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RESEARCH ARTICLE

Coverage HetNet based Picocell and Femtocell for Uplink Condition around Building Environment with Single Knife Edge Method

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Abstract: The development of HetNet (Heterogeneous Network) radio base stations has experienced many developments. This is indicated by the existence of microcells, macrocells, picocells, femtocells, etc. The purpose of this research was to investigate the propagation of communication systems in uplink conditions with HetNet picocells and femtocells. The problem that this research wanted to overcome was knowing the propagation of cellular communication with changes in HetNet stations. UE (User Equipment) propagation was on a trajectory around the building environment. Different heights for each building were modeled. Ten gigahertz was the frequency utilized in this research. The communication between Tx (transmitter) and Rx (receiver) was modeled using a diffraction mechanism, AWGN (Additive et al.) channel, and atmospheric attenuation. The single knife edge (SKE) method was used for the mechanism. Atmospheric attenuation was caused by water vapor and oxygen. AWGN was present in the propagation channel. The analysis of this research included a percentage of the communication coverage area, the AMC (Adaptation Modulation and Coding) level, and the SNR (Signal et al.) value. Modulation and Code Scheme (MCS) was the foundation of the AMC. QPSK (Quadrature Phase Shift Keying), 16QAM (Quadrature Amplitude Modulation), and 64 QAM were some of the MCS modulations utilized. According to the research, gNB1 achieved a communication coverage of 80.59%, gNB2 obtained 65.67%, and the HetNet, with selection combining obtained 95.52%.

Keywords: HetNet, AMC, femtocell, picocell, single knife edge

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1 Introduction

Telecommunications network technology is experiencing rapid growth. Currently, the need to use communication facilities uses very high internet data speeds and without any problems. High data speeds can help in various daily activities, especially for those who use internet access. With internet data access, it would be better if many problems did not hamper communication propagation. To strengthen signal quality so that data access is affordable, developing network infrastructure is important. Utilization of HetNet (Heterogeneous Network) between base stations or eNBs with each other such as femtocell, picocell, microcell, macrocell, and so on. Various kinds of research demonstrate the development of cellular technology. Several studies related to millimeter waves, such as reviewing millimeter wave supporting technologies that are relevant for 5G and 6G networks [1], beam management procedure in millimeter wave communication for 5G NR standard [2], positioning for large intelligent surface on mmWave MIMO systems [3], wireless channel measurement and modeling for 6G [4], and UAV communications and networking using mmWave beamforming [5]. Several studies related to communication coverage areas include aerial base stations user analysis in VhetNets [6], researching sub-THz propagation measurements and path loss models in urban microcell regions [7], zero forcing beamforming and user-selection in resource allocation schemes for LTE-A femtocells [8], the High Altitude Platform Station (HAPS) model is a super macro base station that provides connectivity in many applications with wide coverage targets for remote areas and disasters [9], techniques for making prediction for cellular communication coverage [10], and D2D communication technology uses 5G cellular network coverage [11].

Some research related to diffraction includes NOMA uplink access performance analysis using mmWave, taking into account LOS and NLOS propagation [12], Characterization of LOS and NLOS intervals using mmWave cellular systems in urban areas [13], microcell propagation in urban areas using frequency of 140 GHz [14], base station radio propagation of cellular networks with drones around building environments with a single knife edge [15], multipath propagation and path loss measurements around buildings [16], indoor statistical channel models for mmWave and sub-Terahertz frequency with LOS and NLOS environment [17], the consideration of building diffraction in urban water-land environments with LOS and NLOS conditions using millimeter waves to predict path loss [18], multiple diffraction analysis for millimeter waves caused by trees and buildings [19], measurement based 5G with mmWave propagation in a vegetated sub-urban Macrocell environment [20].

This research discusses the communication system on the HetNet cellular network (picocell and femtocell) with a UE frequency of 10 GHz. Based on previous research only focused on the communication system on macrocell stations, but this research applies HetNet stations. This research contributes to the use of developments in cellular communication technology to maintain communication connectivity. Several things contribute to this research, including being able to determine the propagation of communication systems using the 10 GHz frequency that moves in building environments and the propagation of communication systems using HetNet picocells and femtocells. The UE communication path is around the building environment. NLOS or LOS propagation can occur on the UE trajectory. UE propagation is modeled using uplink conditions. HetNet gNB uses picocell and femtocell. The UE is on a path between the building environment, a picocell gNB, and a femtocell gNB. Both gNBs implement a diversity mechanism. The selection combining

(SC) method is modeled for this diversity mechanism. Signal propagation between the transmitter and receiver is affected by diffraction. That diffraction is modeled with Single Knife Edge (SKE). Modulation and Coding Scheme, or MCS, is the foundation for the application of AMC in communication systems. There are multiple modulations in the MCS, such as QPSK, 16 QAM, and 64 QAM. 1/8, 1/5, 1/4, 1/3, 1/2, 2/3, 3/4, and 4/5 are the QPSK coderates. 1/2, 2/3, 3/4, and 4/5 are the 16 QAM coderates. 2/3, 3/4, and 4/5 are the 64 QAM coderates.

