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Comparison of 5G Network Throughput on Varying Cluster Size

Muhammad Yaser*

Teknik Elektro, Universitas Pancasila, Jakarta
*muhammadyaser@univpancasila.ac.id

***Abstract*—The development of cellular technology is accelerating, as is the exponential increase in data traffic, resulting in the creation of the following technology, namely 5G. This study looks at the throughput of the 5G network in various cluster sizes. In this study, integer frequency reuse (IFR) with a bandwidth of 100 MHz and a frequency of 3.5 GHz was used. The path loss Urban Macro (UMa) based on 3GPP 38.901 is employed in this study. The data was assessed and compared using computer simulations, and a comparison of throughput CDF values for each cluster size was obtained. When CDF = 0.9, the throughput of the N = 3 scenario is 6480 bps, which is greater than the huge throughput of the N = 4 scenario of 4860 bps and the large throughput of the N = 7 scenario of 2777 bps. According to the simulation, the cell with N = 3 cluster size has a greater throughput than the other scenarios. The cell with the smallest cluster size had the maximum throughput, whereas the largest had the lowest.**

Keyword*— Cluster size, Network, Throughput, 5G.

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I. Introduction

With limited power and spectrum resources, the expanding data transmission leads to a quickly increasing demand for data services. As a result, it would be critical to optimally use spectrum resources and alter the current power distribution system in order to increase energy efficiency and achieve better capacity in a cellular network. A spectrum with three primary frequency bands is required for 5G technology: low band, mid band, and high band. Low band frequencies are those less than 1 GHz that are employed for coverage, particularly in mMTC applications. Mid band refers to a frequency range of 1- 6 GHz with a larger bandwidth that is used for eMBB and mission-critical applications. High band frequencies are those above 24 GHz that are used for anything with a large bandwidth

With diverse ways, fifth-generation (5G) wireless technologies alleviate the increasing load of existing data service [1]. The primary goals of the 5G cellular wireless network are to provide high data speeds, increase base station (BS) capacity, improve user quality of service (QoS), and reduce energy usage [2]. The heterogeneous cellular network is a strong network architecture proposed in 5G to increase spectrum and energy efficiency [3]

The hexagonal grid for the BS is the basic structure of all these heterogeneous cellular networks. Furthermore, by utilizing frequency reuse technologies, spectrum resources will be utilized more efficiently and will service a greater area. While frequency reuse approaches enable a wireless communication network to assign the same frequency channels to several cells, the integer frequency reuse (IFR) strategy proposed for GSM systems (reuse factor equals 3) reduces intercell interference when compared to the IFR1 method. In the meantime, each cell receives only one-third of these spectral resources. Even if we utilize the IFR1 strategy, which uses all the spectrum resources for each cell, interference near the cell edge may be critical due to co-channel interference [4].

The goal of this study is to investigate the throughput of the 5G network in different cluster sizes. This study applied integer frequency reuse (IFR) with a bandwidth of 100 MHz and a frequency of 3.5 GHz, the approach employs technical analytical techniques. Using computer simulations, the data was evaluated and compared, and a comparison of throughput CDF values for each cluster size was generated.

The following is how the paper is structured. Section II discusses the literature review. Section III describes the system model that was employed in this study. Section IV presents the evaluation and results, as well as a discussion of the results. Section V outlines the conclusion.

II. Literature Review

The new radio millimeter wave 5G (5G NR mmWave) technology is a newly created interface that is intended to be an expansion of existing 4G technology. Target The key benefit of 5G is that it offers a wide range of services with high data speeds, wide coverage, decreased delays, lower costs, increased system capacity, and more connectivity for customers everywhere. The fundamental goal behind 5G is to give high throughput and spectral efficiency in congested metropolitan settings, which a Wi-Fi network cannot do. 5G cells were separated into three virtual zones based on OFDM modulation to examine the 5G performance in the inner zones against the outer zones for licensed and unlicensed spectrum. Different parameters addressed in the analysis include the chance of loss, delay, throughput, and the aggregate average bit rate in different zones. Numerical studies reveal that 5G performance is always better in the innermost zone (i.e., Pico) than in the outer zone (i.e., micro and macro), and as a result, cell performance is improved overall. Furthermore, when 5G performance is compared to LTE performance using the same simulation conditions, 5G always outperforms LTE, especially in the deepest zones [5]

