# Handover Management in Dense Networks with Coverage Prediction from Sparse Networks

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***Abstract*—Millimeter Wave (mm-Wave) provides high bandwidth and is expected to increase the capacity of the network thousand-fold in the future generations of mobile communications. However, since mm-Wave is sensitive to blockage and incurs in a high penetration loss, it has increased complexity and bottleneck in the realization of substantial gain. Network densification, as a solution for sensitivity and blockage, increases handover (HO) rate, unnecessary and ping-pong HO, which in turn reduces the throughput of the network. On the other hand, to minimize the effect of increased HO rate, Time to Trigger (TTT) and Hysteresis factor (H) have been used in Long term Evolution (LTE). In this paper, we primarily present two different networks based on Evolved NodeB (eNB) density: sparse and dense. As their name also suggests, the eNB density in the dense network is higher than the sparse network. Hence, we proposed an optimal eNB selection mechanism for 5G intra-mobility HO based on spatial information of the sparse eNB network. In this approach, User equipment (UE) in the dense network is connected only to a few selected eNBs, which are delivered from the sparse network, in the first place. HO event occurs only when the serving eNB can no longer satisfy the minimum Signal-to-Noise Ratio (SNR) threshold. For the eNBs, which are deployed in the dense network, follow the conventional HO procedure. Results reveal that the HO rate is decreased significantly with the proposed approach for the TTT values between 0 ms to 256 ms while keeping the radio link failure (RLF) at an acceptable level; less than 2% for the TTT values between 0 ms to 160 ms. This study paves a way for HO management in the future 5G network.**

## I. INTRODUCTION

The need for high-speed connectivity and demand for broadband wireless communication is expected to increase at thousand-fold in the near future [1]. This problem leads researchers to search for another frequency band with high bandwidth to accommodate more User Equipment (UE). Future generations of mobile communication aim to achieve tremendous performances by significantly improving the reliability of connection and while enhancing the speed. Furthermore, future mobile generation, so-called the fifth generation, will mainly focus on the use of mm-Wave band. Motivated by a vast amount of available bandwidth, mm-Wave promises to provide multi-gigabit-per-second transmission throughputs to mobile devices. However, due to the sensitivity of the mm-Wave, deafness and blockages are highly likely to occur, and both diminished the advantageous of the mm-Wave [2]. Deafness refers to a situation where the transmit-receive beams do not point to each other, whereas blockage causes a failed message delivery due to a channel drop, which may be related to obstacles, hand rotations, and other mm-Wave-sensitive events [3]. On the other hand, increasing the transmission power, or waiting for a random back-off time (as done in LTE), are not suitable approaches in mm-Wave networks, since mm-Wave rely on beamforming and limited power for UE [3].

To overcome the limitations of the mm-Wave band, network densification has been observed and considered as a way to reduce these restriction [4], [5]. Moreover, other types of solutions, such as dual connectivity, have also been proposed as the ways to mitigate the problems [6], [7]. However, solving the problem of sensitivity for mm-Wave and coverage by considering the densification of network emerges other complication, such as higher number of unnecessary HO, ping pong HOs. In [8], parameters that can help mitigate the problem of high HO rate are described: Time to trigger (TTT) and HO Margin (HOM). TTT is the length of time when the reference signal received power (RSRP) of serving Evolved NodeB (eNB) is less than the nearest or target eNB. HOM or Hysteresis factor is the minimum RSRP difference between serving eNB and targeted eNB that are needed for start count TTT.

There are various works in the literature addressing the problem of multiple HOs. In [7] and [6], for example, the authors proposed the use of multi-connectivity, such that (i) UE transmits sounding signals in directions that sweep the angular space, (ii) the mm-Wave cells measure the instantaneously received signal strength along with its variance to better capture the dynamics. In [9], a predictive HO management, which can help decrease the number of unnecessary HOs, was introduced. However, the authors did not consider the mm-Wave scenario, where there is huge number of cells, which can subsequently decrease the prediction accuracy. Furthermore, none of above works incorporate the proper selection of TTT. The models in [10], [11] suggest a cooperative HO management in the dense cellular network and use stochastic geometry to evaluate the system performance. However, their analytical model does not consider the effects of TTT and NLOS.

