



Mobility-Cartesian Handover Scheme: A Novel Approach for Seamless Communication for User Equipment in MillimeterWave Heterogeneous Networks

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ABSTRACT

The Mobility-Cartesian handover (MCH) scheme is an advanced communication technique designed to ensure seamless connectivity for user equipment (UE) during handovers in mobile networks. This approach is based on the Cartesian coordinate system, which facilitates efficient and accurate positioning of UEs and enables faster handover decisions. In traditional handover schemes, UEs new serving base station (BS) must be identified and synchronized with the old BS before the handover can be completed. This process can lead to significant delay and potential loss of connectivity, especially during high-speed mobility or in dense network environments. The mobility-Cartesian handover scheme aims to address these challenges by modeling the user mobility patterns as obstacle-based and obstacle-free coefficients in relation to the Line-of-Sight (LoS) and Non-Line-of-Sight (NLoS) communication links whilst computing the handover exponents with respect to the handover margin and Signal-to-interference plus noise ratio (SINR). The performance metric of average system throughput is used to demonstrate the superiority of the proposed model when compared with the standard Rate-based handover (RBH) and the Double Deep Reinforcement Learning handover (DDRL) schemes. Simulation results showed that the developed scheme in terms of mmWave BS density, obtained an average throughput of 35.25% and 2.68% improvement, respectively when compared to the RBH and the DDRL schemes. Furthermore, the developed scheme in terms of user velocity, obtained 23.06% and 2.20% average throughput percentage improvement, respectively when compared to the RBH and DDRL schemes.

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INTRODUCTION

The Fifth Generation (5G) of wireless communication standard is envisaged to offer numerous innovative solutions to meet the growing demand of consumer groups (Zhou *et al.*, 2023). Accordingly, the ultimate aim is to achieve

several key technological targets and a significant reduction in power consumption (Polese *et al.*, 2017). Massive deployment of small cells is seen to be a vital innovation in 5G, which enables frequent frequency reuse and higher data rates (Zhang *et al.*, 2023). Small cells, however,

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present a major challenge for users moving at high speeds (Molle et al., 2019). This is because the smaller coverage areas of small cells lead to frequent handover, resulting in lower throughput and longer delay (Wang et al., 2014).

Furthermore, 5G networks are characterized by extensive bandwidth at millimetreWave (mmWave) frequencies to offer high data rate services in cellular networks (Zhang et al., 2023). Although mmWave signals can provide extensive bandwidth, they are more sensitive to blockage effects than conventional lower band signals (Yu et al., 2021). Therefore, mmWave bands experience severe received signals attenuation due to blockages caused by buildings, trees, and even the user's hand or body (Qi et al., 2021). Overcoming the channel quality gap between Line-of-Sight (LoS) to Non-LoS (NLoS) conditions in mmWave bands still poses a major challenge in 5G networks since it can reduce the network capacity and user Quality-of-Experience (QoE) (Wang & Li, 2024). In the realm of modern telecommunications, the efficient and seamless handover of user equipment (UE) communication in millimeter-wave heterogeneous networks is a critical aspect that significantly impacts network performance and user experience (Priyanka & Chandrasekhar, 2023).

One innovative approach to addressing this challenge is the development of a mobility-Cartesian-based handover scheme. This scheme leverages the unique characteristics of millimeter-wave frequencies and the heterogeneous nature of network deployments to enhance the handover process for UE communication. By introducing the concepts of obstacle-free and obstacle-based coefficients based on Cartesian coordinates, this scheme aims to optimize handover decisions, improve average system throughput, and ensure uninterrupted connectivity for users moving across different network cells within a millimeter-wave heterogeneous environment. The proposed scheme considered the mobility pattern of the user as obstacle-based and obstacle-free coefficients in relation to the LoS and NLoS communication links whilst highlighting the formulation for the probability of the UE being LoS or NLoS.

KEY CONTRIBUTIONS

In the context of millimeter-wave heterogeneous networks, a mobility-cartesian-based handover scheme plays a crucial role in ensuring seamless and efficient communication for user equipment. The unresolved problem of when and where to handover arising from signal blockages as well as the user changing direction still poses a great challenge for LoS and NLoS communication link users in mmWave heterogeneous network. Hence this paper presents a mobility-cartesian handover scheme for seamless communication in MillimeterWave heterogeneous network. The essence is to ensure that user unpredictable mobility patterns are tractable to ascertain when the user is within a LoS or NLoS communication with a base station. This is achieved by modeling the user movement pattern as obstacle-free and obstacle-based coefficients in relation to LoS and NLoS communication links, whilst also setting a distance threshold.