Apart from the introduction section, this paper also includes the research method, results, discussion, and conclusion. The research method section discusses the single knife edge method, atmospheric attenuation, etc. The results section explains the analyzed SNR value, path loss, AMC, amount of node coverage, percentage of node coverage, etc. The discussion section explains interpreting based on the results section. The conclusion section explains the activities carried out.

2 Research Method

The research methods section explained the parameters for communication systems, building environment models, single knife edge method, atmospheric attenuation, and AMC (Adaptive Modulation and Coding). The parameters of the communication system used by the UE were devices that move with a frequency of 10 GHz. The device moved in a straight path between the building environment. The height of the UE was 1.5 meters. Uplink UE propagation to the nearest gNodeB or Radio Base Station with 2 stations. The Radio Base Station or gNB had different cell coverage, namely picocell and femtocell. The UE communication system with HetNet (Heterogeneous Network) from gNB occurred on the communication path. The diversity mechanism in HetNet used the Selection Combining (SC) method. The propagation channel between the UE and HetNet gNB1 and gNB2 used AWGN.

Figure 1 shows the propagation of UE communications to HetNet gNB1 and gNB2. In the picture, there were many buildings around the UE communication path. The building environment could affect the quality of communication signals. LOS and NLOS could cause this due to the height of the building. The buildings or buildings were modeled in various ways with Matlab. These NLOS propagation conditions could cause diffraction mechanisms to occur. The diffraction mechanism was modeled using the SKE approach.

The SKE method between transmitter and receiver is represented by the model in Figure 2. Equation (1) shows several parameters used for the method. The wavelength (m), Kirchoff Fresnel (v), diffraction height (h), distance (d_1) between transmitter (T_x) and barrier (m), and distance (d_2) between barrier and receiver (R_x) (m) are the parameters [21].

$$v = \alpha\sqrt{\frac{2d_1d_2}{\lambda(d_1+d_2))}} \tag{1}$$

The communication frequency on User Equipment (UE) uses 10 GHz, with a transmit power of 30 dBm. GNB picocell antenna gain is 5 dBi. GNB femtocell antenna gain is 3 dBi. Equation 2 is an equation for determining the SNR (Signal to Noise Ratio) value.

$$SNR = \frac{S}{N} \tag{2}$$

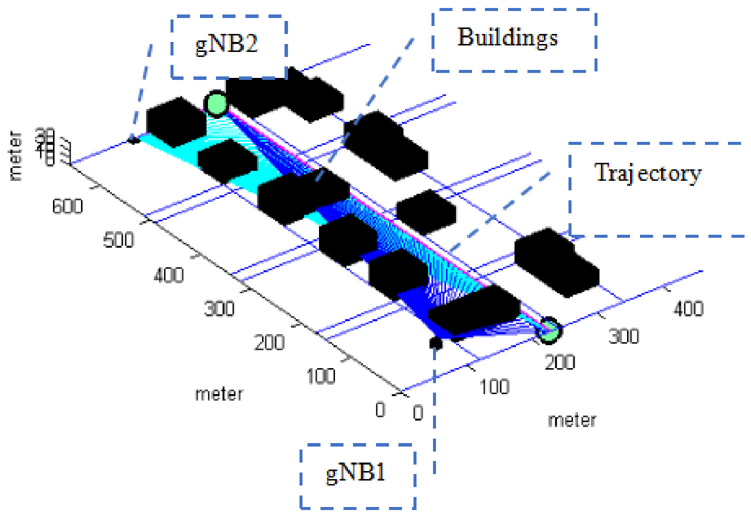

Figure 1: UE propagation with HetNet gNB.

