International Journal of Engineering &Technology, 7 (4) (2018) 6233-6237

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet.v7i4.28294
Research paper

MM-wave backhauling for 5g small cells

Ahmed Thair Al-Heety [1] *, Mandeep Singh Jit Singh [1], Mohammad Tariqul Islam [1], Ali Hameed Ahmed [1]

[1] *Centre of Advanced Electronic and Communication Engineering, Faculty of Engineering and Built Environment, University Kebangsaan Malaysia, Selangor, Malaysia*
**Corresponding author E-mail: ahmedth162@gmail.com*

Abstract

The high capacity requirement for meeting the high demand of wireless application usage is the main issue in researches. Besides, to increase the capacity of the network, a new topology of cell configuration should be deployed which is the use of small cell configuration like micro and Pico cells with such configuration topologies in order to have high data rate network. This article aims to study the performance evaluation of the use of two 5G mm wave backhauling configurations. The first one is the star topology and the second one is the mesh topology. The main difference between them is the cooperation in mesh topology between cells to transfer data. The performance metric used in this project is the energy efficiency obtained from the two configurations when changing the frequency bands and path loss coefficient. The simulation results show that the changing the frequency bands in mesh configuration gives the same energy efficiency reached to 500 Mb/s at 15 nodes while the star configuration results reached less than 100 Mb/s at the same number of nodes.

Keywords: *5G; Mm-Wave; Small Cells; Wirless Backhaul; LOS.*

1. Introduction

The high demand of wireless communications due to the high need of capacity and high data throughput makes the bandwidth of the spectrum is a main issue in wireless modern systems like 5G. Because of this; high frequency bands are used for this reason which gives high spectrum bandwidth and needs mm Wave to communicate [12]. Wireless backhaul, which is an alternative to fiber, is cost effective and rapidly emerging into an attractive candidate for the deployment of high-speed 5G. Unlike half-duplex (HD) small cells in which either additional spectrum or properly-designed time-frequency distribution is required for the provision of wireless backhaul [23].
The proposal of Millimeter wave (mm) technologies has been made in recent times as backhaul for outdoor urban small cells [21]). More so, one of the major ways through which 5G cellular networks can be enabled is by deploying small cells over conventional macrocells [25].There are many issues that considered as challenges towards the use of mm Waves like attenuation in the free space propagation, penetration and indoor propagations and the backhauling between nodes of the network [18].
The high data backhaul traffic still big challenging and many communication mediums are proposed like fiber optic, and wireless communication. However, the microwave communication at high frequency bands with high data rate is considered viable for the small cells communication in NLOS [5]. For promising technology in modern wireless communication systems like 5G networks, the use of dense deployment of small cells in the macro cells systems is considered a very powerful technique and configuration of the system to increase the throughput of the system. However, a fundamental challenge is to provide efficient backhaul connectivity to these small cells which is the main objective of this research study.
One of the main performance metrics that can governs the performance of a cellular system is the system bandwidth that can be increased by using additional spectrum, which leads to a linear increase in system capacity [12].
The limitation of the backhauling strategies for small cells configuration can be such as, the connectivity between dense small cells deployed in the serving area, how to optimize the throughput of the uplink, downlink, and the overall system of all the small cells and the energy consumption of the system and how to optimize the energy dissipated in the system. Other limitation is the limitation of radio frequency spectrum which is a major issue that should be into consideration to design efficient spectrum planning for backhaul/access links of 5G small cells. [2]. proposed two criteria to make a suitable planning of the spectrum. The first one is the maximum received signal power (max-RSP) and the second one is the minimum received signal power (min-RSP) criteria.

1.1. The Motivation of This Study

The motivation of this study is the huge benefits that the use of millimeter wave (mm Wave) bands gives where the available bandwidths are much wider than today's cellular network [12]. Many challenges face the use of mm Waves; like attenuation, free space propagation, penetration and indoor propagations [4]. Which are considered the issues to motivate any researchers to deal with these challenges to overcome them. Non-line-of-sight (NLOS) is also one of the motivated topics that can be subjected in order to overcome extra power loss due to scattering, diffraction and longer traveling distances, resulting in high BER values, low throughput and notable performance degradation compared to LOS propagation conditions. In this thesis, we present the use of mauves backhauling in both star and mesh topologies considering LOS channels between small cells [12].