Furthermore, with the goal of guaranteeing efficient handover process, Signal-to-Interference plus Noise Ratio (SINR) and handover margin parameters were utilized to activate the handover event. This is done by setting the thresholds for both SINR and handover margin parameter with respect to the changing speed of the user in both LoS and NLoS scenarios. This mechanism guaranteed better performance in terms of increasing the average system throughput, thus improving on the overall Quality of Experience (QoE) and Quality of Service (QoS) of the users most of which were not achieved by previous researchers.

LITERATURE REVIEW

In order to improve the performance of handover in mmWave system, some research work starts to exploit reinforcement learning with the consideration of different factors, including Reference Signal Received Power (RSRP), QoS of UEs, UE mobility characteristics, and BS load. In Koda et al., (2018), an algorithm with predicted channel information is designed to help UE decide whether to make the handover or not based on UE speed, location, and other information. In Koda et

al., (2019), a handover-based image-to-decision is proposed with Deep Q-learning, which can map pictures to a handover decision of UE.

Silva *et al.*, (2019) also applied the idea of fuzzy logic and used user speed and wireless channel quality parameters to adjust the hysteresis threshold of the handover strategy in a self-optimizing way, so as to reduce the number of redundant handovers and the probability of handover failure. The proposed algorithm in Shaye *et al.*, (2019) estimated handover parameter settings based on the weight function, which depends on three bounded functions and the weight of each bounded function. The adaptive joint handover decision algorithm in Zhu & Peng, (2020) is realized via a genetic algorithm. Based on the genetic algorithm, the dynamic hysteresis threshold that meets the requirement of fast handover at different moving speeds is achieved by optimizing the handover parameters, thus achieving a higher probability of communication satisfaction. Lee *et al.*, (2019) proposed a radio unit clustering scheme (RCS) that was based on Coordinated Multipoint (CoMP) transmission to check blockage effect of mm Wave links. The authors applied a clustering scheme to increase the network capacity by avoiding data transmission through non-line-of-sight (NLoS) links. Based on stochastic geometry, the coverage probability of the proposed RCS was computed into a closed form expression by modeling the position of base stations as a Poisson point process.

Mollet *et al.*, (2020) proposed an offline strategy based on double deep reinforcement learning (DDRL) to reduce the frequency of handovers (HOs) in millimeter-wave networks, therefore lowering the users' poor quality of service. The designed DDRL algorithm performed much better in terms of handover occurrence and throughput than both the conventional and the currently available artificial intelligence-based HO strategy, according to numerical findings. Wu & O'Brien, (2020) developed a novel handover scheme for Hybrid Light Fidelity (Li-Fi) and Wireless Fidelity (Wi-Fi) networks. The proposed handover skipping scheme combined both the RSRP and its rate of change to decide whether an

Access Point (AP) should be skipped. Additionally, the proposed scheme provided an adaptive Wi-Fi coverage according to the user's speed. This ensured that a fast-moving user remained in Wi-Fi to avoid frequent handovers whilst a slow-moving user was allowed to choose the AP that offers the highest SINR.

Dzaferagic *et al.*, (2020) proposed both a distributed and a centralized 4G/5G technique to lower signaling and latency related to user mobility in cellular networks. The authors leveraged on the standardized protocols by dynamically reorganizing the association between nodes in the Radio Access Network (RAN) and the core. Al Achhab *et al.*, (2021) suggested a reliable algorithm to examine the connection between trigger time and hysteresis margin using a unique mechanism that dynamically sets the handover control parameters to cut down on pointless handover and open up new avenues for handover research in HetNets. Sarkar & Ghosh (2023) proposed a dynamic obstacle tracking technique that is based on short-term historical link failure information. In the work, the authors made attempts at tracking multiple dynamic obstacles in a mm-Wave enabled coverage area in readiness for handover procedure. By achieving proactive handovers, link failures were minimized.

METHODOLOGY

Figure 1 presents the conceptual handover procedure for this study that depicts a hard handover scenario for the mmWave HetNet in which handover takes place between the UE and the candidate cells in both LoS and NLoS communication links. Figure 1 is based on the assumption that hard handover principle is adopted for the 5G scenario. The implication of this assumption is that the UE can only be connected to a cell at a time. This minimizes the complexity in the network analysis whilst guaranteeing better QoS and QoE being delivered to the users.