The directional tracking increases the latency and a poor TTT selection may boost bottleneck in realizing robust mm-Wave networks. The HO procedure introduces signaling overhead between UE, serving eNB and all surrounding eNB which consumes resources and lead to delay that increase overheads, which is critical issue in dense networks. The overhead is very prone to be huge due to the frequent search for the new base station after link disconnections. In addition, TTT is a parameter affecting the latency overhead largely, which in turn degrades network performance. Since TTT can decrease/increase the HO and Radio Link Failure (RLF) rates, it becomes a hyperparameter to be optimized in mobile networks, particularly in dense networks.

In this study, we analyse the effect of TTT in the introduced sparse and dense networks, where LTE HO procedure is adapted for 5G analysis. For HO to take place, there are certain criteria to be met. Unlike 3G and UMTS, 5G will not support soft or softer HO, where soft HO refer HO between two sectors of the same cell in eNB and if occurs between two cell in different eNB is called softer HO. 5G rather support the hard HO procedure: once HO criteria met UE will disconnect from serving BS and connects directly to target BS [7]. Consequently, the UE will experience intermittence connection for a certain amount of time.

The effect of various TTT on the HO performance in self-organized network (SON) is studied in [12], considering the UE mobility from 3 km/h and proposed the optimum value of TTT in LTE for their specific scenario. However, the analysis was based on the frequency less than 6 GHz, and the effects of the obstacles and network densification are not taken into consideration.

This paper presents the effect of network densification for pedestrian users with a velocity of 1-2 m/s and proposes a HO algorithm based on the information obtained from the sparse network. Location of serving eNB are collected for various value of TTT in sparse network, considering the minor HO rate in the sparse network and used for coverage prediction in the dense network. RLF and HO rates are used as Key Performance Indicators (KPIS), and the network is evaluated for different values of TTT in order to determine the best TTT causing lower HO and RLF rates. We restrict ourselves on the assumption that the UE is connected only to the mm-Wave cellular system and analysis is done by quantifying the effects of densification by varying TTT on mm-Wave cellular system only. Note that the simulation are carried out for the sparse network with $\lambda = 50BS/km^2$ and dense network with $\lambda = 100BS/km^2$ equivalent to 3 eNB's and 7 eNB's respectively in 300m by 300m .

The rest of the paper is organized as follows: First, in Section II, the effects of TTT and densification are introduced. Proposed model, and simulation design and parameter selection are described in Section III and Section IV respectively. Results are discussed in Section V. Finally, Section VI concludes the paper.

## II. EFFECT OF DENSE NETWORK TTT ON RLF AND HANDOVER

To evaluate the performance of the dense mm-Wave network, we consider UE undertake only inter-mobility HO. Intra-mobility HO is a type of HO from mm-Wave eNB to another mm-Wave eNB. The HO decision whether a UE should execute a HO is based on the signal quality measurements, which is reported by UE to the eNB. In general, RSRP measurements from serving and neighbouring cells are collected by UEs and transmitted to serving cells. Then, the serving cell compares its RSRP with the neighbour cells, and TTT start to count once RSRP of a neighbouring CELL is greater than the serving cell by HMO [13]. At TTT count, if RSRP of the serving cell becomes greater than all neighbouring cells then leaving event occurs so that HO would not be executed [12] otherwise continue with HO event. The detailed pseudo code of HO algorithm is described in Algorithm 1, where $RSRP_{\text{target}}$ and $RSRP_{\text{serving}}$ are the measured RSRP values from the target and serving eNBs, respectively, and $H$ is the hysteresis factor. The procedure requires signalling overhead between a UE and network which greatly effects the throughput of the system.

**Algorithm 1:** Handover Algorithm [14]

```
Mobility state initialization;
if $RSRP_{target} > RSRP_{serving} + H$ then
    if $Time > TTT$ then
        Handover to target eNB;
    else
        Continue with the serving eNB and update TTT;
    end
else
    Continue with the serving eNB;
end
```

As for intra-mobility HO in LTE, a network provider in 5G will configure the parameter value TTT to have the minimum necessary number of HOs and the minimum number of link failure. This is because each HO consumes valuable network resources and the high number of link failure degrades the quality of service and experience. In consequence, we investigate the effect of eNB densification and find the optimum parameter to achieve the low HO and RLF rates.