1.2. Millimeter Wave

One of the major factors that influences cellular system performance is the signal bandwidth which can be added through the use of extra spectrum, thereby leading to a linear increase in the capacity of data. (Nasser & Fahmy, 2016). According to International Telecommunication Union (ITU), millimeter wave operates in Extremely High Frequency (EHF) within the range of 30–300GHz. The large available bandwidth at millimeter wave (mmWave) frequencies makes them suitable for use in fifth generation cellular networks (Bai & Heath, 2014).

Basically, high rate of data of up to 1-2 Gbps range can be supported by millimeter wave RF. However, in comparison with Microwave RF, the reach is shorter because of high loss of propagation atmillimeter wave (Ahamed & Faruque, 2018). The use of MmWaves is accompanied by numerous challenges such as attenuation, propagation of free space which is subject to research through the use of penetration and indoor propagations, and techniques of antenna design that are subject to research by deploying multicarrier and aggregation of carrier.

Typically, the millimeter wave beams are much narrower compared to microwave beams that create a major constraint which is line of sight (LOS) backhaul solution. When directional antennas are used in mm Wave transmission, narrow directive beams are brought as new feature to mm Wave systems, thereby decreasing interuption, fading and multipath (Wei et al. 2014).

1.3. Small Cells Backhauling

The fifth generation wireless systems (5G) continue to be in need of higher rates of data and low latency. One of the major enablers, which is small cell deification also needs backhaul technology that is cost-effective and has low latency [23].The coverage and capacity of the network can be increased at lower rate through the ultra-dense deployment of small cell networks (SCN) [24].

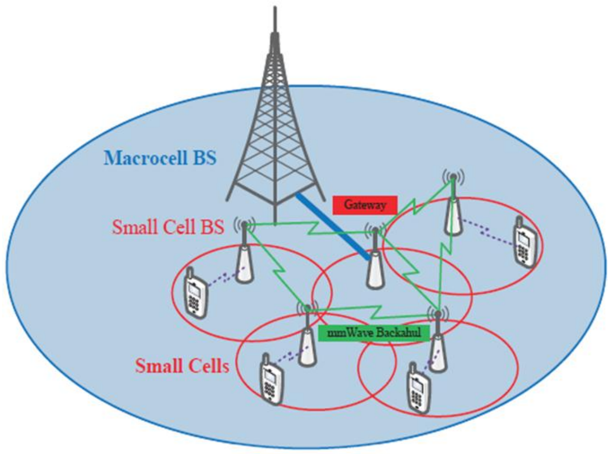

Fig. 1: MM Wave Topology of 5G Network (Niu Et Al. 2017).

Figure 1 shows the legacy base stations (BSs) of macro layer operate typically in mm wave frequency band and cover the wider geographical area but at limited capacity towards user equipments (UEs) (Maccartney et al. 2015). Small-cell layer coverage is provided by mm Wave Access Points (APs) that utilize beam-steerable narrow-beam ("pencil-beam") antennas to minimize energy consumption, limit interferences and focus capacity to where it is needed.

Some key parameters that differentiate steerable pencil-beam antennas from fixed sector antennas are the level of directivity (i.e. antenna gain) and steering range. The envisioned BH connections are assumed to be wireless in this topology while macro BH quite often is implemented with optical fiber (Taori&Sridharan 2015).

The backhaul links can create relay chains in this manner, providing extra coverage and routes behind obstacles. The envisioned UEs can simultaneously connect to both macro and small cell radio access technologies (RATs) (Dehos et al. 2014).

2. Small Cells Configurations

2.1. Star Configuration in 5g Networks

The system model of the star topology which is one of the centralized scenario configurations. It consists of a macrocell BS (MBS) assumed to be located in the macrocell center, and SBSs are assumed to be uniformly distributed in the macrocell. All SBSs are configured with the same transmission power and coverage [12].

