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AMC HETNET Macro and Femto Cell used 10 GHz for Drone Communication with SKE Method around Building Environment

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ABSTRACT

Communication propagation between a drone and a HetNet (Heterogeneous Network) gNB (generalized Node B) in uplink conditions. The drone moves on a straight path between built-up environments. The communication frequency of 10 GHz can affect oksigen and water vapor at that frequency. Propagation of communication systems in a building environment can cause diffraction. The diffraction mechanism was modeled with Single Knife Edge (SKE) method. AMC (Adaptive Modulation and Coding) dynamically modifies the coding rate and modulation scheme according to signal quality. MCS (Modulation and Coding Scheme) consisting of QPSK, 16QAM, and 64QAM was used in AMC. Research analysis includes SNR values on the drone path, coverage percentage, and MCS percentage. As a result of research for MCS 64QAM coderate 4/5 with Selection Combining (SC) between HetNet gNB macrocell and gNB femtocell, 64 nodes or 95.52% were obtained. The communication coverage was obtained using MCS for drone communication on this route.

Keywords : AMC, SKE, gNB, diffraction, drone

ABSTRAK

Propagasi komunikasi antara drone dengan HetNet (Heterogeneous Network) gNB (generalized Node B) pada kondisi uplink. Drone bergerak pada lintasan lurus diantara lingkungan bergedung. Frekuensi komunikasi yang digunakan 10 GHz, pada frekuensi tersebut dapat dipengaruhi water vapor dan oksigen. Perambatan sistem komunikasi di lingkungan gedung dapat menyebabkan difraksi. Mekanisme difraksi dimodelkan menggunakan metode Single Knife Edge (SKE). AMC (Adaptive Modulation and Coding) secara dinamis memodifikasi laju pengkodean dan skema modulasi sesuai dengan kualitas sinyal. MCS (Modulation and Coding Scheme) yang terdiri dari QPSK, 16QAM, dan 64QAM digunakan pada AMC. Analisa penelitian diantaranya nilai SNR pada jalur drone, persentase cakupan, dan persentase MCS. Sebagai hasil penelitian untuk MCS 64QAM coderate 4/5 dengan Selection Combining (SC) antara HetNet gNB macrocell dan gNB femtocell, didapatkan sebanyak 64 node atau 95,52%. Pada penggunaan SC HetNet didapatkan cakupan komunikasi sebesar 100%.

Kata kunci: AMC, SKE, gNB, difraksi, drone

I. INTRODUCTION

The development of wireless communication technology, up to 5G, has been rapidly accelerated. Stable services such as high-speed data, low latency, and consistent service quality are required by users' access demands. Service quality can be improved through the use of Heterogeneous Network base stations. There are several research related to 5G HetNet Cellular [1], 5G HetNet topologies user distribution [2], HetNet configurations [3], HetNets with multi antenna [4], Performance evaluation of Heterogeneous cellular network [5], Throughput performance HetNets [6], Mobility management HetNets [7], load balancing cell for 5G [8], cellular network with baeam alignment [9], Mobile edge computing for 5G [10], Interference management in HetNets [11], pedestrian mobility in HetNets [12]. Some studies related to coverage analysis for HetNet based 5G [13], map-assisted millimeter wave [14], and THz radio propagation in indoor factories [15].

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Several studies related to AMC propagation in building environments include outdoor to indoor communication systems at 10 GHz [16], doppler shift effect propagation at 10 GHz in building environments [17], drone communication propagation using cellular communication networks in building environments [18], diversity using selection combining for drone communication in building environments [19]. Some research related with drone, such as 5G network with UAV [20], and millimeter wave beamforming for UAV communication [21].