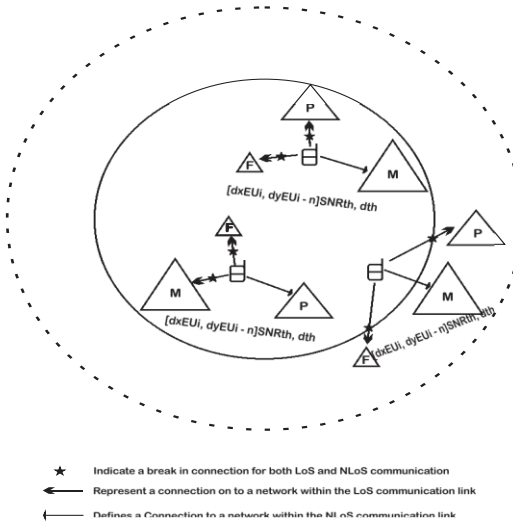


Figure 1: Conceptual Handover Procedure for LoS and NLoS Communication

Hypothetical Coordinate for movement of the UE

Figures 2 and 3 present conceptual representations for obstacle-free and obstacle-based scenarios of the UE mobility patterns in relation to LoS and NLoS communication links respectively. In Figure 2, the conceptual UE trajectory diagram within a Cartesian plane that depicts the UE probable mobility pattern with respect to the placement of the UEs for LoS communication is presented.

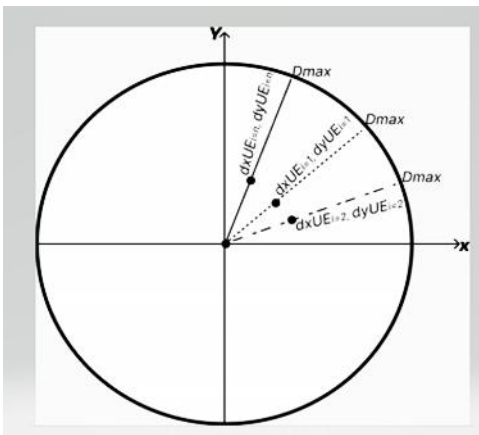


Figure 2: UE Placement Trajectory for Obstacle-free Scenario

This paper considered a typical density of the UEs in 5G to be around $300UEs/km^2$ (3GPP, 2013). A base station density range of $10 - 70 BSs/km^2$ is used in this study. This range captures the 3GPP standard specifications for base station density with respect to the number of UEs/ km^2 in ultra-dense networks (3GPP, 2013). Furthermore, Figure 2 defines the scenario whereby the $C_{x=0}$ exponent acts as an obstacle-free coefficient that shows the UE mobility pattern to be within a defined threshold, denoted as D_{max} . Therefore, so long as the UE movement remains within this set distance threshold, the UE is considered to be within LoS communication link with a base station. Additionally, it is assumed that a UE movement from an initial point to any point within the distance threshold (D_{max}) of the Cartesian plane is the distance covered within the LoS communication link. In Figure 3, the conceptual UE trajectory diagram within a Cartesian plane that shows the UE probable mobility pattern with respect to the placement of the UEs for NLoS communication is presented.

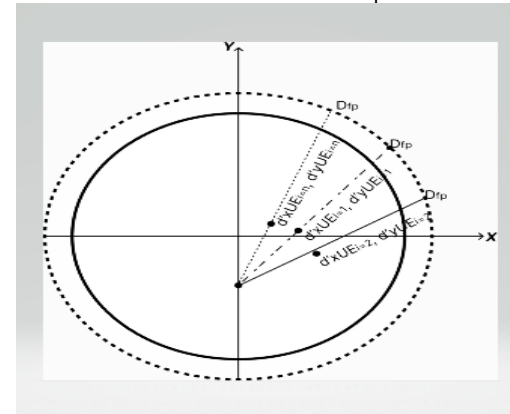


Figure 3: UE Placement Trajectory for Obstacle-based Scenario

Figure 3 illustrates the scenario whereby the $C_{x=-1}$ exponent acts as an obstacle coefficient that indicates the UE mobility pattern to be outside the set threshold distance, which is assumed to be the Distance of the footprint (D_{fp}). Thus, with the presence of the $C_{x=-1}$ exponent, a UE outside the D_{max} would still

maintain communication link with a base station within the D_{fp} . This scenario depicts an NLoS communication link. Additionally, it is assumed that a UE movement from an initial point to any point outside the D_{max} but within the D_{fp} of the Cartesian plane is the distance covered within the NLoS communication link.