Research conducted by [6] presented wireless user equipment (UE) hardware design to reveal key 5G UE hardware design restrictions on circuits and systems. A new, highly reconfigurable system architecture for 5G cellular user equipment, namely distributed phased arrays-based MIMO (DPA-MIMO), is proposed on top of the aforementioned inquiry and design tradeoff analysis. For evaluating the suggested design, the link budget calculation and data throughput numerical results are presented.

According to the findings of a study that was carried out by [7], In a typical indoor office environment in downtown Brooklyn, New York, on the campus of New York University, ultra-wideband millimeter-wave (mmWave) propagation tests were carried out in the 28- and 73-GHz frequency bands. The observations give large-scale route loss and temporal statistics that will be relevant for future mmWave ultra-dense indoor wireless networks. The results reveal that the innovative large-scale path loss models presented here are simpler and more physically based than prior 3GPP and ITU indoor propagation models, which need more model parameters and provide little additional accuracy while lacking a physical basis. Multipath time dispersion statistics for mmWave systems with directional antennas are presented for co-polarization, cross polarization, and combined-polarization scenarios, demonstrating that the multipath root mean square delay spread can be reduced by using transmitter and receiver antenna pointing angles that result in the highest received power. Raw omnidirectional path loss data and closed-form optimization algorithms for all path loss models are available in the Appendices.

As presented in the study [8] cell planning techniques comparable to LTE can be used to plan a 5G network in the sub-6GHz spectrum. In the Australian context, the n78 band (3.3-3.8GHz TDD) is roughly 1GHz higher than the 2.6GHz spectrum used in current LTE networks. As a result of the same coverage area, co-locating 5G NR (New Radio) on existing LTE base stations is a frequent method for initial network rollout. Any variation in coverage can be adjusted by raising beamforming gain, decreasing down tilting, or boosting the transmit power of the gNodeB. This study describes an initial data connection budget, a coverage projection, and measurements for a 5G NR NSA (Non-Stand Alone) trial radiating at 3.5GHz with 60 MHz bandwidth. The coverage prediction is prepared using the RF planning tool Atoll and then compared to trial coverage measurements. These insights can be used to help plan a future 5G network in Sydney or a comparable setting.

Because of the worldwide bandwidth bottleneck, wireless carriers are investigating the underutilized millimeter wave (mm-wave) frequency spectrum for future broadband cellular communication networks. However, there is insufficient understanding of cellular mm-wave propagation in heavily crowded indoor and outdoor contexts. This data is critical for the design and operation of future fifth-generation cellular networks that employ the mm-wave band. In [9] the impetus for new mm-wave cellular systems, measurement methods, and hardware, as well as a range of measurement findings demonstrating that 28 and 38 GHz frequencies can be employed when employing steerable directional antennas at base stations and mobile devices.

In 2019, research [10] was undertaken by simulating a MIMO antenna system with six elements in the frequency bands 31.22-34.17 GHz and 31.79-33.37 GHz for -6 dB and -10 dB with a resonance frequency of 32.56 GHz, respectively. The anticipated 5G spectrum, 31.8 - 33.4 GHz, is also included in frequency band utilization. 5G technology prioritizes fast data transmission speeds as well as increased spectrum efficiency. MIMO antenna systems can boost a communication system's capacity and transmission speed. The simulation findings aid in the examination of numerous characteristics, including return loss and antenna isolation, with isolation values of 17 dB obtained in the 31.8 - 33.4 GHz frequency band.

III. Method & System Model

The network model used in this study is a cellular network with varying cluster sizes. In this study, link budget estimations are based on 3GPP 38.901, which is based on the path loss Urban Macro (UMa).