One of the challenges is the provision of large capacity with even coverage in densely populated environments such as urban areas with high-rise buildings. The quality of communication signals can be affected by propagation conditions under these circumstances. In this study, one approach that is used to overcome this problem is HetNet (Heterogeneous Network). Diversity from macrocells and femtocells is utilized in HetNet, and the selection combining method is applied to this mechanism. Coverage and capacity can be increased through the combination of cells. In this research, the communication system between the drone and the gNB is placed in a building environment. The drone has the characteristic of working by accessing many base stations, so that the communication coverage area becomes very wide, so as an assumption, the drone in this research is more suitable for drone-UAV (Unmanned Aerial Vehicle) drone. The propagation of communication in such environments can cause a decrease in signal quality, one of which is caused by the diffraction mechanism. The diffraction mechanism is modeled using the Single Knife Edge method. The transmission scheme employed is AMC (Adaptive Modulation and Coding), with MCS (Modulation and Coding Scheme) including QPSK, 16QAM, and 64QAM. QPSK modulation is implemented using various code rates, such as 1/8, 1/5, 1/4, 1/3, 1/2, 2/3, 3/4, and 4/5. 16QAM modulation is implemented using various code rates, such as 1/2, 2/3, 3/4, and 4/5. 64 QAM modulation is implemented using various code rates, such as 2/3, 3/4, and 4/5. As a novelty of this research, namely the analysis of signal quality between buildings for the propagation of drone communication systems during uplink conditions on heterogeneous networks (HetNet) macrocells with microcells, as well as the use of 10 GHz frequencies.

II. LITERATURE

This section explains some literature related to the research conducted, including the single knife edge (SKE) method, atmospheric attenuation, SNR, and noise. The single knife edge method can be seen in Figure 1.

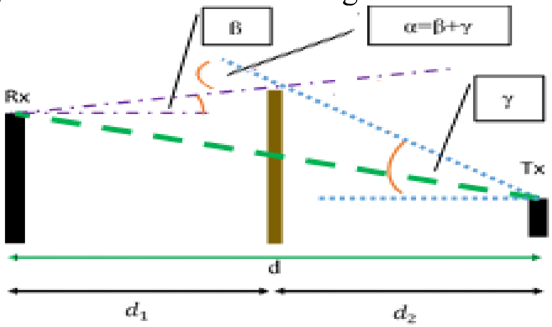

Figure 1. Single Knife Edge Method

$$v = h\sqrt{\frac{d(d_1 + d_2)}{\lambda d_1 d_2}} = \alpha\sqrt{\frac{2d_1 d_2}{\lambda (d_1 + d_2)}} \quad (1)$$

The Fresnel Zone is affected by the relative heights of gNB and drone. The Fresnel zone is explained in Equation (1), with parameters λ for wavelength (m), v for Fresnel Khichhoff, h for height of diffraction, d1 for transmission distance through node (m), and d2 for receiver distance through node (m) [22].

Atmospheric attenuation can be affected by the use of this frequency, as shown in the following equation, where atmospheric attenuation is shown in Equation (2). The atmospheric attenuation is influenced by oxygen and water vapor [23]. The parameters γ and r_o are described as gaseous attenuation and path length (km).

$$A = \gamma r_o \, dB \quad (2)$$

SNR equation was showed at equation (3). Parameters were used such as N (noise power), S (signal value), and SNR (signal to noise ratio) [22].

$$SNR = \frac{S}{N} \quad (3)$$

$$N = k\,To\,B + NF \quad (4)$$

The parameter N is shown in Equation (4). The parameters K, B, NF, and T are defined as the Boltzmann constant, bandwidth, noise figure, and standard noise temperature (290 °K).

Table 1. AMC Specification parameters

Modulation	Code Rate	SNR (dB)	Modulation	Code Rate	SNR (dB)
QPSK	1/8	-5.1	16QAM	1/2	7.9
QPSK	1/5	-2.9	16QAM	2/3	11.3
QPSK	1/4	-1.7	16QAM	3/4	12.2
QPSK	1/3	-1	16QAM	4/5	12.8
QPSK	1/2	2	64 QAM	2/3	15.3
QPSK	2/3	4.3	65 QAM	3/4	17.5
QPSK	3/4	5.5	66 QAM	4/5	18.6
QPSK	4/5	6.2			

AMC (adaptive modulation coding) specification parameters can be seen in table 1, using MCS (Modulation and Coding Scheme) with QPSK, 16QAM, and 64QAM [24]. ETSI standard provides outdoor propagation definition for drone - UAV communications [25].