The hypothetical assumption for obtaining results is based on Figure 4 which depicts obstacle-free and obstacle-based scenarios for LoS and NLoS communication links, respectively.

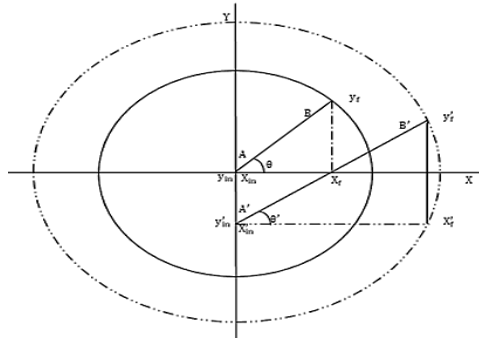


Figure 4: Conceptual Angle of Movement for LoS and NLoS Scenarios

UE Motion Pattern with Respect to LoS and NLoS Communication

From the conceptual model, it is assumed that given a certain service area, it is expected that the UE will receive signals from the surrounding base stations without any obstacle which is indicative of the UE been in a LoS communication. However, obstacles such as buildings, trees etc. within a given service area could impede the QoS and by extension the QoE been delivered to the UE . This depicts a NLoS communication scenario. Consequently, this paper modeled the UE motion pattern based on the assumption that the UE movement is subject to the second equation of motion (Crutchfield & McNamara, 1987) given by equation (1):

$$\partial_{L_{LoS}} = d_o + \frac{1}{2}(1) \quad (1)$$

where;

$\partial_{L_{LoS}}$ is the distance between a UE that is D_{max} away from the base station and UE that is d_i away from the base station ($d_i < D_{max}$)

d_o indicates the distance of the LoS communication link

ϑ represents the end-to-end latency within the LoS communication range.

Therefore, to obtain the UE distance whilst in LoS communication, equation (1) is re-arranged to give equation (2)

$$d_o = \sqrt{|(D_{max})^2| + |(d_i)^2|} \frac{1}{2} a \vartheta^2 \quad (2)$$

Consequently, based on the UE_i placement, equation (2) is re-written in equation (3):

$$d_o.UE_i = \partial_{L_{LoS}} UE_i - \frac{1}{2} a \vartheta^2. UE_i \quad (3)$$

Similarly, to obtain the UE distance whilst in NLoS communication, equation (1) becomes:

$$d_i = \sqrt{|(D_{FP})^2| + |(D_{max})^2|} \frac{1}{2} a \vartheta^2 \quad (4)$$

Consequently, based on the UE_i placement, equation (4) is re-written in equation (5):

$$d_i.UE_i = \partial_{L_{nLoS}} UE_i - \frac{1}{2} a \vartheta^2. UE_i \quad (5)$$

It is assumed in this paper that hard handover principle which forms the basis for handover in LTE is also applicable for 5G. Since hard handover approach is adopted in this paper, then the appropriate base station selection during handover becomes more critical since the connection is broken before a new connection is re-initiated. The time expended for a successful completion of the handover event, where the UE is changed from the current base station to the target base station without data transmission is termed the handover delay time (t_d) because it adds to the handover cost. The accumulation of t_d has a vital effect on the average throughput of the UE . The cumulative t_d and total number of handovers in a given handover event is called handover cost β_c . This overall handover cost

(Mollel *et al.*, 2020) is mathematically formulated by equation (6):

$$\beta_c = \min(H_l \times v \times t_d, 1) \quad (6)$$

where:

H_l denotes the total number of handovers per unit length in meters.

v represents the velocity of the UE in m/s .

t_d is the handover time delay in seconds.

Computing Handover Decision Parameters

When in an event where the signals from a certain base station within a given service area is weak or the UE moves to a distance that is considered to be farther away from the LoS link, handover is expected to be initiated. The aim of setting the handover condition is to ensure that in both LoS and NLoS communication, handover can be initiated. Two key decision parameters which address the UE signal quality and required distance are considered. These parameters are SINR and handover margin. The reason for the choice of the SINR as a handover decision parameter is that it offers a more realistic acceptable scenario in the handover decision process, especially as all cells within the service area are assumed to operate at mmWave frequencies. Mathematically, SINR is expressed (Ngo, 2015) using equation (7):

$$SINR = \frac{P_T M_T M_R}{I + \delta^2} \quad (7)$$

where:

P_T represents the base station transmit power.