Fig. 1 shows the effect of eNB densification in the area of interest, where the UE moves with constants speed and be expected to connect to a specific cell. However, due to reflection; multiple obstacles; and nature of mm-Wave in the dense mm-Wave network, the HO rate becomes higher compared to when UE moves in the sparse mm-Wave network. The adverse effect of the sparse network is a considerably high occurrence of RLF and outage probability due to poor coverage compared to a dense mm-Wave network which provide reliable coverage [15] for a given trajectory, given that both eNB's in sparse and dense have the same transmission power. Besides, line of sight (LOS)&non-line of sight (NLOS) signals and reflection increase signal fluctuations in the dense mm-Wave network. UE might get excellent signals from an eNB, which is far away, due to LOS channel while nearest eNB might not provide the relatively high signal due to obstacles. Signal fluctuations and poor TTT configurations increase the HO and RLF rates.

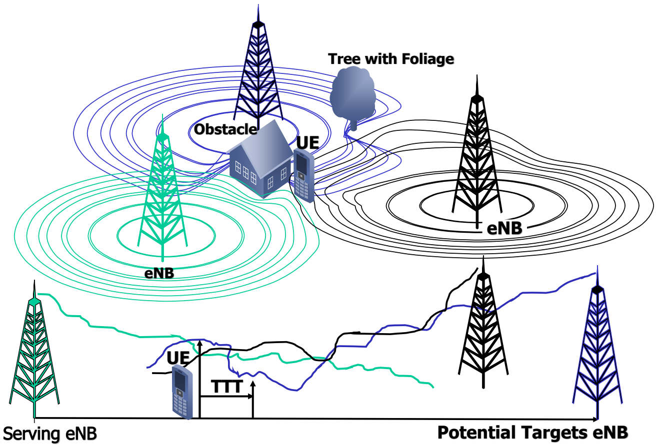


Fig. 1. Dense mm-Wave increase handover rate scenario

**Algorithm 2:** Proposed HO Algorithm

```
Mobility state initialization;
Extract information from Sparse Network;
if $eNB_{sparse} == eNB_{\text{with maximum RSRP at location}}$ then
    if $eNB_{serving} == eNB_{sparse}$ then
        Continue with serving eNB;
    else
        Handover to sparse eNB;
    end
else
    if $eNB_{serving} == eNB_{sparse}$ then
        if $SNR_{serving} <= Threshold\ SNR$ then
            Handover to eNB$_{\text{with maximum RSRP}}$;
        else
            Continue with Serving eNB;
        end
    else
        if $RSRP_{\text{with maximum RSRP}} > RSRP_{serving} + H$ then
            if $Time > TTT$ then
                Handover to eNB$_{\text{with maximum RSRP}}$ ;
            else
                Continue with the serving eNB and
                  update TTT;
            end
        else
            Continue with the serving eNB and reset
              TTT;
        end
    end
end
```