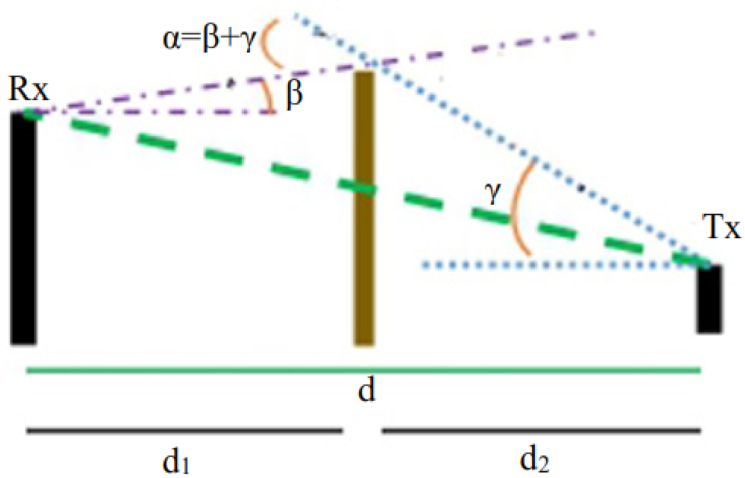

Figure 2: Propagation single knife edge method.

$$N = k \times T_0 \times B + NF \tag{3}$$

The N (Noise power) equation in equation (3) [21], consists of several parameters including k is the Boltzman constant, noise bandwidth is 200 MHz, noise factor on the gNB picocell is 1 dB, noise factor on the femtocell is 0.3 dB, and noise temperature (290oK), shown in Table 1.

$$A = \gamma r_o dB \tag{4}$$

Table 1: Parameter for noise power

Parameter	Value
k	$1.380649 \times 10^{-23} J/K$
B	200 MHz
NF	1dB (picocell) ; 0.3 (femtocell)

Equation 4, parameter A is atmospheric attenuation, which consists of several other parameters, namely distance (r_o), and gas attenuation [22]. MCS utilization was the foundation of AMC. QPSK, 16 QAM, and 64 QAM were the MCSs that are utilized 1/8, 1/5, 1/4, 1/3, 1/2, 2/3, 3/4, and 4/5 were some of the QPSK code rates. 1/2, 2/3, 3/4, and 4/5 were included in code rate 16 QAM. 2/3, 3/4, and 4/5 were included in code rate 64 QAM [23].

3 Results

This section presents the results and discussion of research about UE communication that moves at trajectory around building with 10 GHz frequency. UE propagation of uplinked conditions to HetNet gNB picocell and gNB femtocell. The diversity mechanism of HetNet was modeled using the Selection Combining method. The NLOS condition diffraction mechanism, the SKE method, was used to represent the propagation of UE around the building. The channel between the sender and receiver used AWGN. QPSK, 16 QAM, and 64 QAM were some variations on MCS that were used to determine AMC.

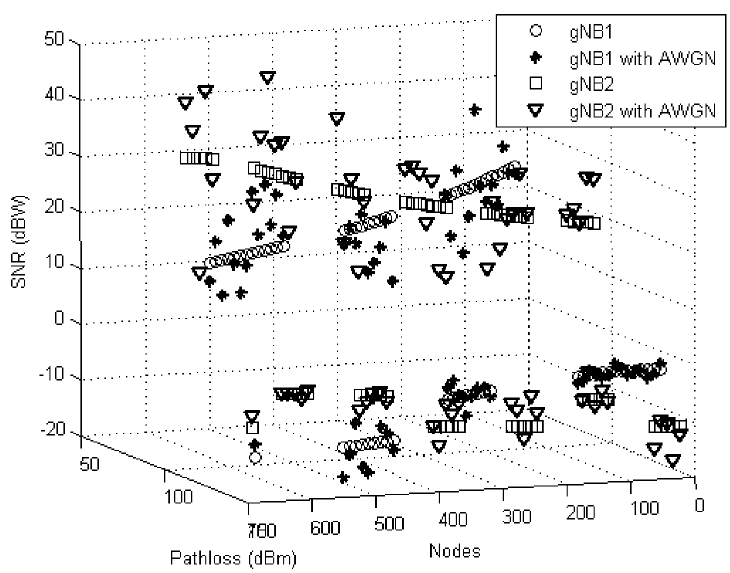

Figure 3: SNR value, pathloss, and nodes of UE communication.

In Figure 3, the SNR value of the UE communication system with HetNet gNB picocell and gNB femtocell. The UE moves as long as 660 meters or 660 nodes with take data every 10 meters of track length on a straight path between building environments, where the height of the buildings varies. Several SNR values with AWGN based on this data are shown by the UE when at the 30 meter point, gNB1 is -3.23 dB, and gNB2 is -10.64 dB. When the UE is at the 140 meter point, gNB1 is 28.75 dB, and gNB2 is -7.14 dB. When the UE is at the 560 meter point, gNB1 is 30.86 dB, and gNB2 is –2.98 dB. When the UE is at the 650 meter point, gNB1 is 14.32 dB, and gNB2 is -44.6 dB.