III. RESEARCH METHODS

The drone communication, with characteristic of working by accessing many base stations, so that the communication coverage area becomes very wide, so as an assumption, the drone in this research is more suitable for the UAV (Unmanned Aerial Vehicle) drone. That drone used transmit power of 30 dBi is moved along a straight path in a building environment, is passed through a gNB macrocell with a gain of 16 dBi and a gNB femtocell with a gain of 3 dBi. The propagation of communication between Drone and gNB macrocell within a building environement is shown in Figure 2. That simulation was created using Matlab.

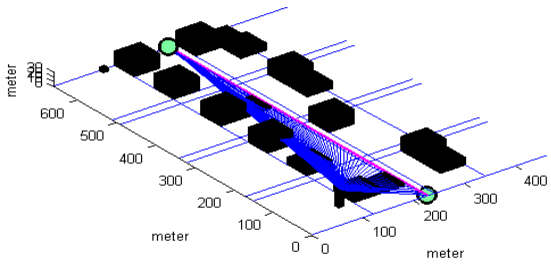

Figure 2. Drone path propagation with gNB Macrocell

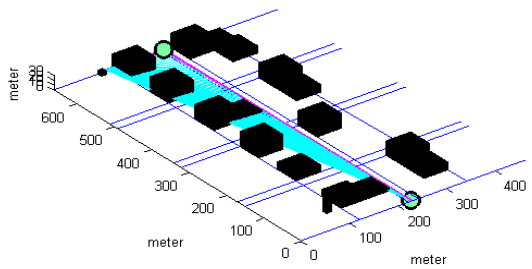

Figure 3. Drone path propagation with gNB Femtocell

The communication propagation between the Drone and the gNB femtocell within a building environment is shown in Figure 3. The communication frequency was used 10 GHz. Larger data transmission is made possible by the usage of this frequency, which makes it possible for drones to be used in future applications that require a lot of data, such as central communication points or users. Drone communication system is directed through the HetNet gNB, where varying building heights are encountered. Building height variations of 5 m, 15 m, and 30 m are considered. NLOS communication conditions are recognized as factors that can affect signal quality. One such condition is the diffraction mechanism. The diffraction mechanism is evaluated using the Fresnel Zone. The single knife edge method is used to model the diffraction mechanism. The height of the gNB macrocell is specified as 30 meters, the gNB femtocell as 2 meters, and the drone as 20 meters. Based on equation 4, NF value of the gNB femtocell is used as 0.5 dB, NF value of the gNB macrocell is used as 6 dB, and the B value is used as 200 MHz.

The application of diversity to HetNet from the macrocell and femtocell is modeled using the selection combining method. The performance of the transmission scheme in the form of AMC is determined to evaluate the percentage of MCS usage on the Drone path. The Adaptive Modulation and Coding (AMC) process is based on the Modulation and Coding Scheme (MCS). MCS was used such as QPSK, 16 QAM, and 64 QAM. Modulation of QPSK was used some code rate consist of 1/8, 1/5. 1/4, 1/3, 1/2, 2/3, 3/4, and 4/5. Modulation of 16 QAM was used some code rate consist of 1/2, 2/3, 3/4, and 4/5. Modulation of 64 QAM was used some code rate consist of 2/3, 3/4, and 4/5.

IV. RESEARCH RESULTS AND DISCUSSION

In this section, the research results of a Drone traveling along a straight path between buildings through a HetNet consisting of a gNB macrocell (gNB1) and a gNB femtocell (gNB2) are explained. The Drone traveled 660 meters around varying building heights. Communication quality during propagation between the Drone and the gNB macrocell and gNB femtocell is influenced by several factors, including communication distance, the AWGN channel, and atmospheric attenuation.