M_T, M_R indicates the antenna gain of the desired link.

I defines the interference power density from other base stations

δ is the noise power density of the mmWave cells.

Furthermore, the handover margin is an additional parameter added to the SINR with the aim of mitigating Ping-Pong effect that may arise from considering only the SINR parameter to make the handover decision. Mathematically, the

handover margin (Deswal & Singhrova, 2017) is computed using equation (8):

$$\delta = \max\left\{1 - \left(\frac{D}{R}\right), 0\right\} \quad (8)$$

where, D denotes the distance between the UE and the serving BS and R represents the radius of the serving BS.

Equation (8) can be re-written to include LoS and NLoS communication links as defined in equations (9) and (10):

$$\delta_{los} = \max\left\{1 - \left(\frac{d_o}{D_{max}}\right), 0\right\} \quad (9)$$

$$\delta_{nlos} = \max\left\{1 - \left(\frac{d_i}{D_{fp}}\right), 0\right\} \quad (10)$$

where, D_{max} and D_{fp} are the maximum distance and footprint distance of the UE, respectively. However, in order to initiate handover, the SINR and δ thresholds are computed. The threshold is the average value of all SINR values in the network. It is giving by equation (11):

$$SINR_{th} = \frac{\sum_{n=1}^N SINR_n}{N} \quad (11)$$

where, N is the total number of UE in the network and n denote the SINR of a serving UE. Also, the set SINR threshold adopted in this report is $-8db$ (3GPP, 2014).

The handover margin threshold for determining both LoS and NLoS communication is the average values of individual handover margin values of the UE in the network. This is expressed using equation (12):

$$\delta_{th} = \frac{\sum_{n=1}^N \delta_n}{N} \quad (12)$$

where N is the number of cells

Furthermore, a set value of $-2db$ (3GPP, 2019) is used to define the handover margin threshold. During transmission, the $SINR_{th}$ and δ_{th} are the factors to be considered if handover is to be initiated. Thus, the condition for handover initiation for either LoS or NLoS communication is computed using equation (13):

$$HO_{LoS, NLoS} = \begin{cases} 1 & \text{if } SINR, \delta_{los, nlos} \geq SINR_{th}, \delta_{th} \\ 0 & \text{otherwise} \end{cases} \quad (13)$$

A value of 1 indicates that handover should be initiated for the UE. A value of 0 implies that handover for UE should not be initiated. Furthermore, if the UE's $SINR > SINR_{th}$, it means that the UE is classified as LoS communication. Also, if the UE's $SINR < SINR_{th}$, it defines NLoS communication. This is mathematically expressed using equation (14):

$$UE_{LoS,NLoS} = \begin{cases} LoS & \text{if } SINR > SINR_{th} \\ NLoS & \text{if otherwise} \end{cases} \quad (14)$$

After the handover process is initiated, it takes a period of time to complete the handover process in order for the UE to change connection from its current BS to the target BS. The factor β_c is computed as the total time wasted without meaningful data transmission due to signaling overhead. The network performance becomes 0 if $(H_l \times V \times t_d) \geq 1$. The reason being that the UE has no data transmitted during the entire time of transmission. β_c is vital as shown in the average throughput equation obtained from the Shannon capacity formula (Mollet *et al.*, 2020) given by equation (15):

$$\tau = B \times \log_2(1 + \mu) \times (1 - \beta_c) \quad (15)$$

where: B is the total bandwidth.

μ denotes the average SINR.

τ represents the system throughput capacity.

The DDRL scheme initiates handover based on the criteria defined by 3GPP (3GPP, 2019). The goal is to prevent a short-sighted decision by choosing a BS with a superior SINR. Consequently, handover decision to the target cell is obtained using the triggering criteria (Mollet *et al.*, 2020) as defined in equation (16):

$$HO_{Triggering} = \begin{cases} 1 & \gamma_s < \gamma_{th} \text{ initiate handover} \\ 0 & \gamma_s \geq \gamma_{th} \text{ otherwise} \end{cases} \quad (16)$$

where, γ represents the SINR from the serving BS and γ_{th} is the minimum SINR required by the UE to maintain connection based on the network type. Furthermore, since this work considers $SINR_{th}$ as a decision parameter to access the quality of signal delivered to the UE during handover, equation (15) is re-written as equation (17):

$$\tau^* = B \times \log_2(1 + SINR_{th}) \times (1 - \beta_c) \quad (17)$$

where, $SINR_{th}$ has a set value of $-8db$ (3GPP, 2019).