The wireless configuration is a star topology which means that all the traffic of the small cells are transmitted to the main base station called MBS in the macro cell using mm Waves. All the traffic then from the MBS to the mobile network center is forwarded by using fiber to the cell (FTTC) links which considered the backhauling of the system [16].

2.2. Mesh Configuration in 5G Networks

The Mesh topology is the second configuration of the small cells in 5G. This considered one of the distributed scenario architectures. The main difference between this topology and that obtained from figure1 is that there is no MBS in the system in order to gather the small cells information and relayed it to the network center. Because of this, all traffic backhauling is transferred to the small cell base station (SBS) which are assumed to be uniformly distributed in the served area. The process of work starts from gathering information from users in the small cells then each SBS transfers the backhaul traffic to the adjacent SBS in a cooperative way where the system here called cooperative wireless system. To forward all backhaul traffic, a specific SBS is introduce to perform this operation and connected to the network center by an FTTC links [18].

3. Simulation Environment

The simulation process for all simulation stages starts from determining all variable parameters required for the simulation which are the node positions, the data message, the energy used for each node, the distances between nodes and the main node, and the path loss coefficient which is determined by the environment surrounding the system. The system simulation calculates the energy efficiency of the system for all cells in the network for both scenarios in order to study the performance of the system for LOS simulation.

There are 15 node with varying radius for each node starts from 30 m to 100m. The carrier frequency used is the 28 GHz to satisfy the 5G requirement and mm wave concept. The simulation starts to simulate the energy efficiency of both configurations under changing the mm wave frequency band to determine the effect of changing frequency bands on 5G backhauling. The effect of changing the path loss coefficient on 28 GHz band is also simulated

4. Simulation Scenarios

This simulation considers 15 nodes base stations mounted on the top of street lamp post for a height up to 4m. Only one base station, labeled BS1, has an FTTC link. All the other base stations have to route their data to BS1. Two different topologies are considered for this layout, the star topology and the mesh topology as shown in Figure 2.

The connections between every two small cells take the LOS communication is used in the simulation based on a Rayleigh fading channel model with 10 taps of multipath channels considering working in the 28 GHz frequency band for changing path loss coefficient, and different frequency bands to study the effect of each band on the backhauling performance.

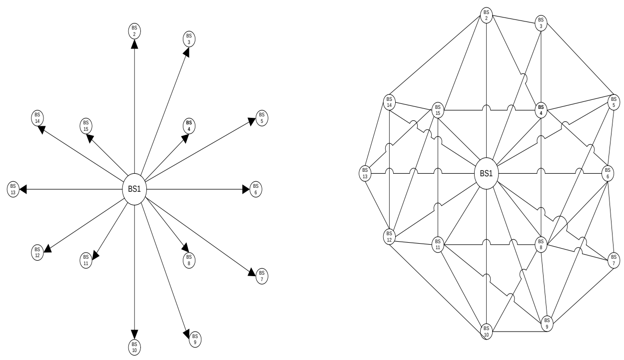

Fig. 2: Simulation Scenarios for Star and Mesh Topology.

Table 1: Simulation Parameters and Values

Parameters	Values
Nodes height (m)	3 – 4
Carrier frequency (GHz)	5.8, 28, 60
Bandwidth	20 MHz
Small cells radius (m)	30 - 100
Configuration types	Mesh and Star
Number of nodes	15 with main BS
Communication types	LOS
Path loss coefficient	3,4, 5

5. Performance Metrics

5.1. Energy efficiency

Energy efficiency = Energy for successfully transmitted bits / Total energy (1)

5.2. Coverage Probability

Pc = P [SINR ≥ β (2)

6. Results and Discussions

6.1. 28 GHZ with Comparison with Other mm Wave Bands

This section studies the performance analysis of using different mm wave frequency bands to in order to discuss the performance evaluation of the energy efficiency of the two scenarios. All simulation performed under LOS communication