In Figure 4, the SNR value of drone communication with gNB macrocell (gNB1) is SNR when without AWGN and when using AWGN. Communication propagation between the two is in uplink conditions. Some data without AWGN are obtained SNR value, such as drone moves 50 meters obtained SNR of 38.85 dB, drone moves 400 meters obtained SNR of 25.15 dB, and drone moves 590 meters obtained SNR of 21.59 dB. Some data with AWGN are obtained SNR value, such as drone moves 50 meters obtained of 34.21 dB, drone moves 400 meters obtained SNR of 17.16 dB, and drone moves 590 meters obtained SNR of 12.58 dB.

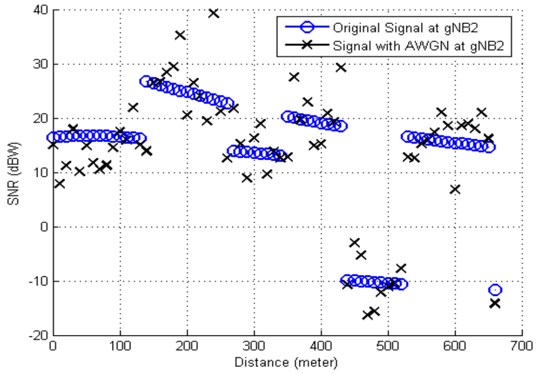

Figure 4. SNR value of gNB macrocell

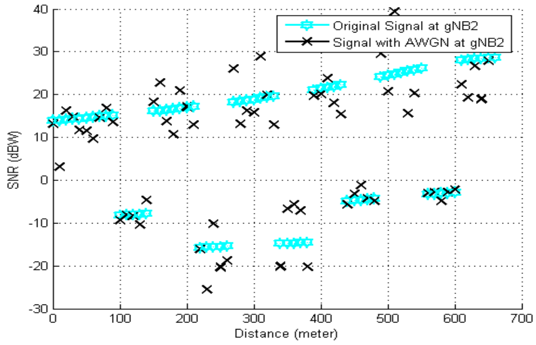

Figure 5. SNR value of gNB femtocell

In Figure 5, the SNR value of drone communication with the gNB femtocell (gNB2) is shown both without AWGN and with AWGN. Communication propagation between the two is carried out under uplink conditions. Data without AWGN are obtained SNR value, such as drone moves 50 meters obtained SNR of 14.55 dB, drone moves 400 meters obtained SNR of 21.39 dB, and drone moves 590 meters obtained SNR of 33.7 dB. Some data with AWGN are obtained SNR value, such as drone moves 50 meters obtained SNR of 12.28 dB, drone moves 400 meters obtained SNR of 21.35 dB, and drone moves 590 meters obtained SNR of 27.93 dB.

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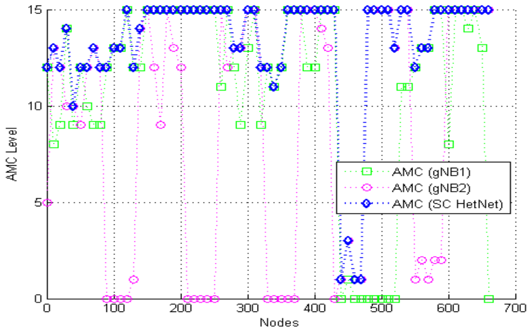

Figure 6. AMC with AWGN

AMC was used adaptation of SNR value. AMC value is represented by MCS value. Several modulation schemes are used in MCS, such as 64QAM with code rates 4/5, 3/4, and 2/3; 16QAM with code rates 4/5, 3/4, 2/3, and 1/2; and QPSK with code rates 4/5, 3/4, 2/3, 1/2, 1/3, 1/4, 1/5, and 1/8.

