Navigating Heterogeneity: A Proactive Approach to Handover Management

A Priyanka
Department of Computer Science,
Periyar University, Salem, India.
venkatpriya57@gmail.com

C Chandrasekar
Department of Computer Science,
Periyar University, Salem, India
ccsekar@gmail.com

***Abstract* - Emerging technologies rely on rapid advancements to boost connectivity. 5G stands out as a crucial enabler for a connected future. However, user mobility poses challenges for seamless handover management. Traditional methods, like structure-based cell measurements, require frequent measurement intervals, impacting performance. The proliferation of ultra-dense small cells (UDSC) alongside macro-cells forms heterogeneous networks (HetNets), leading to increased handovers and radio link failures. Effective mobility management is vital for self-organizing networks to enhance performance. A proposed solution aims to minimize frequent handovers and handover failures. Simulation results comparing 4G and 5G networks demonstrate significant reductions in handover ping-pongs and failures compared to existing literature.**

Keywords: Microcell, Macrocell, Handover, Handover Control Parameter, Heterogeneous Networks.

1. INTRODUCTION

Technology's rapid expansion revolutionizes human life, epitomized by IoT devices. These wireless, sensor-based objects require robust connectivity for seamless operation. 5G stands out as a game-changer for IoT, powering applications like autonomous driving, VR, and online gaming with its low-latency, high-capacity data delivery. Its advancements in RAN slicing and beamforming surpass previous generations, making it the ultimate performer in energy efficiency and connectivity.

The surge in mobile users, especially with the widespread adoption of 5G, emphasizes the importance of seamless handovers (HO) between networks. HO guarantees continuous coverage, even during the 4G–5G transition, enabling the best possible speed and efficiency. On the other hand, excessive HO initiation may result in extraneous data flow. Early techniques often assess the cell's capacity, which adds to the data transit. In wireless contexts, minimizing this traffic is essential. In addition to faster speeds, 5G improves device connectivity, energy efficiency, and security. Because 4G and 5G cells have comparable signal ranges, signal strength-based HO methods may produce incorrect results in heterogeneous situations. It becomes crucial to choose the ideal target cell as a result. HO is essential for the transfer of data during device mobility. Network selection is important, and it frequently necessitates periods for evaluation, which causes measurement gaps and performance constraints. This work aims to address these challenges by proposing solutions for measurement gaps and HO management, ensuring minimal delays in connectivity.

A lot of nations are preparing for the rollout of 5G to drive technological progress. In communications networks, maintaining ongoing communication requires effective handover (HO) management. Previous techniques for evaluating networks based on weight have revealed needless handling of HO, which has been made worse by varying cell performance. This variation calls for a 5G architecture that is time-efficient because long measurement times during HO initiation can cause delays. Reducing the number of pointless handover attempts (HOA) and handover failure rates (HOF) is the goal of this study.

"Right now, picking networks sometimes means there are missing measurements. This can make connections worse when measurements are being taken. This paper suggests a new way to manage handovers (HO) that uses machine learning. By using computers that are closer to the user, it makes delays shorter. The idea is to collect data based on what users experience and use that to decide when to switch networks, using information from the past. The best way to predict which network is best is chosen, but it needs data first. A way to collect this data is explained, which keeps track of network history. This method can work for all types of networks, whether they're all the same or different."

2. RELATED WORK

XGBoost is a famous method used in different ways, especially in predicting handovers, which helps fix the problem of missing measurements [1]. This method makes things better by using machine learning and reaches a 100% success rate for handovers. It looks at different parts of the network and tries to make downloads faster. But sometimes, using fresh information to pick which cell to connect to might not be the best because users' experiences change. Machine learning is becoming more important in new networks like 5G and 6G. Researchers are trying out different machine learning methods for handovers. They're looking at things like Recurrent Neural Networks (RNN) and Ant Colony Optimization (ACO) [3], [4]. RNN is good at guessing how strong the signal is, but ACO is hard to use because it's complicated. Other methods like Multi-Attribute Decision Making (MADM) and Fuzzy MADM also have problems, like waiting for measurements and not always picking the best cell [7], [8], [11]. Optimization methods like Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) help a lot with picking cells and which channels to use, which stops interference [9]. But old methods, like asking for a handover or using signal strength, might not work well because the environment can change unexpectedly, which can affect how well the network works in real life [10].

3. PROACTIVE APPROACH

The simulation model uses a network setup called HetNet. It has 4G cells and small 5G cells. Each macro cell has three small cells placed evenly inside it. The macro cells are shaped like hexagons with three parts, and each part has one small cell. You can see how it's set up in Figure-1, where 'R' is macro cell and 'r' is small cell. The big cells work as 4G LTE using frequencies under 5 GHz, while the small cells work in higher-frequency mm-wave bands.