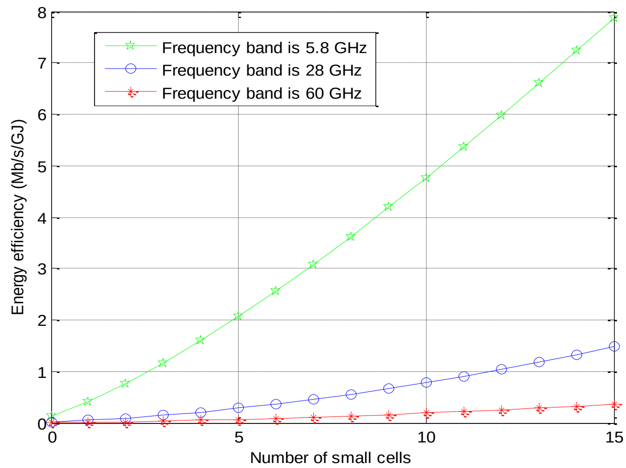

Fig. 3: Energy Efficiency of the Star Configuration for Different Mmwave Bands for 15 Nodes Only.

In Figure 3 the energy efficiency of wireless backhaul networks linearly increases with the increase in the number of small cells in the star solution. When the number of small cells is fixed, the energy efficiency of wireless backhaul networks decreases with the increase of frequency bands. However, obviously there are energy efficiency gaps for 5.8 GHz, 28 GHz, and 60 GHz frequency bands in the star solution

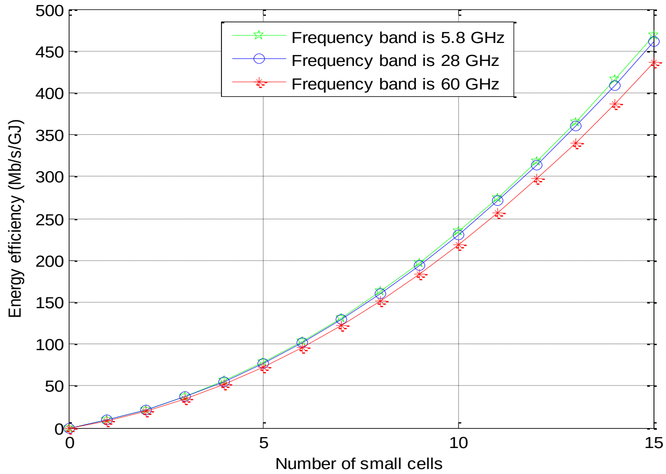

Fig. 4: Energy Efficiency of the Mesh Configuration for Different Frequency Bands for 15 Nodes Only.

In Figure 4, the energy efficiency of wireless backhaul networks exponentially increases with the increase of the number of small cells in the mesh solution. The results in the Figure 4 show that the three mm wave frequency bands in mesh configuration have nearly the same energy efficiency reached to 450 Mb/s at 15 nodes.

This result obtained because of the cooperative topology of the mesh configuration while the star configuration results reached less than 1.5 Mb/s at the same number of nodes at 28 GHz.

6.2. Path Loss Effect at 28 GHz

The energy efficiency of wireless backhaul networks with respect to the path loss coefficient considering different small cell radius is shown in Figure 5 for the star configuration and Figure 6 for the mesh one.

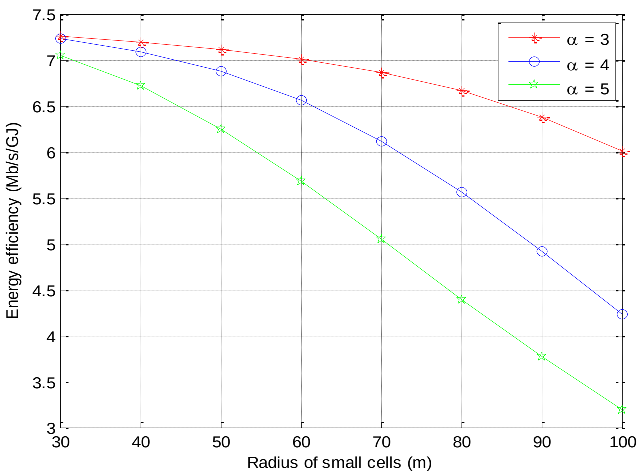

Fig. 5: Energy Efficiency of the Star Configuration for Different Values of Path Loss Coefficient.