In Figure 6, the AMC results in the communication system between drone and gNB macrocell, gNB femtocell, and SC HetNet are shown. Several MCS results in the communication system with AWGN from the diversity HetNet of the gNB macrocell and gNB femtocell are obtained as follows, when the drone moves 50 meters, MCS 16QAM 4/5 is obtained on gNB1, 16QAM 3/4 on gNB2, and 16QAM 4/5 on SC HetNet. When the drone moves 400 meters, MCS 64QAM 2/3 is obtained on gNB1, 64QAM 4/5 on gNB2, and 64QAM 4/5 on SC HetNet. When the drone moves 590 meters, MCS 16QAM 3/4 is obtained on gNB1, 64QAM 4/5 on gNB2, and 64QAM 4/5 on SC HetNet.

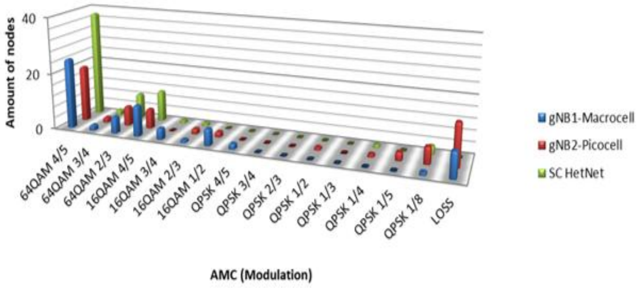

Figure 7. Number of MCS usage on drone path

In Figure 7, the number of MCS usages at nodes communication along the drone path with a communication system using AWGN is shown. From the accumulated number of MCS, the type of modulation and the best code rate for the communication system can be identified. Based on gNB1 data, 64QAM modulation is obtained for 52 nodes, 16QAM modulation for 5 nodes, and QPSK modulation for 10 nodes. Based on gNB2 data, 64QAM modulation is obtained for 43 nodes, 16QAM modulation for 10 nodes, and QPSK modulation for 7 nodes. Based on SC HetNet data, 64QAM modulation is obtained for 65 nodes, 16QAM modulation for 1 node, and QPSK modulation for 1 node. For 64QAM modulation with a code rate of 4/5, 48 nodes are obtained in gNB1, 37 nodes in gNB2, and 64 nodes in SC HetNet. For 16QAM modulation with a code rate of 4/5, 3 nodes are obtained in gNB1, 5 nodes in gNB2, and 0 node in SC HetNet. For QPSK modulation with a code rate of 4/5, 1 node are obtained in gNB1, 1 node in gNB2, and 1 node in SC HetNet.

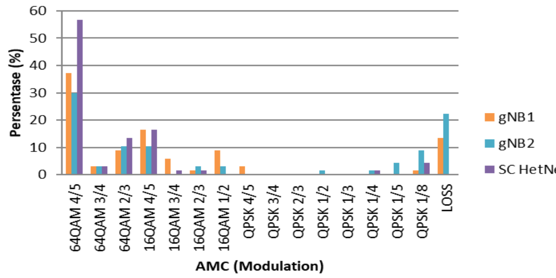

Figure 8. Percentage of MCS on the drone path

In Figure 8, the usage of MCS during drone movement along the path at around building environment is shown. Several data from the figure indicate that the highest percentage of MCS usage is obtained for 64QAM with all coderate, 77.61% of gNB1, 64.17% of gNB2, and 97.01% of SC HetNet. The percentage of coverage area resulting from the uplink communication system with AWGN between the drone and gNB1, gNB2, and SC HetNet is obtained as follows, 100% of gNB1, 89.55% of gNB2, and 100% of SC HetNet.

This section discusses the research results on the drone communication system which is on a straight path around building environments using a frequency of 10 GHz. The communication propagation is affected by atmospheric attenuation, AWGN channels, and diffraction mechanisms. AMC based on the MCS used, including Modulation of QPSK was used some code rate consist of 1/8, 1/5. 1/4, 1/3, 1/2, 2/3, 3/4, and 4/5. Modulation of 16 QAM was used

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some code rate consist of 1/2, 2/3, 3/4, and 4/5. Modulation of 64 QAM was used some code rate consist of 2/3, 3/4, and 4/5.