A. *Network Model*

Figs. 1, 2, and 4 depict cell networks with cluster sizes of N = 3, N = 4, and N = 7, respectively. In this approach, users are randomly distributed from the base station, and the base station transmit power Pt provides SINR to the n-th user cell.

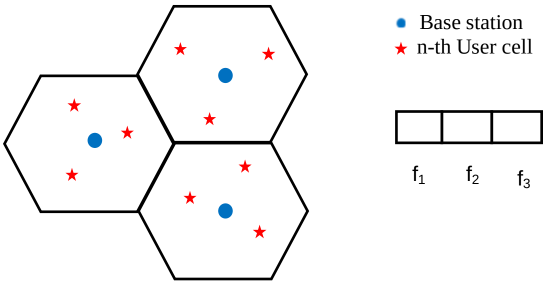

Figure 1. Cellular network with N=3

In Fig.1 illustrates integer frequency reuse which is applied to cell network with N =3. Bandwidth allocation is divided into three sub bands (f_1, f_2, f_3). Then each sub band is allocated fairly to each cell. Users are spread across each cell randomly namely *n*-th user cell and it use the sub bands allocated to each cell which is 1/3 of total bandwidth.

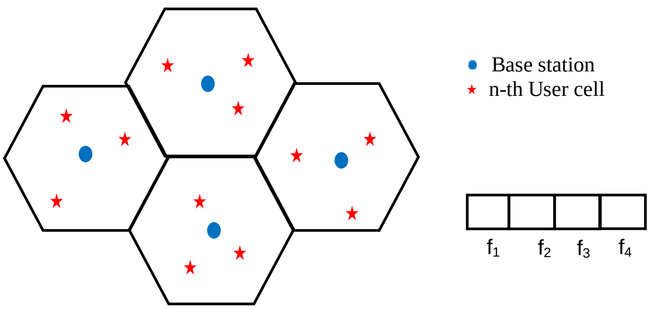

Figure 2. Cellular network with N=4

The bandwidth allocation in Fig.2 is divided into four sub bands (f1, f2, f3, f4). Then, each sub band is assigned to each cell fairly. Users are assigned at random to each cell, especially the n-th user cell, and they use the sub bands assigned to each cell, which is 1/4 of the total bandwidth.

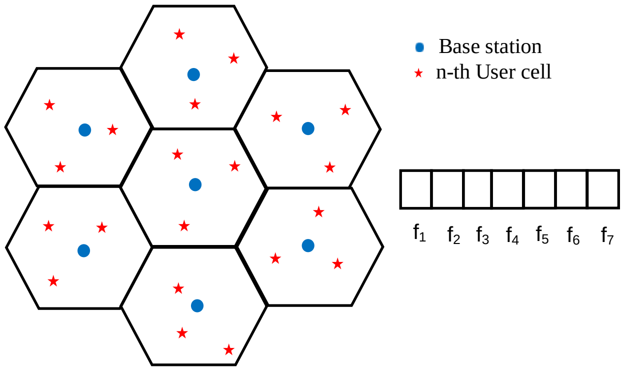

Figure 3. Cellular network with N=7

Fig.3 illustrates integer frequency reuse which is applied to cell network N = 7. Bandwidth allocation is divided into seven sub bands (f_1, f_2, f_3, f_4, f_5, f_6, f_7). Users are spread across each cell randomly namely *n*-th user cell and it use 1/3 of total bandwidth for each cell.