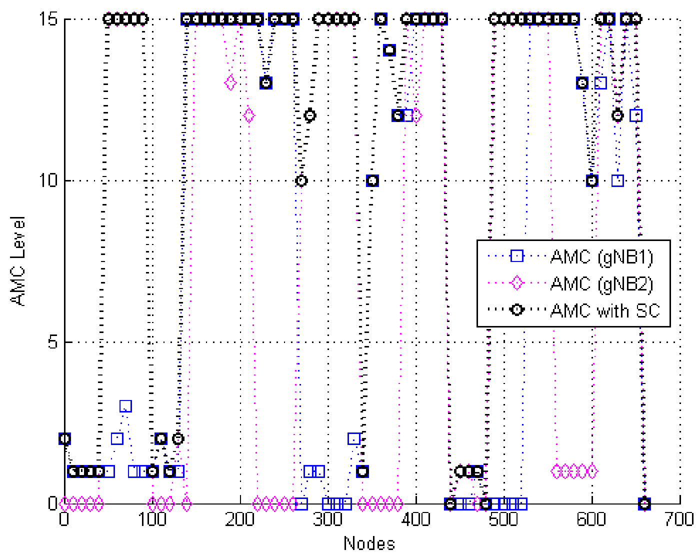

Figure 4: AMC level of UE communication.

Figure 4 shows the AMC level at each communication point between Tx and Rx. Levels 1 until 15 showed the type modulation of MCS. Some data based on this image was that the UE moving 30 meters was obtained by gNB1 QPSK coding rate of 1/8 AMC level 1, gNB2 AMC level 0, and selection combining HetNet QPSK coding rate of 1/8 AMC level 1. The UE moving 140 meters was obtained by gNB1 64 QAM coding rate of 4/5 level AMC 15, gNB2 level AMC 0, and selection combining HetNet 64 QAM coding rate of 4/5 level AMC 15. The UE moved 560 meters obtained by gNB1 64 QAM coding rate of 4/5 level AMC 15, gNB2 QPSK coding rate of 1 /8 level AMC 1, and selection combining HetNet 64 QAM coding rate of 4/5 level AMC 15. The UE moved 650 meters obtained by gNB1 16 QAM coding rate of 4/5 level AMC 12, gNB2 64 QAM coding rate of 4/5 level AMC 15, and selection combining HetNet 64 QAM coding rate of 4/5 level AMC 15.

Figure 5 shows the number of UE and gNB communication points that are part of the MCS usage is shown. The number of communication points between the UE and gNB1 picocell for QPSK use was 19 points, 16 QAM was 6 points, and 64 QAM was 29 points. The number of communication points between the UE and the gNB2 femtocell using QPSK was 8 points, 16 QAM was 5 points, and 64 QAM was 31 points. The probability of UE coverage area with SC HetNet using QPSK was 13 points, 16 QAM was 6 points, and 64 QAM was

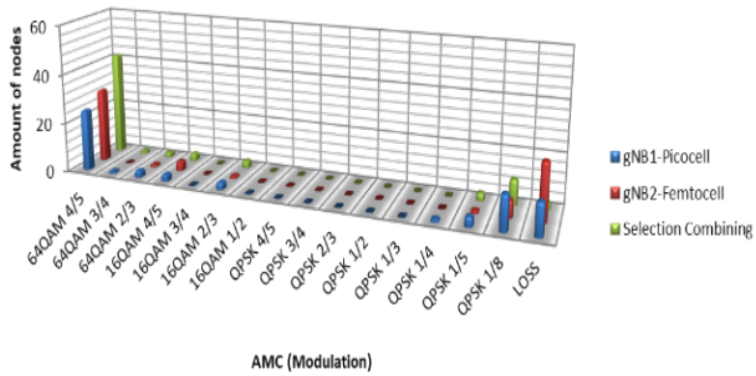

Figure 5: Amount of coverage node with MCS.