Figure 5 considers the Signal-to-Interference plus Noise Ratio threshold ($SINR_{th}$) and handover margin threshold (δ_{th}) as decision parameters in making the handover decision. This resulted in a reduction in the handover cost of its process whilst also achieving an improvement on the average system throughput.

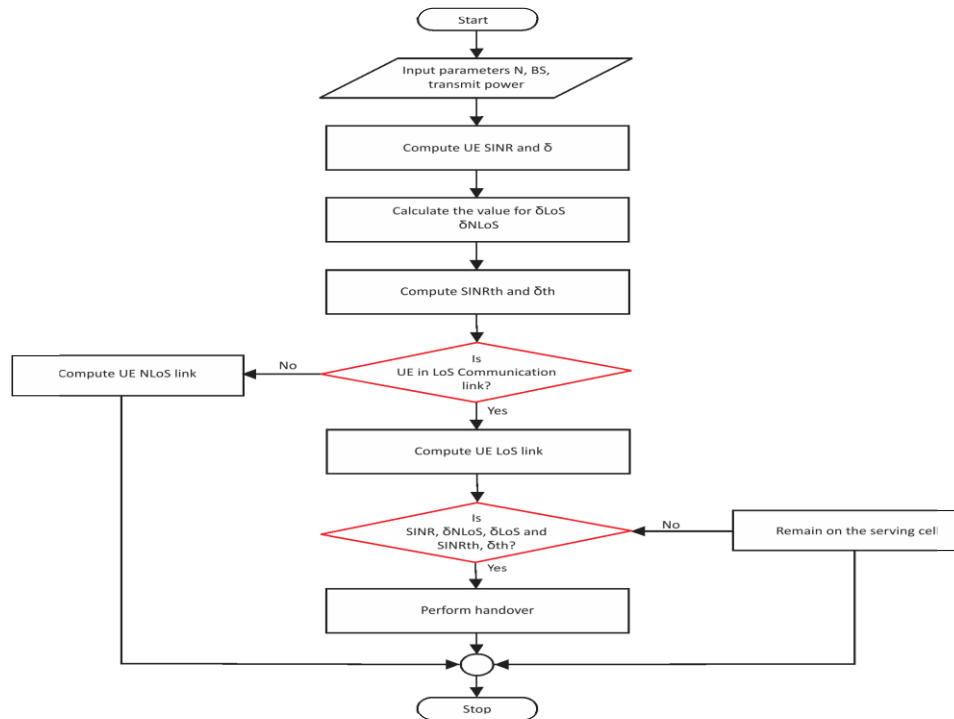


Figure 5: Flowchart for the Handover Decision Scheme only

Simulation Set-Up

MATLAB R2018a is used for the simulation of the developed MCH scheme. The standard parameters used for the simulation are shown in Table 1 which are consistent with the simulation scenario used in a system-level simulator for 5G mobile networks (Mollet *et al.*, 2020).

Table 1: Simulation Parameters (Molli *et al.*, 2020)

Parameters	Values
Maximum coverage length of	
LoS Path	200m
Macro BS bandwidth	20MHz
Macro BS frequency	2GHz
mm-Wave BS bandwidth	5GHz
mm-Wave BS frequency	38GHz
Macro BS transmit power	20W
Pico BS transmit power	1W
Femto BS transmit power	0.1W
Velocity of UE	2.7 m/s, 10 m/s
Minimum UE data rate	10 Gbps
End-to-end latency	10 ms
Antenna gain	10 dB
Antenna transmit power	30 dB
Interference power density	0.5 dBm/Hz
Noise power density	-174 dBm/Hz
Reference signal Received power	-80 dBm

Average Throughput At Varying Mmwave Bs Density

A 3GPP standard specification for base station intensity ranging from $10 - 70 \text{ BS}/\text{km}^2$ is used in this study. For a typical 5G deployment, base station intensity range of $10 - 70 \text{ BS}/\text{km}^2$ is widely adopted for analysis with the aim of achieving high coverage probability at a maximum of $300 \text{ UEs}/\text{km}^2$. Figure 4.4 indicates the performance results in terms of average throughput at varying mmWave base station for the existing Rate-based Handover policy (RBH), Double Deep Reinforcement Learning (DDRL), and the developed handover schemes, respectively. Increasing the density of mmWave base stations potentially improve average throughput by providing better coverage and reducing the impact of blockage.

Conversely, excessively high BS density without proper coordination will lead to increased interference levels, inefficient resource utilization, and higher deployment costs.