B. *Model of Propagation.*

The propagation model used by 5G differs from those of prior technologies. In 5G, the standard 3GPP propagation model 38.901 is used, which comprises the conditions UMa (Macro dense urban/urban/suburban), RMa (rural macro), and UMi (Macro urban/dense urban). Equation (1) is the standard propagation equation for the 3GPP 38.901 UMa LOS model.

$$PL_{Uma-LOS} = 28.0 + 30\log(d3D) + 20\log(fc) - 9\log[(d'BP)^2 + (hBS - hUT)^2] \quad (1)$$

Where:

$PL_{Uma-LOS}$ = Pathloss (dB)
d3D = Resultant of distance h_{BS} and h_{UT} (m)
hBS = Antenna Height of gNodeB (m)
hUT = Transmission user height (m)
fc = Frequency of carrier (Hz)
d'BP = Breakpoint distance (m)
d 'BP ≤ d2D ≤ 5000m

Equation (2) is used to get the value of d2D and (3) to obtain the value of d'BP:

$$\sqrt{(d3D)^2 + (hBS - hUT)^2} \quad (2)$$

$$d'BP = 4 \cdot h'BS \cdot h'UT \cdot \frac{fc}{c} \quad (3)$$

Where:

c = Speed of light ($3 \cdot 10^8$) (m/s)
d2D = BS-UT Distance/ Cell Radius (m)
h'BS = Antenna Height of gNodeB-height of equipment (m)
h'UT = Transmission user height -height of equipment (m)

C. *Throughput*

The Shannon equation is used to estimate throughput, as seen below [11]

$$C = B \log_2(1 + SINR) \quad (6)$$

In which B is the bandwidth allocation and SINR is the signal to interference noise ratio.

IV. Evaluation and Result

Simulations were carried out to investigate and compare throughput of 5G network in various cluster sizes. The CDF of throughput is numerically analyzed with three different cluster sizes, which are N = 3, N = 4, and N = 7. The simulation was run over 10,000 iterations at random location of user. The simulation parameters are summarized in Table 1.

Table 1. Parameters of simulation.

Parameter	Values
Cluster size	N = {3,4,7}
Cell radius	5000 (m)
Antenna Height(hBS)	25 (m)
User terminal height (hUT)	1,75 (m)
Frequency	3.5 GHz
Transmit Power	43 dBm
Bandwidth	100 MHz
Noise power density	-174 dBm/Hz
Subcarrier spacing	15 kHz

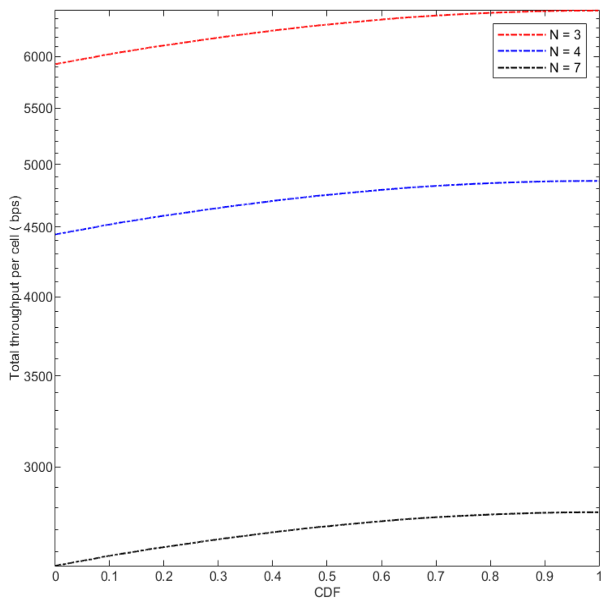

Figure.4 Comparison of throughput in various cluster size

Fig. 4 shows a comparison of throughput per cell for cluster sizes N = 3, N = 4, and N = 7. The graph illustrates that the cluster size of N = 3 provides higher throughput than the other scenarios. When CDF 0.9, the throughput of the N = 3 scenario is 6480 bps, which is more than the N = 4 scenario's large throughput of 4860 bps and the N = 7 scenario's large throughput of 2777 bps. This occurrence happens because in the N = 3 scenario, each cell receives a greater bandwidth allocation than in the other scenarios. In the N = 3, each cell receives 1/3 of the overall bandwidth allocation, whereas in the N = 4 and N = 7 scenarios, each cell receives 1/4 and 1/7 of the total bandwidth allocation, respectively. The available bandwidth of each cell has a significant impact on the throughput per cell.