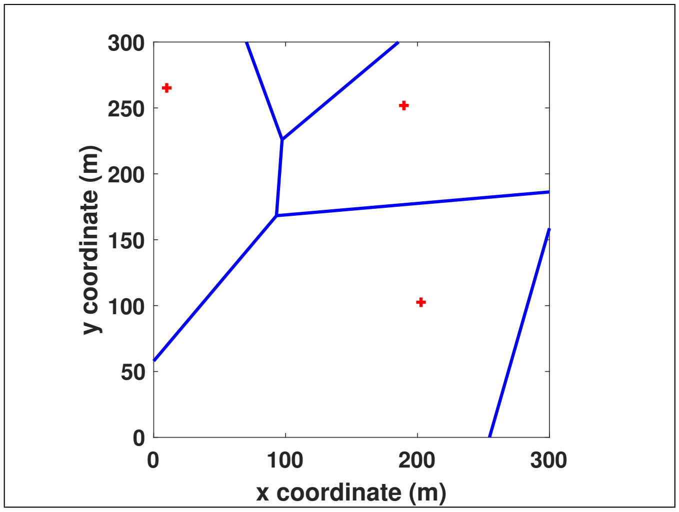
## III. PROPOSED MODEL

In our proposed scheme, we assumed that for the given trajectory or area of interest, there are a few number of eNB that can serve UE with a minimum HO rate and reasonable UE satisfactory. This network of a few eNb to serve a UE with minimum HO we called sparse network. For both cases, sparse and Dense, the eNB's are deployed and positioned at the specific location to maximize the minimum SNR in the area of interest [16], and we assigned average minimum SNR of 0 dB and 3 dB specified for sparse and dense network respectively. The number of HOs and RLF rates are analysed in the sparse network with a different value of TTT. From intra-mobility in the sparse network, spatial locations of the best serving eNBs for every TTT are stored. That means for specific UE trajectory with given TTT, there is best serving eNBs in term of low percentage HO rate, if UE connected to it, provides minimum HO for every point within the trajectory irrespective to channel quality. The eNBs obtained from the sparse network will be treated as the pillar eNBs hereafter, and all pillar eNBs stay in the same position and maintain the same power in the course of network densification. This is advantageous to future mobile generation and coordinating multpoint (CoMP) systems. Since, it will reduce time for search eNB or make comparison with other signals for HO decision.The main purpose of densifying network is to increase the quality of service (QoS) and quality of experience (QoE), however, unnecessary HO degrade the system performance. After adding eNB's to increase the reliability, coverage and capacity in the network. The prediction comes, once UE starts moving at that trajectory, UE uses spatial location and refer to sparse network table for serving eNB at that location. If UE is connected to a certain eNB at a given location , and that eNB connected to is also matched from sparse network table, then, UE will continue to be served by that eNB regardless of RSRP at that particular point until SNR of the serving eNB reached minimum. This paper use minimum SNR of 10 dB [17], and when this value reached, UE perform hard HO immediately to the eNB that has maximum RSRP. HO conventional method applies after UE starting to be served with eNB that is not registered as the pillar eNB. Moreover, the optimum location and selection for pillar eNB will depend on the many factor including presence of blockages, terrain profile and general is the function of particular area. To enhance the effectiveness of this model is straight forward by extending the analysis of location selection for pillar eNB by means of clustering and artificial intelligence. The detailed pseudo code for proposed HO algorithm is described in Algorithm 2.

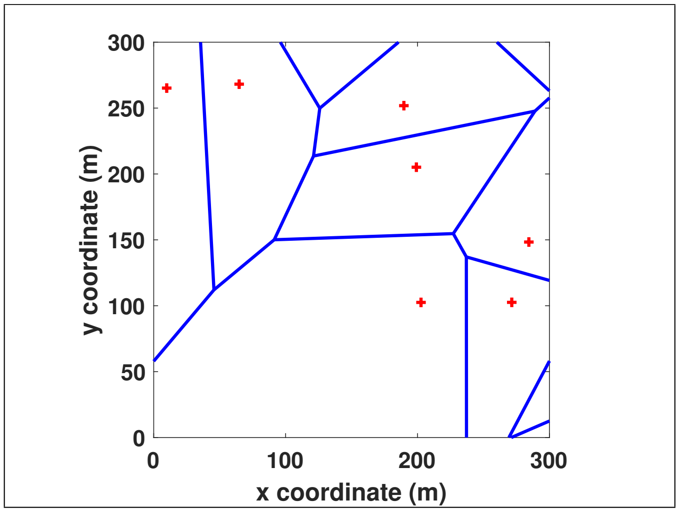
## IV. SIMULATION MODEL AND PARAMETERS

### A. *Base Station Modelling*

In the simulation, we deployed eNB adhere to a model by [16] for base station modeling. Number of deployed eNB for sparse and dense are 3 and 7 respectively. For both cases,we obtained the optimum location of eNB in two-dimension by maximizes the minimum SNR of any point over the entire region location. The coordinates obtained is taken and deployed into wireless insite Software. UE is assumed to be served by the eNB providing the highest received power. Moreover, all eNBs are assumed to transmit with the same effective isotropic radiated power. The eNB deployment resulting that comprises a Voronoi tessellation on the plane, as shown in Figs. 2a and 2b for sparse and dense network respectively.



(a) $0.3 \times 0.3$ km view of eNB in urban area with $\lambda = 50BS/km^2$, with the cell boundaries corresponding to Voronoi tessellation.



(b) $0.3 \times 0.3$ km view of eNB in urban area with $\lambda = 100BS/km^2$, with the cell boundaries corresponding to Voronoi tessellation.