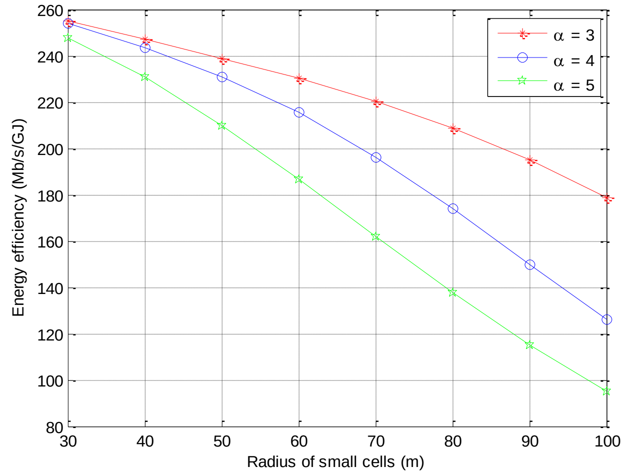

Fig. 6: Energy Efficiency of the Mesh Configuration for Different Values of Path Loss Coefficient.

In the star configuration, When the radius of small cells is less than or equal to 50 m, the energy efficiency of wireless backhaul networks increases with the increase of the path loss coefficient, When the radius of small cells is larger than 50 m, the energy efficiency of wireless backhaul networks decreases with the increase of the path loss coefficient.

When the system energy consumption is fixed, the energy efficiency is proportional to the wireless capacity in wireless backhaul networks. Compared with star and mesh configuration in Figure 5 and Figure 6, the energy efficiency of the star configuration is obviously less than the energy efficiency of the mesh solution under the same radius of small cells and the path loss coefficient.

The effect of this parameters comes from that it affects the received power delivers to the destination BS because increasing path loss exponents means increasing in the path loss of LOS communication.

6.3. SINR Coverage Probability for 28 GHz Mesh Configuration

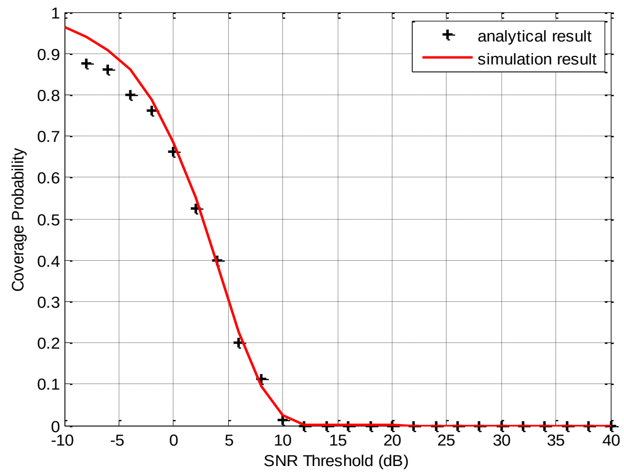

Fig. 7: SINR Coverage Probability of Mesh Configuration.

Figure 7 shows the SINR coverage probability of the mesh configuration as a type of D2D network as a function of the SINR threshold.It shows that by increasing the density of blockages, the SINR coverage probability of mesh base station receivers in the 28 GHz mmWave band decreases. It is in agreement with the observation that increasing the number of blockages in the environment, lowers the chance of LOS links, decreases the SINR coverage probability.

7. Conclusion

This paper studies the use of MmWave in small cells backhualing. The first one is the star configuration and the second one is the mesh. The energy efficiency of wireless backhaul networks is compared for different network architectures and mm wave frequency bands with addition to different values of path loss coefficient. The simulation results show that the mm wave frequency band plays an important role to choose the network configuration. If the application needs high energy efficiency, the suitable network configuration chosen is the mesh configuration. If the frequency band used is 5.8 GHz, and there is no need for high energy efficiency, the suitable chosen network is the star configuration.

References

[1] Ahamed, M. M. & Faruque, S. 2018. 5g Backhaul: Requirements, Challenges, and Emerging Technologies. Dlm. (pnyt.). Broadband Communications Networks-Recent Advances and Lessons from Practice, hlm.: IntechOpen. https://doi.org/10.5772/intechopen.78615.