End Users (EUs) are randomly generated and exhibit random mobility models within macro and small cells, moving freely throughout the geographical area over time 't'. EUs are represented as E = {e1, e2, ..., ep}, with each EU 'e' capable of traveling in a random direction within [0, 2 π], with an average velocity Ve within [vmin, vmax]. Macro cells are denoted as M = {m1, m2, ..., mq}, and small cells as S = {s1, s2, ..., sr}.

Handover (HO) procedures may occur within the same or different networks as an EU transitions from a serving cell to a target cell. The serving cell determines HO decisions based on measurement reports provided by the EU. Both macro and small cells offer high-quality radio links within their transmission ranges, evaluated using Reference Signal Received Power (RSRP). Network Download Rate (NDR) is determined based on RSRP, and Handover Control Parameter (HCP) settings are manually configured in all cells, influencing the network assessment process significantly.

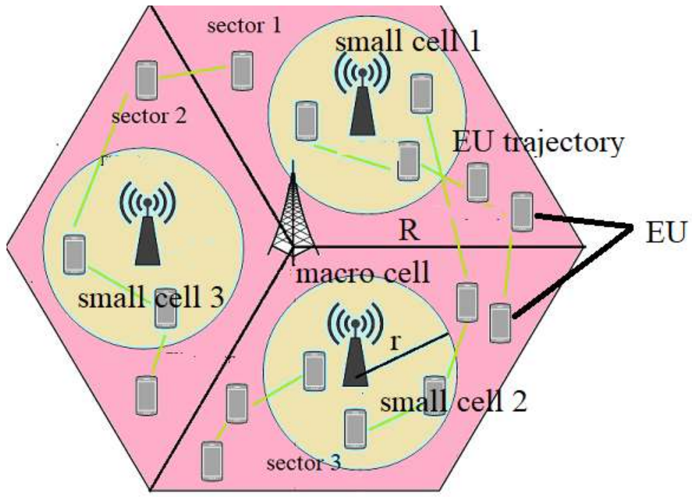

Fig.1. HetNets Model

When devices move away from the current network area, they need to start a Handover (HO) process to keep the connection strong. As they move, the signal they get might get weaker, which could slow down data delivery [4]. Handover helps fix this by switching to a better connection. There's a set level that shows when the signal is getting too weak. If it falls below this level, the Handover process starts automatically.

There are two reasons why the device might start the Handover process: first, if the signal from the current network gets too weak; second, if it finds another network with faster download speeds nearby. All devices in the area measure something called Reference Signal Received Power (RSRP) [7], which helps figure out how strong the signal is. This is important for deciding which network is best for everyone. Handover Control Parameters (HCPs) are important for picking devices and getting reports about signal strength and download speeds from them regularly. These reports help predict which network will be best, which is important for keeping the connection smooth and avoiding problems like Handover Failures (HOF) and unnecessary Handover triggers.

To predict NDR, the HCP utilizes the Second-Degree Parabolic Regression method, with ASU as the independent variable and NDR as the dependent variable. Minimum, average, and maximum ASU values are considered to forecast NDR, with the average of these forecasts determining the HCP value for network selection.

Table:1 Handover Control Parameter values.

Cells	**M_1**	**M_2**	**S_1**	**S_2**	**S_3**
HCP value (Mbps)	32.18	47.12	88.26	95.14	82.78

In this scenario, the EU considers five neighboring cells for reselection. After assessing the measurement reports, the EU selects the top-performing cell for the HO process. In this case, S2 (a small cell) exhibits the highest HCP value of 0.86, indicating superior performance. Thus, the EU chooses S2 as the target cell for HO management.

During the simulation, the End User (EU) dynamically changes its position using a random mobility model, traversing within the same cell or between different cells. A fixed time duration governs the EU's minimum and maximum velocities. The EU measures the Reference Signal Received Power (RSRP) from the source cell every second.

The Handover (HO) trigger process initiates when the EU observes two conditions: (1) RSRP (Source cell) falls below a predefined threshold, or (2) NDR (Source cell) is lower than NDR (Neighbours). Upon HO trigger, the EU collects Handover Control Parameter (HCP) values from all neighboring cells to select the target cell. The cell with the highest HCP score is chosen, and the EU forwards the target cell information and measurement report to the source cell.

Additionally, the EU checks the load of the selected cell. If the network load reaches full capacity, the EU moves to the next highest-scoring cell. After considering all conditions, the EU selects a suitable target cell, and the source cell initiates HO management accordingly.

4. SIMULATION ENVIRONMENT

The proposed technique is implemented using NS3, providing a robust framework for future technologies. The model simulates a HetNets comprising 52 macro cells and 156 small cells spanning an area of 8×8 km². Each macro cell is equipped with 3 small cells positioned at the center of each sector.

