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# Improving the eNodeB Coverage of a Bad Spot Area by Using A Relay Node

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ABSTRACT

The quality of LTE (Long Term Evolution) network in WR Supratman Street, Bandung is categorized as quite bad as shown by the average RSRP (Reference Signal Receive) and SINR (Signal to Interference Noise Ratio) values of -101.30 dBm and 2.43 dB, respectively. Both parameters are below the standard operator with the average RSRP and SINR standard values of ≥ -85 dBm and ≥ 5 dB, respectively. The previous field measurement indicated that the area belonged to a bad spot area caused by shadowing buildings. This study used the node scheme of decode and forward and physical mode of inband relay node with the aim of extending the eNodeB coverage. By applying this technique, the average RSRP value increased by 18% and the average SINR value increased by 53%. Based on the RF (Radio Frequency) parameters, the average RSRP value with samples below the -85 dBm standard improved by 81%, while the average SINR value with samples below 5 dB improved by 45%.

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## 1. Introduction

The LTE technology developed by 3GPP (The Third Generation Partnership Project) not only aims to speed up access to the uplink and downlink data but also reduces the latency either on the user or the transmitter. Besides the mentioned aspects, this technology introduces a newly developed multiple access type, i.e. OFDMA (Orthogonal Frequency Division Multiple Access), that can save up to 50% on the transmission bandwidth; in addition, the provided bandwidth can be combined (Carrier Aggregation) so that this technology has bandwidth scalability and flexibility aspects [1]. However, there are some problems that occur in the field; one of which is a bad spot area that causes a decrease in network quality as indicated by poor RSRP and SINR values.

Previous studies [2] suggest that relay nodes can extend the coverage of eNodeB by employing two types of relay node with a duplexing technique, i.e. half duplex. Additionally, another two studies have described the use of relay node with physical mode of inband relay node for expansion of coverage and increase in user capacity [3] and suggested that relay nodes can manage resource allocation and user allocation by applying the duplexing method of TDD (Time Division Duplexing) and the relay node scenario using 1 hop and 2 hops.

The previous field measurement indicated that the quality of LTE network in the area of W.R Supratman Street, Bandung was quite bad as shown by the average RSRP and SINR values of -101.30 dBm and 2.43 dB, respectively. Both parameters are below the standard operator with the average RSRP and SINR standard values of ≥ -85 dBm and ≥ 5 dB, so this area can be categorized as a bad spot area.

Based on the existing problem, the current study is aimed at optimizing the LTE network by using a relay node to increase eNodeB coverage in the bad spot area of intersection of W.R Supratman Street, Bandung which is currently surrounded by tall and big trees and high-rise (shadowing) buildings. This problem cannot be solved by using tilting antenna and power addition because these will affect the network quality of the surrounding sites.

## 2. Design

The e-NodeB coverage area is important to consider as this is the users' location in accessing the cellular network. Figure 1 illustrates a model used in the implementation of the relay node. A relay node model designed in this study was used to increase the bad eNodeB coverage caused by shadowing buildings. A relay node was placed in a point around the buildings which are located in a crossroad area (an urban hot spot area) in downtown Bandung. This area also has a high traffic.

### 2.1. Relay Node

The LTE (Long Term Evolution) has introduced a new technique that can be used to improve or expand network coverage and can increase the throughput of an LTE network. This technique is known as relay node [4]. A relay node is a fixed small cell commonly built in a dead zone, bad spot or densely populated areas. It is defined as one of the main aspects of LTE network that can be used to help the network to meet the requirements set by ITU (International Telecommunication Union) as one of the requirements to meet the specific criteria set by IMT (International Mobile Telecommunications)-Advanced system [5].

A relay node is directly connected wirelessly to the donor eNodeB. Subsequently, the relay will receive information, signals, and others from eNodeB after which those will be forwarded from the relay node to the user. A relay node is commonly placed on cell edges or areas within a site that has a bad coverage condition. In addition, a relay node can be used to increase the donor eNodeB capacity such as crowded streets in a city or office environment [6].