Fig. 2. (a) Sparse and (b) Dense. All eNB's from the sparse network stay in the same position and maintain the same power in the course of network densification

### B. *Building Model Development*

For modelling building, a random object process (ROP) is used to construct randomly sampling object in 2-D space. The heights of the buildings are randomly assigned. The simulation assumed a typical urban area having a dimension of $300m \times 300m$, where different building non-overlapping with different size and height are placed for a moving user in order to experience both LOS and NLOS transitions. The terrain elevation profile is not considered, and all buildings height are considered with the reference to the terrain.

### C. *Self-blockage Model*

For the sake of simplicity, we assume that a mobile self-blocking model is neglected, extending the result of this paper to the case of incorporating self-blocking is straight forward by including loss from [18].

TABLE I
SIMULATION PARAMETERS

| **Parameter** | **Value** |
|---|---|
| BS intensity | 50 BS/$km^2$ and 100 BS/$km^2$ |
| mmWave frequency | 28 GHz |
| mmWave bandwidth | 1 GHz |
| eNB transmit power | 30 dBm |
| TTT | {0, 40, 64, 80, 100, 128, 160, 256, 320, 480, 512, 640, 1024, 1280, 2560, 5120} ms |
| Antenna pattern | Isotopric |
| Pedestrian velocity | 1.2 m/s |
| Noise figure | 5 dB |
| Threshold SNR | 10 dB |

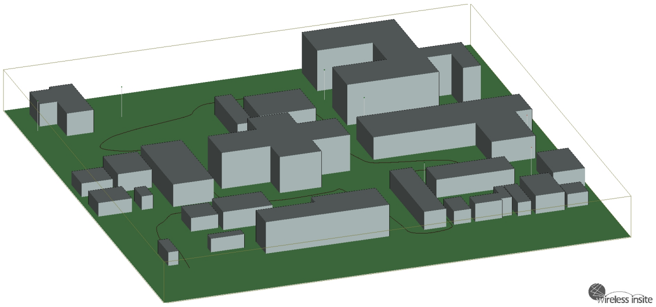


Fig. 3. The figure Illustrates simulation setup where UE is moving in street corridor

### D. *Directional model and interference avoidance*

In the mm-Wave cellular network, the antennas can form directional beamforming that will provide interference isolation, which reduces the impact of other-cell interference. This paper made an assumption that the antenna is isotropic in order to capture the effect of ping pong, moreover, we assume that the RLF occurs when the received signal-to-noise ratio (SNR) from the serving eNB below is 10 dB before completing the HO execution [17].

### E. *Simulation Parameters*

In the simulation, we use X3D ray tracing model from the commercial Wireless Insite$^{\text{TM}}$ (WI) software. X3D model does not have any restrictions on geometry shape or transmitter/receiver height. The software is verified and is widely used in mm Wave research [19]. The setup environment from WI is shown in figure 3 where UE is moving in a street corridor ,and experience LOS and NLOS in a trajectory. Each eNB is installed on the tower at 20 m height, and dipole antenna is deployed. UE trajectory is randomly in the $300m \times 300m$ area with maximum trajectory length of $800m$, and no moving obstacle apart from obstacle caused by UE within the trajectory. The trajectory is same for both cases, $\lambda = 100$ and $\lambda = 50$ and parameters are based on realistic 5G system design summarized in the Table I.

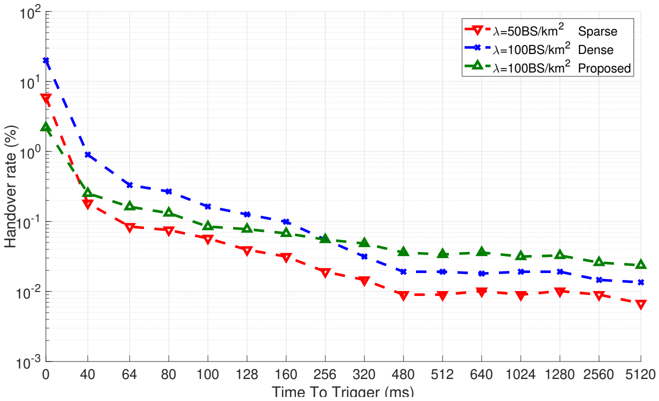


Fig. 4. Handover rate in mmwave as function of TTT at 28GHz.