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Furthermore, this thesis report assumes that there is negligible interference from other networks operating in adjacent frequency bands or using overlapping coverage areas. This assumption allows for a focused assessment of the impact of mmWave BS density on average throughput within the specific network. The RBH results represent the 3GPP standard for measuring effective handover as it has the same triggering conditions as stipulated by 3GPP for both LTE and 5G networks.

It is observed that the developed handover scheme obtained a higher average throughput in comparison to the existing RBH and DDRL schemes respectively. This is because densely deploying small cell networks will result in an increased tendency of LoS transmission between the base stations and the UE, thus mitigating the effect of interference power arising from blockages in NLoS scenarios. Furthermore, the developed handover scheme showed better performance by adopting an appropriate SINR threshold within which handover decision is to be affected. This guarantees an efficient handover process amongst the different cell networks. Achieving optimal network performance requires a balanced approach that considers the trade-offs amongst BS density, interference management, resource allocations, advanced antenna technologies, and overall network architecture. Tables 2 and 3 show the simulation results obtained for the existing RBH and the developed schemes, as well as the existing DDRL scheme and developed scheme.

Table 2: Average Throughput for RBH in terms of mmWave BS

mmWave BS Density (BS/km ²)	RBH SCHEME (×10 ⁹)	Developed Handover Scheme (×10 ⁹)	Percentage Improver
10	6.40	8.20	28.12
20	6.50	9.10	40.00
30	6.75	9.80	45.18
40	7.00	10.20	45.71
50	8.00	1.20	40.00
60	9.10	11.60	27.47
70	9.85	11.85	20.30

The average throughput percentage improvement of 35.25% is obtained using equation (18) here under.

$$\% \text{ Average throughput improvement} = \frac{\sum_{i=10}^{70} \frac{AT_{Developed\ scheme}^i - AT_{RBH\ scheme}^i}{AT_{RBH\ scheme}^i}}{7} \times 100 \quad (18)$$

Table 3: Average Throughput for mmWave BS

mmWave BS Density (BS/km ²)	RBH SCHEME (×10 ⁹)	Developed Handover Scheme (×10 ⁹)	Percentage Improver
10	8.00	8.20	2.50
20	8.90	9.10	2.25
30	9.50	9.80	3.16
40	10.00	10.20	2.00
50	11.00	1.20	1.82
60	11.30	11.60	2.62
70	11.35	11.85	4.40

The average throughput percentage improvement of 2.68% is obtained using equation (19) here under.

$$\% \text{ Average throughput improvement} = \frac{\sum_{i=10}^{70} \frac{AT_{Developed\ scheme}^i - AT_{DDRL\ scheme}^i}{AT_{DDRL\ scheme}^i}}{7} \times 100 \quad (19)$$

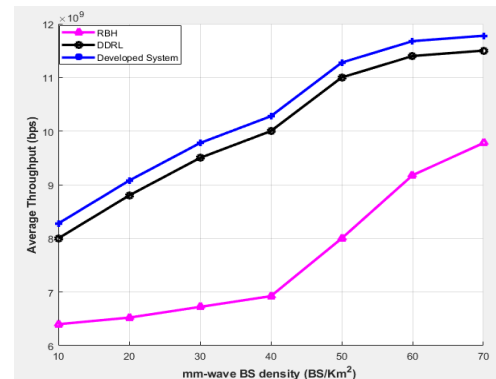


Figure 6: Average Throughput at varying mm-wave BS

Average Throughput at varying User Velocity

A 3GPP standard specification for base station intensity ranging from 10 – 70BS/km² is used in this study. For a typical 5G deployment, base station intensity range of 10 – 70BS/km² is widely adopted for analysis with the aim of achieving high coverage probability at a maximum

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of 300UEs/km². Figure 4.4 indicates the performance results in terms of average throughput at varying mmWave base station for the existing Rate-based Handover policy (RBH), Double Deep Reinforcement Learning (DDRL), and the developed handover schemes, respectively.

Increasing the density of mmWave base stations potentially improve average throughput by providing better coverage and reducing the impact of blockage. Conversely, excessively high BS density without proper coordination will lead to increased interference levels, inefficient resource utilization, and higher deployment costs. Furthermore, this thesis report assumes that there is negligible interference from other networks operating in adjacent frequency bands or using overlapping coverage areas. This assumption allows for a focused assessment of the impact of mmWave BS density on average throughput within the specific network.