Fluctuations in SNR and AMC values are observed in the drone communication system operating along a path between building environments. The communication system is influenced by AWGN, atmospheric attenuation, communication distance, and diffraction mechanisms due to buildings. In Figure 4 and 5, differences in SNR values are shown between communication without AWGN and with AWGN. For instance, in gNB1 when the drone moves 400 meters, the SNR value with AWGN is 17.16 dB, which is lower than the 25.15 dB obtained without AWGN. Similarly, in gNB2 when the drone moves 400 meters, the SNR value with AWGN is 21.35 dB, which is lower than the 21.39 dB obtained without AWGN. Figure 6 illustrates that AMC values based on MCS vary according to the communication nodes. Some data, with SC HetNet, when the drone moves 50 meters, MCS 16QAM 4/5 is obtained, whereas at 590 meters MCS 64QAM 4/5 is obtained. Figure 7 shown the MCS usage, showing the number of communication nodes covered. MCS 64QAM with a code rate of 4/5 in SC HetNet is the most frequent, with 64 nodes (95.52%), compared to 48 nodes (71.64%) in gNB1 and 37 nodes (55.22%) in gNB2.

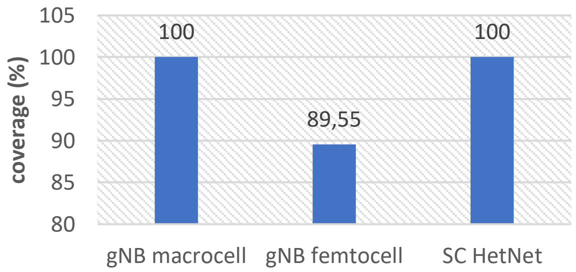

Figure 9. Percentage of MCS on the drone path

Figure 9 was shown the percentage of coverage area to be 100% for SC HetNet combining gNB macrocell and gNB femtocell, compared to 100% for gNB macrocell and 89.55% for gNB femtocell. The coverage of individual gNB macrocells is better than that of gNB femtocells, according to a comparison. Similar results are obtained when gNB macrocells and SC HetNet are compared, however SC HetNet better than gNB macrocells when modulation is used with the coderate. This coverage percentage is due to the use of a heterogeneous network of macrocells and femtocells in drone-UAV communication propagation.

V. CONCLUSION

The conclusion of this study is explained through the analysis of the drone communication system operating along a path between building environments through a HetNet consisting of gNB macrocell and gNB femtocell at a frequency of 10 GHz. Diversity in HetNet with gNB macrocell and gNB femtocell is modeled using the selection combining method. The communication system is shown to be influenced by variations in building height, atmospheric attenuation, communication distance, and AWGN. The diffraction mechanism is modeled using the Single Knife Edge method, while the selection combining method is applied for the HetNet gNB diversity mechanism. At certain nodes, the best SNR values are obtained when not obstructed by buildings and closest to the gNB, whereas the worst SNR values are obtained when obstructed by tall buildings and farthest from the gNB. AMC based on MCS is employed, with 64QAM modulation at a code rate of 4/5 for HetNet diversity being identified as the best at 95.52%. The overall coverage for the drone path using HetNet diversity is obtained at 100%. The coverage of individual gNB macrocells is better than that of gNB femtocells, according to a comparison. Similar results are obtained when gNB macrocells and SC HetNet are compared, however SC HetNet better than gNB macrocells when modulation is used with the coderate. Based on the results of this research, it is shown that selection combining for heterogeneous networks is able to maintain and increase the use of high-order MCS along the drone's trajectory in a building environment. The continuation of this research includes communication systems while inside the building, coordination with other types of HetNet cells, and so on.

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