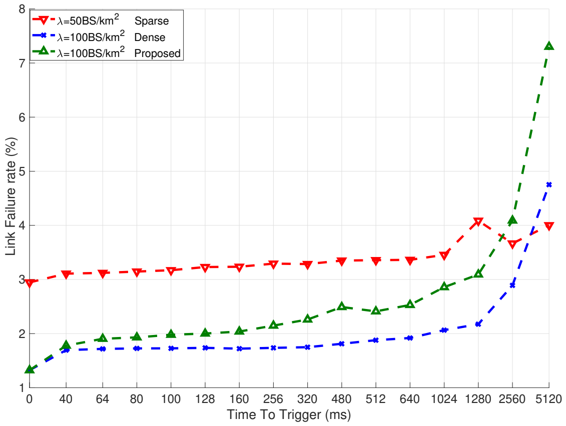


Fig. 5. The RLF in mmwave as function of TTT at 28GHz.

## V. SIMULATION RESULTS

In this section the behaviour of the mm-Wave and response to obstacles is analysed, in order to evaluate what extent the densification of network in mm-Wave cellular network affect the overall performance of the system. The simulations are performed under the setting illustrated in Table I. Comparison between sparse $\lambda = 50BS/km^2$ and dense $\lambda = 100BS/km^2$ are studied respectively and results from the proposed model are presented as well.

Fig. 4 shows the comparison between HO rate in three cases, it can be clearly seen that the proposed model for the dense network has the low number of HO for value of TTT from 0 ms to just below 256 ms and start increased slightly above 256 ms. In addition the HO rate in the proposed solution provides worse results compared to conversion algorithms from 256 ms. In general, all value of TTT from sparse network show a few number of HO, however for TTT = 0 ms, the proposed model has shown the minimum number of HO rate.

Fig. 5 shows that a high number of link failures occurred in sparse compared to dense. The simulation results shows the RLF increased in all three cases. In case of sparse network it can been seen if the KPI of the network is 2% as maximum allowed RLF in [12], then $\lambda = 50BS/km^2$ is not satisfying to serve the UE if value of TTT $> 0$; however, for $\lambda = 50BS/km^2$ the RLF has increased slowly for all values of TTT except the minor fluctuation which occurred at TTT = 1280 ms. The proposed solution shows that RLF increased sharply just above 0% at 0 ms to 1.75% at 40 ms in the proposed algorithms and keep increased steadily to just above 2% at 160 ms and continuously increased sharply to 7% at 5120 ms. The rate of RLF become higher in the proposed solution as most of the time try to connect with the eNB from the sparse network regardless of the time for which SNR become small below the threshold. On the other hand, same as the proposed solution the RLF starts changing dramatically from just above 0% at 0 ms to just below 1.75% at 40 ms and from 40 ms the RFL keep rise slowly and reached the maximum RLF of 2% at the TTT between 640 ms and 1024 ms.

## VI. CONCLUSION

This paper sheds light on the effect of network densification in the mm-Wave network for a pedestrian user, and proposed HO algorithms which based on the location awareness from few eNBs (sparse network) with $\lambda = 50BS/km^2$. Although we delivered the sparse network from classical mathematics, the model still show improvement in reducing HO in the dense network with little impact on RLF rate for TTT between 0 ms to 160 ms. In addition, the mm-Wave cellulalar system uses Multiple Input Multiple Output (MIMO) and beamforming technique, and the signalling overheads are comparatively higher in MIMO if a link failure occurs due to channel search and the use of two-tier for data plane and control plane. In the future, it is interested to extend the study for M-MIMO system and to develop solution based on Artificial Intelligence (AI) by means of delivered sparse network from clustering in particular trajectory for mm-Wave cellular system in order to reduce unnecessary HO due to rapid channel dynamic while appreciating the benefit of low RLF.

## REFERENCES

[1] L. Wei, R. Q. Hu, Y. Qian, and G. Wu, "Key elements to enable millimeter wave communications for 5g wireless systems," *IEEE Wireless Communications*, vol. 21, no. 6, pp. 136–143, 2014.

[2] D. Liu, L. Wang, Y. Chen, M. Elkashlan, K. Wong, R. Schober, and L. Hanzo, "User association in 5g networks: A survey and an outlook," *IEEE Communications Surveys Tutorials*, vol. 18, no. 2, pp. 1018–1044, Secondquarter 2016.

[3] M. Giordani, M. Mezzavilla, and M. Zorzi, "Initial access in 5G mmwave cellular networks," *IEEE Communications Magazine*, vol. 54, no. 11, pp. 40–47, Nov. 2016.