The RBH results represent the 3GPP standard for measuring effective handover as it has the same triggering conditions as stipulated by 3GPP for both LTE and 5G networks. It is observed that the developed handover scheme obtained a higher average throughput in comparison to the existing RBH and DDRL schemes respectively. This is because densely deploying small cell networks will result in an increased tendency of LoS transmission between the base stations and the UE, thus mitigating the effect of interference power arising from blockages in NLoS scenarios.

Furthermore, the developed handover scheme showed better performance by adopting an appropriate SINR threshold within which handover decision is to be affected. This guarantees an efficient handover process amongst the different cell networks. Achieving optimal network performance requires a balanced approach that considers the trade-offs amongst BS density, interference management, resource allocations, advanced antenna technologies, and overall network architecture. Tables 2 and 3 shows the simulation results obtained for the existing RBH and the developed schemes, as well

as the existing DDRL scheme and developed scheme.

Table 4: Average Throughput for mmWave BS

User Velocity (m/s)	RBH Scheme	Developed Handover Scheme	Percentage Improvement
1	12.75	12.75	0.00
2	12.50	12.50	0.00
3	11.20	12.25	9.37
4	11.00	12.25	11.36
5	10.95	12.75	11.87
6	9.50	11.75	23.68
7	9.00	11.25	25.00
8	7.25	10.50	44.83
9	6.95	10.47	50.65
10	6.50	10.00	53.85

The average throughput percentage improvement of 23.06% is obtained using equation (20) here under.

$$\% \text{ Average throughput improvement} = \frac{\sum_{i=1}^{10} \frac{AT_{Developed\ scheme}^i - AT_{RBH\ scheme}^i}{AT_{RBH\ scheme}^i}}{10} \times 100 \quad (20)$$

Table 5: Average Throughput for DDRL Scheme in Terms of Uder Velocity Simulation Set-Up

User Velocity (m/s)	RBH Scheme	Developed Handover Scheme ($\times 10^6$)	Percentage Improvement
1	12.75	12.75	0.00
2	12.50	12.50	0.00
3	11.20	12.25	9.37
4	11.00	12.25	11.36
5	10.95	12.75	11.87
6	9.50	11.75	23.68
7	9.00	11.25	25.00
8	7.25	10.50	44.83
9	6.95	10.47	50.65
10	6.50	10.00	53.85

The average throughput percentage improvement of 2.20% is obtained using equation (21) here under.

$$\% \text{ Average throughput improvement} = \frac{\sum_{i=1}^{10} \frac{AT_{Developed\ scheme}^i - AT_{DDRL\ scheme}^i}{AT_{DDRL\ scheme}^i}}{10} \times 100 \quad (21)$$

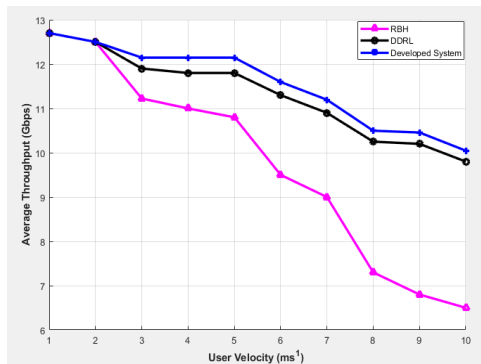


Figure 7: Average Throughput at varying User Velocity

CONCLUSION

Simulation results show that the developed scheme in terms of mmWave BS density, obtained an average throughput value of 10.28×10^9 bps when compared to the RBH scheme which obtained 7.66×10^9 bps and the DDRL scheme that obtained 10.00×10^9 bps. This corresponds to 35.25% and 2.68% average throughput percentage improvement, respectively. Additionally, developed scheme in terms of user velocity, obtained an average throughput value of 11.60Gbps when compared to the RBH scheme which obtained 9.76Gbps and DDRL scheme that obtained 11.35Gbps. This represents 23.06% and 2.20% average throughput percentage improvement, respectively.

This was achieved by the formulation of a Mobility-Cartesian Handover (MCH) scheme that took into consideration the obstacle-free and obstacle-based coefficients for both LoS and NLoS communication links, respectively whilst considering and controlling the UE unpredictable movement patterns by taking into cognizance the varying distances of the UE, the handover margin, and the signal-to-interference-plus-noise ratio. In conclusion, by leveraging the benefits of Cartesian coordinates and mobility prediction, this novel approach aims to enhance the handover process in high-frequency networks, thereby improving the overall user experience and network performance.

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