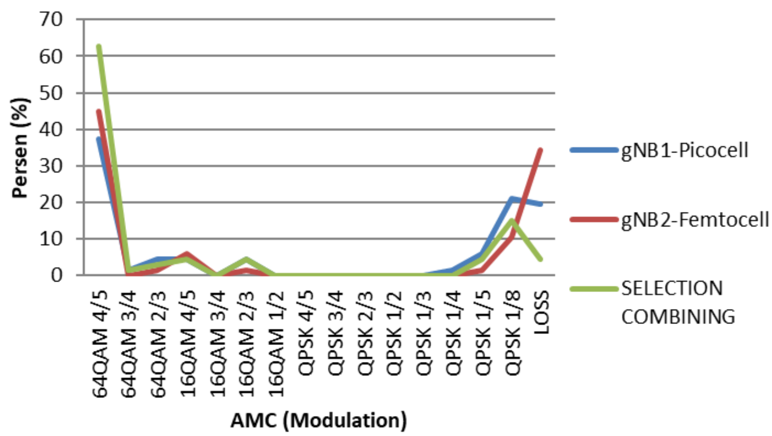

Figure 6: Percentage of coverage node with MCS.

45 points. The percentage of coverage nodes with MCS QPSK, 16QAM, and 64QAM is shown in Figure 6. This percentage value was obtained by dividing the number of nodes that successfully communicated according to the range of MCS values used divided by the nodes on their path.

4 Discussion

This section is a discussion of the UE communication system that moves at trajectory between buildings using the 10 GHz frequency on the gNB HetNet. During the UE's journey, it was shown that at the beginning of its journey, it was less than 50 meters, and the SNR values of both HetNet had equally low values due to the influence of the height of the building. At other UE communication points less than 130 meters, gNB picocell did not dominate the propagation because the influence of building height was still the cause, so it was dominated by gNB picocell. As the UE travels less than 290 meters, the gNB picocell dominated its communication SNR value. The influence of the dominance of gNB femtocell was reduced even though it had a high SNR value, which was higher than gNB picocell. Furthermore, until it was nearing the end of the journey, where the UE was far from the gNB picocell but close to the gNB femtocell, the SNR value shown was dominated by the gNB femtocell.

Fluctuations in the SNR value affected the AMC level for communication. As in Figure 5, the number of communication points with HetNet gNB can be seen. The best modulation quality was 64 QAM with 29 nodes of gNB picocell, while the gNB femtocell had 31 points. The difference in signal quality was influenced by the height of the buildings between the communication lines, so the GNB femtocell dominated the signal quality with 64 QAM modulation. However, the overall dominance of the communication point was the gNB1 picocell. This is shown in Figure 6.

Figure 6 shows the percentage of each modulation from the number of communication points. The percentage of total communication between the UE and the gNB1 picocell showed that the use of QPSK was 28.36%, 16 QAM 8.95%, and 64 QAM 43.28%. The percentage of total communication between the UE and the gNB2 femtocell showed that the use of QPSK was 11.94%, 16 QAM 7.46%, and 64 QAM 46.26%. The percentage of total communication between UEs with selection combining HetNet obtained the use of QPSK 19.4%, 16 QAM 8.95%, and 64 QAM 100%. The overall percentage of communication coverage on gNB1 was 80.59 percent, gNB2 65.67%, and selection combining HetNet 95.52%. Based on this discussion, of course, there would be differences in signal quality values under certain conditions. So, different parameters would cause different results. The limitations of this research included referring to the diffraction mechanism because the height of the building was only modeled using the single knife edge method, the communication frequency used was 10 GHz, and the gNB HetNet coverage area used picocells and femtocells.

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5 Conclusion

This section is the conclusion of research on 10 GHz frequency UE communications in uplink conditions for HetNet gNB picocells and femtocells. That research contributed to maintaining the connectivity of communication systems by utilizing gNB coverage or femtocell and picocell stations, especially communication systems with a frequency of 10 GHz. This was demonstrated by several conclusions as follows. The propagation environment between Tx and Rx was modeled by varying the height of the building around the propagation. For the building environment-induced diffraction mechanism, the Single Knife Edge (SKE) analysis was used. The result of the UE communication system found that of the total 65 communication points on gNB picocell covering 54 points or 80.59%, gNB femtocell covered 44 points or 65.67%, and SC HetNet covered 64 points or 95.52%. In the comparison results, the percentage of use of 64 QAM modulation on gNB1 was 43.28%, gNB2 46.26%, and SC HetNet 67.16%. Thus, by implementing the selection combining HetNet gNB1 picocell and gNB2 femtocell, AMC 64 QAM could be utilized better than single cells from gNB1 or gNB2. In the future, based on this research, it can be developed to carry out analyses other than the Single Knife Edge method and the type of communication coverage used. In the future, based on this research, it can be developed even better, namely by applying different frequency diffraction methods other than the Single Knife Edge method and so on. So that the development of this research can be more detailed and in-depth, especially the development of modeling and implementation for communication propagation.

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