[2] Alsharif, M. H. & Nordin, R. 2017. Evolution Towards Fifth Generation (5G) Wireless Networks: Current Trends and Challenges in the Deployment of Millimetre Wave, Massive Mimo, and Small Cells. Telecommunication Systems 64(4): 617-637. https://doi.org/10.1007/s11235-016-0195-x.

[3] Chaudhari, A. & Murthy, C. S. R. 2017. Femto-to-Femto (F2f) Communication: The Next Evolution Step in 5g Wireless Backhauling. Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt), 2017 15th International Symposium on, hlm. 1-8. https://doi.org/10.23919/WIOPT.2017.7959917.

[4] Chen, D., Schuler, J., Wainio, P. & Salmelin, J. 2015. 5g Self-Optimizing Wireless Mesh Backhaul. Computer Communications Workshops (INFOCOM WKSHPS), 2015 IEEE Conference on, hlm. 23-24. https://doi.org/10.1109/INFCOMW.2015.7179324.

[5] Coldrey, M., Berg, J.-E., Manholm, L., Larsson, C. & Hansryd, J. 2013. Non-Line-of-Sight Small Cell Backhauling Using Microwave Technology. IEEE Communications Magazine 51(9): 78-84. https://doi.org/10.1109/MCOM.2013.6588654

[6] Feng, X., Wang, H., Li, Z., Zou, W. & Kenan, X. 2017. Fast Access in V2v Communication Services by Dynamic Resources Allocation, Google Patents.

[7] Ghosh, A., Thomas, T. A., Cudak, M. C., Ratasuk, R., Moorut, P., Vook, F. W., Rappaport, T. S., MacCartney, G. R., Sun, S. & Nie, S. 2014. Millimeter-Wave Enhanced Local Area Systems: A High-Data-Rate Approach for Future Wireless Networks. IEEE Journal on Selected Areas in Communications 32(6): 1152-1163. https://doi.org/10.1109/JSAC.2014.2328111.

[8] Index, C. V. N. 2014. Global Mobile Data Traffic Forecast Update, 2013–2018-Cisco Systems. Inc., San Diego, White Paper

[9] Jungnickel, V., Manolakis, K., Zirwas, W., Panzner, B., Braun, V., Lossow, M., Sternad, M., Apelfrojd, R. & Svensson, T. 2014. The Role of Small Cells, Coordinated Multipoint, and Massive Mimo in 5g. IEEE Communications Magazine 52(5): 44-51. https://doi.org/10.1109/MCOM.2014.6815892.

[10] Kalimulin, R., Artemenko, A., Maslennikov, R., Putkonen, J. & Salmelin, J. 2015. Impact of Mounting Structures Twists and Sways on Point-to-Point Millimeter-Wave Backhaul Links. Communication Workshop (ICCW), 2015 IEEE International Conference on, hlm. 19-24. https://doi.org/10.1109/ICCW.2015.7247069.

[11] Medbo, J., Kyosti, P., Kusume, K., Raschkowski, L., Haneda, K., Jamsa, T., Nurmela, V., Roivainen, A. & Meinila, J. 2016. Radio Propagation Modeling for 5g Mobile and Wireless Communications. IEEE Communications Magazine 54(6): 144-151. https://doi.org/10.1109/MCOM.2016.7498102.

[12] Nasr, A. I. & Fahmy, Y. 2016. Millimeter-Wave Wireless Backhauling for 5g Small Cells: Star Versus Mesh Topologies. Microelectronics (ICM), 2016 28th International Conference on, hlm. 85-88. https://doi.org/10.1109/ICM.2016.7847914.

[13] Niu, Y., Gao, C., Li, Y., Su, L., Jin, D., Zhu, Y. & Wu, D. O. 2017. Energy-Efficient Scheduling for Mmwave Backhauling of Small Cells in Heterogeneous Cellular Networks. IEEE Transactions on Vehicular Technology 66(3): 2674-2687. https://doi.org/10.1109/TVT.2016.2582785.