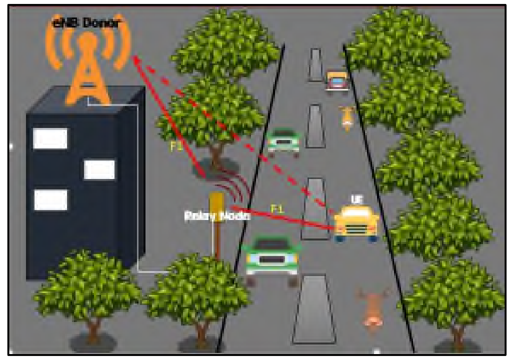


**Figure 1** A relay node model

This study used the transparent relay node since the distance from the node relay to the donor eNodeB was quite close and the users were still within the coverage of the donor eNodeB so the control signaling from the donor eNodeB can be accessed directly by the user equipment (EU), while the traffic data was passed through the relay node [7]. Meanwhile, the used antenna was the sector antenna. Figure 2 illustrates the transparent relay node configuration.

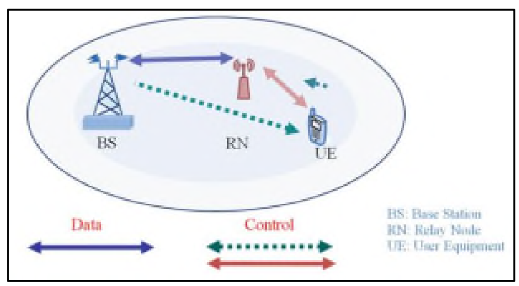


**Figure 2** Transparent relay node configuration

In this study, the relay node design applied the same frequency as the donor eNodeB, or commonly referred to as inband relay node [6] from which the access and backhaul links used the same frequency, but the access was separated in a time domain. Figure 3 illustrates the inband relay node configuration.

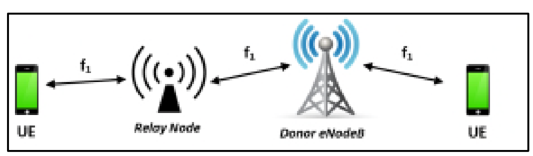


**Figure 3** Inband relay node

## 2.2. Urban Hot Spot Scenario

Relay nodes can be used in several area condition scenarios; one of which is an urban hot spot. A relay node can be used to improve throughput and improve coverage area, especially for high traffic areas such as at city stops. It also serves to improve signal quality that is attenuated as a result of shadowing buildings [8].

This study applied *a decode and forward*-type relay node. This type has a function similar to eNodeB, so using this type of relay node will minimize the interference with its donor eNodeB or eNodeB around the relay node area. In addition, the use of this type of relay node can increase throughput and minimize inter-cell interference and noise due to power amplification.

## 3. Methodology

### 3.1. Coverage Planning

The input parameters used in the coverage planning can be seen in Table 1 below [9][10].

**Table 1** Input parameters for coverage planning

| Input | Up Link (UL) | Down Link (DL) |
|---|---|---|
| Data Type Channel | Physical Uplink Shared Channel | Physical Downlink Shared Channel |
| Duplex mode | FDD | |
| Frequency | 1800 MHz | |
| System Bandwidth (MHz) | 10 | |
| MIMO Scheme | 2x2 | |
| User Environment | Indoor | |

### 3.2. Radius Relay Node

The radius value was obtained from the calculation using a propagation model which is suitable for the area and working frequency of a technology. The propagation model used in this study was COST-231 Hatta with some input parameters used to adjust with the specification of the propagation model [11][12][13]. The following Table 2 shows the input parameters for the calculation of the propagation model.

**Table 2** Parameters for the calculation of radius relay node

| No. | Input parameter | Specification of COST-231 HATTA | Usage |
|---|---|---|---|
| 1. | Frequency | 1500-2000 MHz | 1800 MHz |
| 2. | Height of antenna MS ($h_m$) | 1-10 m | 1.5 m |
| 3. | Height of relay node's antenna/eNodeB ($h_b$) | 30-200 m | 10 m* |
| 4. | MAPL | 128.609 dBm | |

*The height of the antennas was not in accordance with the specification since the type of relay antenna was installed in street lamps or existing poles with a height of approximately 10-15 m.

After getting the value of input parameters, the calculation of the relay node radius was subsequently performed. From the calculation, the used radius value of relay node was 0.427 km. This value was used as an input parameter in the optimization simulation using the software program Atoll 321.

## 4. Results

### 4.1. Placement of Relay Node

Before placing the node relay in the site, a placement simulation was needed to perform first. The simulation was done to obtain the targeted results.