[4] W. Feng, Y. Wang, D. Lin, N. Ge, J. Lu, and S. Li, "When mmwave communications meet network densification: A scalable interference coordination perspective," *IEEE Journal on Selected Areas in Communications*, vol. 35, no. 7, pp. 1459–1471, July 2017.

[5] T. S. Rappaport, Y. Xing, G. R. MacCartney, A. F. Molisch, E. Mellios, and J. Zhang, "Overview of millimeter wave communications for fifth-generation (5g) wireless networkswith a focus on propagation models," *IEEE Transactions on Antennas and Propagation*, vol. 65, no. 12, pp. 6213–6230, Dec 2017.

[6] M. Giordani, M. Mezzavilla, S. Rangan, and M. Zorzi, "Multi-connectivity in 5G mmwave cellular networks," in *Proc. Mediterranean Ad Hoc Networking Workshop (Med-Hoc-Net)*, Jun. 2016, pp. 1–7.

[7] M. Polese, M. Giordani, M. Mezzavilla, S. Rangan, and M. Zorzi, “Improved handover through dual connectivity in 5G mmwave mobile networks,” *IEEE Journal on Selected Areas in Communications*, vol. 35, no. 9, pp. 2069–2084, Sep. 2017.

[8] G. T. 36.331., “3rd generation partnership project; technical specification group radio access network; evolved universal terrestrial radio access (eutra); radio resource control (rrc); protocol specification (release 10),” 2011.

[9] M. Ozturk, P. V. Klaine, and M. A. Imran, “Introducing a novel minimum accuracy concept for predictive mobility management schemes,” in *2018 IEEE International Conference on Communications Workshops (ICC Workshops)*, May 2018, pp. 1–6.

[10] R. Arshad, H. Elsawy, S. Sorour, T. Y. Al-Naffouri, and M. Alouini, “Handover management in 5G and beyond: A topology aware skipping approach,” *IEEE Access*, vol. 4, pp. 9073–9081, 2016.

[11] R. Arshad, H. ElSawy, S. Sorour, T. Y. Al-Naffouri, and M. Alouini, “Cooperative handover management in dense cellular networks,” in *2016 IEEE Global Communications Conference (GLOBECOM)*, Dec 2016, pp. 1–6.

[12] Y. Lee, B. Shin, J. Lim, and D. Hong, “Effects of time-to-trigger parameter on handover performance in SON-based LTE systems,” in *Proc. 16th Asia-Pacific Conf. Communications (APCC)*, Oct. 2010, pp. 492–496.

[13] M. Polese, M. Mezzavilla, and M. Zorzi, “Performance comparison of dual connectivity and hard handover for LTE-5G tight integration,” in *Proceedings of the 9th EAI International Conference on Simulation Tools and Techniques*, ser. SIMUTOOLS’16. ICST, Brussels, Belgium, Belgium: ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 2016, pp. 118–123. [Online]. Available: http://dl.acm.org/citation.cfm?id=3021426.3021445

[14] F. Yang, H. Deng, F. Jiang, and X. Deng, “Handover optimization algorithm in lte high-speed railway environment,” *Wireless Personal Communications*, vol. 84, no. 2, pp. 1577–1589, 2015.

[15] X. Ge, S. Tu, G. Mao, C. Wang, and T. Han, “5g ultra-dense cellular networks,” *IEEE Wireless Communications*, vol. 23, no. 1, pp. 72–79, February 2016.

[16] X. Li, D. Guo, J. Grosspietsch, H. Yin, and G. Wei, “Maximizing mobile coverage via optimal deployment of base stations and relays,” *IEEE Transactions on Vehicular Technology*, vol. 65, no. 7, pp. 5060–5072, July 2016.

[17] J. Geier, “How to: Define minimum snr values for signal coverage,” *Webpage article. Last accessed December*, vol. 22, 2018. [Online]. Available: http://http://www.wireless-nets.com/resources/tutorials/define_SNR_values.html

[18] I. K. Jain, R. Kumar, and S. Panwar, “Limited by capacity or blockage? a millimeter wave blockage analysis.”

[19] A. Alkhateeb and I. Beltagy, “Machine learning for reliable mmwave systems: Blockage prediction and proactive handoff.”