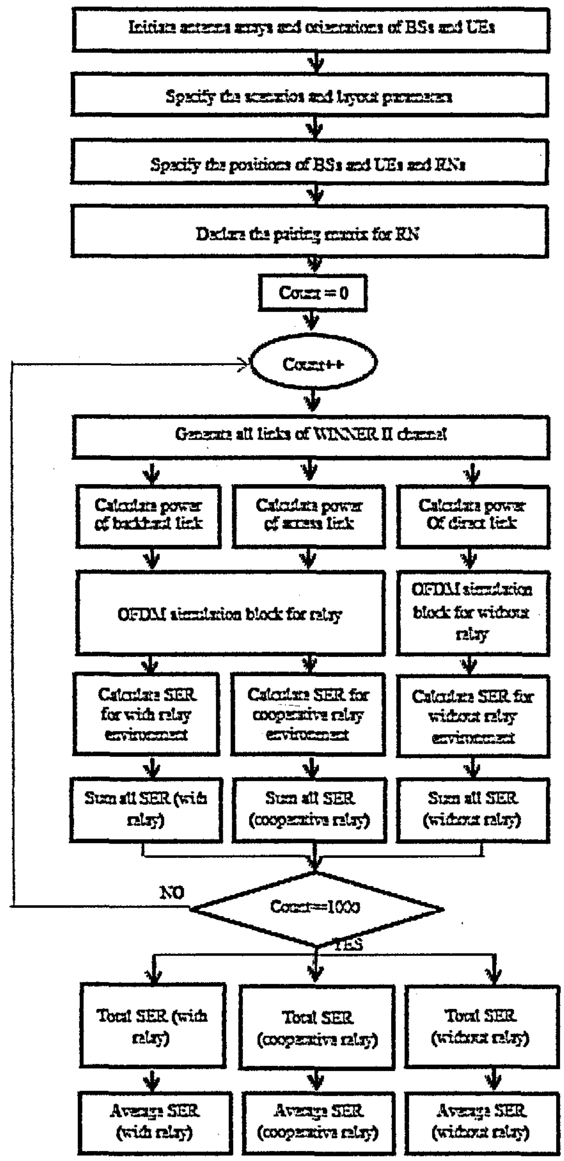

Figure 5: Flowchart of simulation algorithm

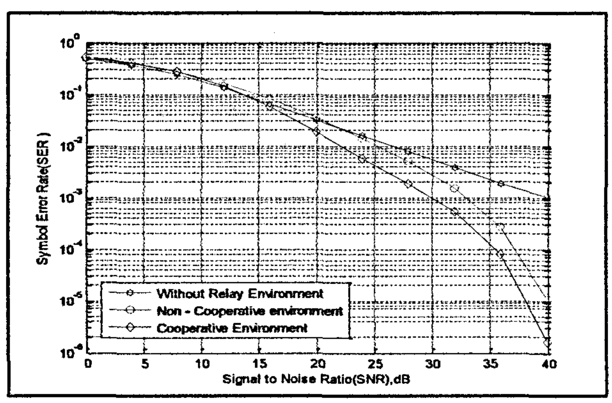

Figure 6: SER versus SNR results for indoor to outdoor scenario.

Based on the result in Figure 6, it can be observed that relay can potentially enhance the transmission diversity gain. For instance, at the level 10^{-3}, the cooperative environment yields a gain of 27dB. The non-cooperative and without relay environments however have higher SNR values which of 32dB and 36 dB respectively. Figure 7 and Figure 8 show the SER curve values of typical urban microcell and bad microcell scenarios. Resembling the result in Figure 6, the same assumption can also be made in both results for typical urban and bad urban microcell. That is to say, relay with cooperative environment demonstrates a substantial enhancement in upgrading the reliability of signal transmission.