**Figure 4** Placement of relay node

Figure 4 shows the location of the relay node, which is between the existing eNodeBs. The relay node uses 1 active sector antenna. The antenna is transmitted to the intersection of W.R Supratman Street, Bandung because the area belongs to an urban hot spot. The relay node coordinate is located at 6˚54'19.32" S, 107˚37'45.35" E.

### 4.2. Simulation Result Using Relay Node

After the simulation of the existing eNodeB placement, the relay node was placed. Afterward, the prediction area stage was performed to determine the values of RSRP and SINR. This stage was applied to prove that the node relay placement on the coordinate could improve the eNodeB quality.

(a) (b)

**Figure 5** Simulation result of node relay implementation using Atoll

The result of relay node placement as in Figure 5 (a) shows an increase in RSRP value by 18 dBm when compared to the initial drive test result, i.e.-101.30 dBm to -83.12 dBm.

In addition to the RSRP value, the prediction area based on the SINR value was also performed as in Figure 5 (b). The addition of a relay node on W.R Supratman Street indicates that the average SINR value is 10.16 dB. The result shows an increase of 7.73 dB when compared to the SINR initial drive test.

The two observation parameters also suggest that the coordinate placement of the relay node is correct. Accordingly, in the implementation process later, this relay node is installed at the coordinate point.

### 4.3. Implementation of Relay Node Placement Scenario

In the implementation process, the relay node was installed at the coordinate according to the planning simulation, i.e. 6˚54'19.32" S, 107˚37'45.35" E. The distance between the donor eNodeB and the relay node is 23 meters. There are several parameters to consider when implementing the relay node scenario as can be seen in Table 3.

**Table 3** Parameters of relay node installation

| No. | Parameter | Value |
|---|---|---|
| 1. | Antenna Direction (Azimuth)/Tilting Antenna | 150° / 2° |
| 2. | Height of tower | 10 m |
| 3. | Relay Node Coordinate | 6°54′19.32″ S<br>107°37′45.35″ E |
| 4. | Type of Antenna | AAU3940 |
| 5. | *Donor eNodeB* | Site DIVRE 3 |
| 6. | Communication system with donor eNodeB | Fiber optic |

This node relay implementation used a frequency band of 1800 MHz. In addition, there are several scenarios of the antenna installation used for the relay node such as illustrated in Figure 6.

**(**a) (b) (c)

**Figure 6** Antenna installation scenario

Figure 6 (a) illustrates a scenario for the antenna placement on the building, Figure 6 (b) illustrates a scenario for the antenna placement on the street lighting pole, and Figure 6 (c) illustrates a scenario for the antenna attached to the wall of the building. In the implementation, the scenario (b) was applied. Since the optimization location was on a road covered by the buildings, the antenna needed to be placed in a lower place than the main site. In addition, existing street lighting lamps were also utilized as a place for placing the antenna.

After the installation, the network quality was measured to determine the performance after being added with a relay node. Figure 7 illustrates a comparison of the initial and final drive test results for RSRP parameters, while Figure 8 illustrates a comparison of the initial and final drive test results for the SINR parameters. The figure shows that there is a very significant performance improvement after the relay node installation.

(a) (b)

**Figure 7** Initial drive test for the RSRP parameters (a);
Final drive test for the RSRP parameters (b)

(a) (b)

**Figure 8** Initial drive test for the SINR parameters (a);
Final drive test for the SINR parameters (b)

After the addition of the relay node, the comparison of mean values of RSRP and SINR can be seen in Table 4.

**Table 4** Performance measurement results after relay node implementation

| No. | Parameter | Before Optimization | | | After Optimization | |
|---|---|---|---|---|---|---|
| | | Initial Drive Test | | Simulation Result | Final Drive Test | |
| 1 | RSRP | -101.30 dBm | No. of samples < -85 dBm as many as 90% | -83.12 dBm | -83.14 dBm | No. of samples < -85 dBm as many as 13% |
| 2 | SINR | 2.43 dB | No. of samples < 5 dB as many as 75% | 10.16 dB | 5.27 dB | No. of samples < 5 dB as many as 30% |

## 5. Conclusion

By performing simulation scenarios using a transparent relay node and an in-band relay node, this study succeeds to increase the LTE network coverage area at W.R Supratman Street. Based on the calculation of link budget, the required number of relay node antenna is 1 (one). In addition, the performance measurement done after the relay node simulation and implementation shows an increase in RSRP and SINR values by 13% and 45%, respectively. The improvement of these two parameters indicates that the eNodeB coverage has increased in the area.

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