[14] Niu, Y., Li, Y., Jin, D., Su, L. & Vasilakos, A. V. 2015. A Survey of Millimeter Wave Communications (Mmwave) for 5g: Opportunities and Challenges. Wireless Networks 21(8): 2657-2676. https://doi.org/10.1007/s11276-015-0942-z.

[15] Prasad, A., Uusitalo, M. A. & Maeder, A. 2017. Energy Efficient Coordinated Self-Backhauling for Ultra-Dense 5g Networks. Vehicular Technology Conference (VTC Spring) https://doi.org/10.1109/VTCSpring.2017.8108609.

[16] Rajagopal, S., Taori, R. & Abu-Surra, S. 2014. Self-Interference Mitigation for in-Band Mmwave Wireless Backhaul. Consumer Communications and Networking Conference (CCNC), 2014 IEEE 11th, hlm. 551-556. https://doi.org/10.1109/CCNC.2014.6866625.

[17] Rappaport, T. S., Maccartney, G. R., Samimi, M. K. & Sun, S. 2015. Wideband Millimeter-Wave Propagation Measurements and Channel Models for Future Wireless Communication System Design. IEEE Transactions on Communications 63(9): 3029-3056. https://doi.org/10.1109/TCOMM.2015.2434384.

[18] Robson, J. 2012. Small Cell Backhaul Requirements. NGMN White Paper 1-40.

[19] Shariat, M., Dianati, M., Seppänen, K., Suihko, T., Putkonen, J. & Frascolla, V. 2015. Enabling Wireless Backhauling for Next Generation Mmwave Networks. Networks and Communications (EuCNC), 2015 European Conference on, hlm. 164-168. https://doi.org/10.1109/EuCNC.2015.7194061.

[20] Shokri-Ghadikolaei, H., Fischione, C., Fodor, G., Popovski, P. & Zorzi, M. 2015. Millimeter Wave Cellular Networks: A Mac Layer Perspective. IEEE Transactions on Communications 63(10): 3437-3458. https://doi.org/10.1109/TCOMM.2015.2456093.

[21] Taori, R. & Sridharan, A. 2015. Point-to-Multipoint in-Band Mmwave Backhaul for 5g Networks. IEEE Communications Magazine 53(1): 195-201. https://doi.org/10.1109/MCOM.2015.7010534.

[22] Bogale, T.E. & Le, L.B. 2016. Massive MIMO and mmWave for 5G wireless HetNet: Potential benefits and challenges. IEEE Vehicular Technology Magazine 11(1): 64–75. https://doi.org/10.1109/MVT.2015.2496240.

[23] Choi, J., Bai, J., Yeh, S.-P., Choi, Y.-S. & Talwar, S. 2018. Full-Duplex Self- Backhaul Small Cell: Capacity Gain and Traffic Adaptation. In 2018 IEEE International Conference on Communications Workshops (ICC Workshops). pp. 1–6. IEEE. https://doi.org/10.1109/ICCW.2018.8403647.

[24] Malila, B., Falowo, O. & Ventura, N. 2017. An Energy Efficiency Analysis for Outdoor Wireless Small Cell Backhaul. In Wireless Communications and Networking Conference (WCNC), 2017 IEEE. pp. 1–6. IEEE. https://doi.org/10.1109/WCNC.2017.7925704.

[25] Siddique, U., Tabassum, H. & Hossain, E. 2017. Downlink spectrum allocation for in-band and out-band wireless backhauling of full-duplex small cells. IEEE Trans. Commun 65(8): 3538–3554. https://doi.org/10.1109/TCOMM.2017.2699183.

[26] Wei, L., Hu, R.Q., Qian, Y. & Wu, G. 2014. Key elements to enable millimeter wave communications for 5G wireless systems. IEEE Wireless Communications 21(6): 136–143. https://doi.org/10.1109/MWC.2014.7000981.

[27] (Ridel et al. 2018) Ridel, E., Soffer, R., Kanari, U., Levitan, E., Zalitzky, I. & Bar, Y. 2018, June 7. Digital Full Duplex Over Single Channel Solution for Small Cell Backhaul Applications. US Patent App. 15/888,226.