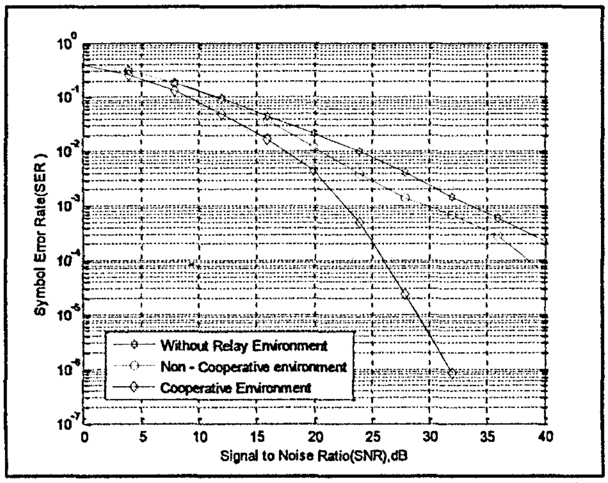

Figure 7: SER versus SNR results for typical urban microcell scenario

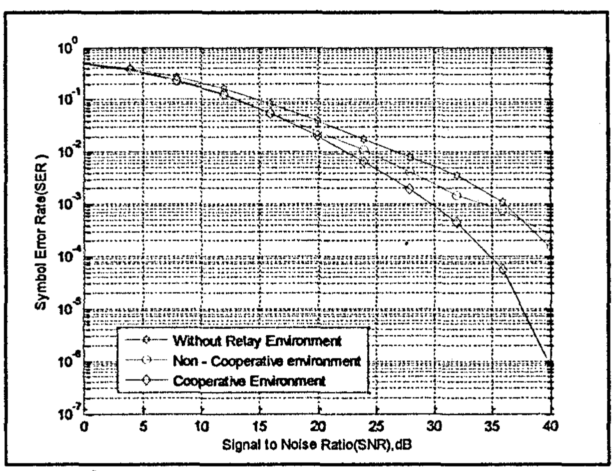

Figure 8: SER versus SNR results for bad urban microcell scenario

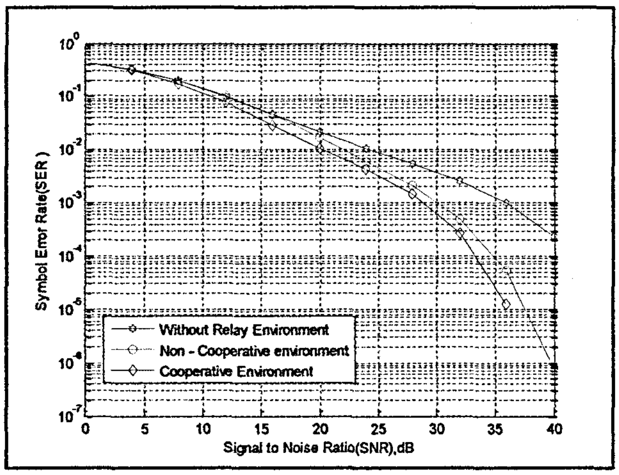

Figure 9: SER versus SNR for indoor hotspot scenario

Figure 9 above presents the SER curves for indoor hotspot. Although in general relay under cooperative environment seems to perform better than the rest of environments, the diversity gains of without relay, non-cooperative relay and cooperative relay, are much higher in hotspot indoor scenario with 32 dB, 34 dB and 40 dB. A contributing factor for the high SNR values could be due to the high shadowfading resulted from multipath propagation such as reflection or refraction against the wall.

IV. CONCLUSIONS AND FUTURE WORK

Relaying technology in 3GPP LTE network is a viable solution to boost the signal coverage and enhance system capacity. Three (3) different types of relay deployment scenarios have been deliberated in the study and results have demonstrated that the signal transmission can be improved with relay deployment.

The overall results also show that relay in cooperative environment has the best performance. Transmission signal in the cooperative environment operates via two different radio links and thus provides better performance than relay in non-cooperative and without relay environment. The added up two signals in cooperative environment results in a strong signal which is translated as lower symbol error rate in the SER curves. In short, it is observed that RN does help network performance.

Subsequent to the finding, it is recommended to perform further performance analysis for other types of scenarios in different relay deployments such as multi relay cooperative system in outdoor and so on. This is to help us understand the factors and effects of varying propagation model as well as to deploy relay wisely.

REFERENCES

[1] 3rd Generation Partnership Project (3GPP). TR 36.814 v9.0.0: Technical specification group radio access network; further advancements for EUTRA physical layer aspects (release 9), Sep. 2006.

[2] W. Liping, J. Yusheng, L. Fuqiang, "Joint Optimization for Proportional Fairness in OFDMA Relay-Enhanced Cellular Networks," Wireless Communications and Networking Conference (WCNC), pp1-6, April 2010, Sydney Australia

[3] A. Quaium, "Evolution of Relay-Enhanced LTE-Advanced Networks", April 2011

[4] L. Hentilä, P. Kyösti, M. Käske, M. Narandzic , and M. Alatossava. (2007, December.) MATLAB implementation of the WINNER Phase II Channel Model ver1.1

[5] T.C. Wen, M.L. Tzu, L.T.Shiao, "A Simple and Efiicient Data Forwarding Mechanism in Wireless Relay Networks," IEEE 69th Vehicular Technology Conference, PP1-5, April 2009

[6] S. Chen, W. Xiaojun, W. Weidong, C. Gaofeng, W. Xiaofei, "A Novel Route Selection Strategy in Decode-and-Forward Relay Enhanced LTE-A Network," Proceedings of the 2010 IET International Conference on Communication Technology and Application, pp 384-388, October 2011, Beijing, China

[7] H. Christian, C. Wanshi, G. Alexander, K. Chrsostomos, S. Xiaodong, "Relaying Operation in 3GPP LTE Challenges and Solution," IEEE Communication Magazine, pp156-162, February 2012

[8] R. Letian, E.E. Salah, B.H. Olfa, "Impact of relays on LTE-Advanced Performance," *Proceeding of the IEEE ICC 2010.*

[9] V. Venkatkumar, T. Wirth and T. Haustein and E. Schulz, "Relaying in Long Term Evolution: Indoor Full Frequency Reuse," Wireless Conference, 2009, pp. 298–302, May 2009.

[10] M. Salem, A. Adinoyi, M. Rahman, H. Yanikomeroglu, D. Falconer, K. Young-Doo, K. Eungsun, and C. Yoon-Chae, "An Overview of Radio Resource Management in Relay-Enhanced OFDMA-Based Networks," IEEE Commun. Surveys and Tutorials, vol. 12, no. 3, pp. 422 –438, Apr. 2010.

[11] 3GPP R1-084324, "Effect of Relaying on Coverage", Nokia Siemens Networks, Nov. 2008.

[12] R. Pabst et al., "Relay-based Deployment Concepts for Wireless and Mobile Broadband Radio", IEEE Communications Magazine, vol. 22, no. 6, Sep. 2004