V. Conclusion

We investigated the 5G Network throughput in various cluster sizes. Users were randomly allocated in cells with cluster size, N = 3, N = 4, and N = 7 in this study. The simulation showed that the cell with N = 3 cluster size has a higher throughput than the other scenarios. The cell with the smallest cluster size had the highest throughput, while the one with the largest had the lowest.

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References

[1] W. S. H. M. W. Ahmad *et al.*, “5G Technology: Towards Dynamic Spectrum Sharing Using Cognitive Radio Networks,” *IEEE Access*, vol. 8, pp. 14460–14488, 2020, doi: 10.1109/ACCESS.2020.2966271.

[2] F. Hu, B. Chen, and K. Zhu, “Full Spectrum Sharing in Cognitive Radio Networks Toward 5G: A Survey,” *IEEE Access*, vol. 6, pp. 15754–15776, 2018, doi: 10.1109/ACCESS.2018.2802450.

[3] B. Xie, Z. Zhang, R. Q. Hu, G. Wu, and A. Papathanassiou, “Joint Spectral Efficiency and Energy Efficiency in FFR-Based Wireless Heterogeneous Networks,” *IEEE Trans. Veh. Technol.*, vol. 67, no. 9, pp. 8154–8168, Sep. 2018, doi: 10.1109/TVT.2017.2701356.

[4] S. H. Lee, M. Kim, H. Shin, and I. Lee, “Belief Propagation for Energy Efficiency Maximization in Wireless Heterogeneous Networks,” *IEEE Trans. Wireless Commun.*, vol. 20, no. 1, pp. 56–68, Jan. 2021, doi: 10.1109/TWC.2020.3023079.

[5] A. I. Zreikat and S. Mercan, “Performance Study of 5G Downlink Cell,” in *Internet of Things, Smart Spaces, and Next Generation Networks and Systems*, vol. 11660, O. Galinina, S. Andreev, S. Balandin, and Y. Koucheryavy, Eds., in Lecture Notes in Computer Science, vol. 11660. , Cham: Springer International Publishing, 2019, pp. 377–389. doi: 10.1007/978-3-030-30859-9_32.

[6] Y. Huo, X. Dong, and W. Xu, “5G Cellular User Equipment: From Theory to Practical Hardware Design,” *IEEE Access*, vol. 5, pp. 13992–14010, 2017, doi: 10.1109/ACCESS.2017.2727550.

[7] G. R. Maccartney, T. S. Rappaport, S. Sun, and S. Deng, “Indoor Office Wideband Millimeter-Wave Propagation Measurements and Channel Models at 28 and 73 GHz for Ultra-Dense 5G Wireless Networks,” *IEEE Access*, vol. 3, pp. 2388–2424, 2015, doi: 10.1109/ACCESS.2015.2486778.

[8] T. Curry and R. Abbas, “5G Coverage, Prediction, and Trial Measurements,” 2020, doi: 10.48550/ARXIV.2003.09574.

[9] T. S. Rappaport *et al.*, “Millimeter Wave Mobile Communications for 5G Cellular: It Will Work!” *IEEE Access*, vol. 1, pp. 335–349, 2013, doi: 10.1109/ACCESS.2013.2260813.

[10] M. Zahid, S. Shoaib, and M. Rizwan, “Design of MIMO Antenna System for 5G Indoor Wireless Terminals,” in *2019 International Conference on Engineering and Emerging Technologies (ICEET)*, Lahore, Pakistan: IEEE, Feb. 2019, pp. 1–4. doi: 10.1109/CEET1.2019.8711818.

[11] M. Yaser, R. P. Astuti, and. A. F., “Pengaruh Posisi Penyebaran Femtocell Pada Implementasi LTE Femto yang Terintegrasi Dengan Jaringan GSM,” *JETT*, vol. 5, no. 2, p. 703, Mar. 2019, doi: 10.25124/jett.v5i2.1809.