Mobile node movement is governed by the Random Waypoint mobility model, simulating realistic user mobility patterns. To route data packets between mobile nodes, Dynamic Source Routing (DSR) is employed, facilitating efficient communication within the network.

Table-3 Simulation Parameters

Parameter	Value	
	Small cell	Macro cell
Number of cells	150	50
Cell radius(m)	150	250
System Bandwidth(MHz)	500	20
Simulation area	1×1 km^2	
Number of EUs	250	
Mobility model	Random Mobility Model	
Simulation time (s)	300	
EU speed (meter/minute)	20,40,60,80,100	
Thermal noise density (dbm/Hz)	-174	
Prediction models	Second degree parabolic regression	

5. PERFORMANCE EVALUATION

To evaluate how well the new network selection method, which prioritizes user experience and performance, performs, we conducted simulations considering various user speeds. We compared the performance of our proposed model with that of MADM [7], Neural Network [2], and Fuzzy MADM [8] network selection methods. Throughout the simulation, we analyzed metrics such as Handover Accuracy (HOA), Handover Failures (HOF), and Handover delay.

5.1 HOA

HOA measures how often handovers occur between the source cell and target cell. We calculate the probability of switching links between different cells for all users and then take the average HOA for comparison. Here, "p" represents the total number of users.

$$\overline{HOA} = \frac{\sum_{i=1}^{p} HOA}{p} \tag{1}$$

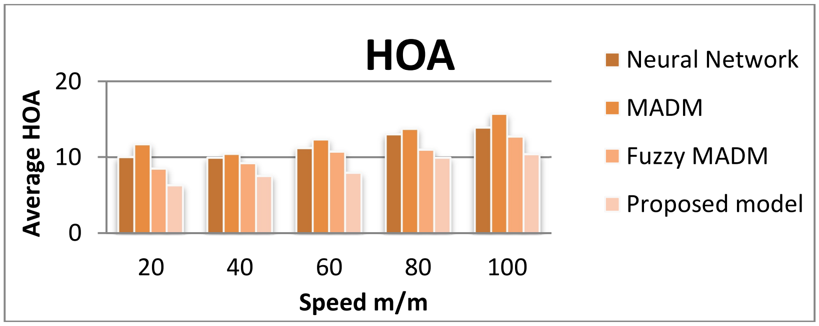

Fig.3. Average HOA

In Figure 3, we see the average HOA for various EU speeds obtained from the simulation. The results indicate that the average HOA from our proposed model is lower compared to the other models. This suggests that our model effectively reduces the average HOA across all EU speeds.

5.2 HOF

One reason for Handover Failures (HOF) is the absence of enough resources in the target cell. When the Handover process starts, the device looks for nearby cells to switch to. If there aren't enough resources in those cells, it can lead to a Handover Failure. Another reason for HOF is when the device moves out of the coverage area of the new cell before the Handover process is fully completed.

$$\overline{HOF} = \frac{N_{HOF}}{N_{HOA}} \quad (2)$$

Where N_{HOF} is count of HOF and N_{HOA} is number of HO attempted.

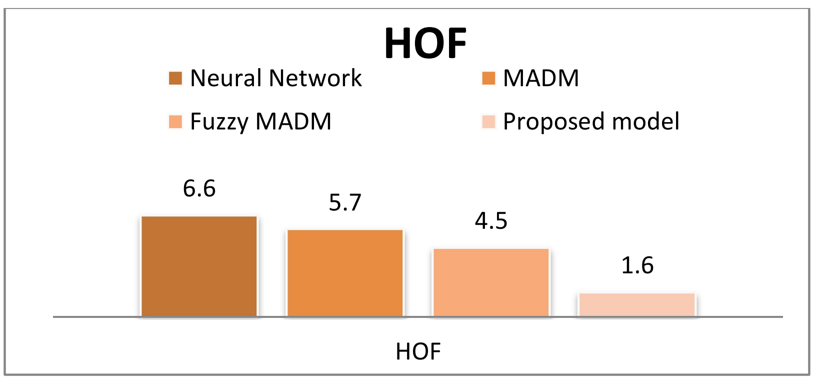

Fig.6. Average HOF

Figure-6 displays the unusual occurrences of Handover Failures (HOF) observed during the simulation. The overall occurrences of typical HOF from our model are fewer compared to the other models. Our model significantly reduces the frequency of common HOF incidents.

5.3 Handover Delay

The time it takes to switch from the old cell to the new one is called the handover delay. If the method takes too long to pick a cell, the delay can be significant. We measure the handover delay by finding the time the device spends in the new cell (Tnew cell) and the time it spends in the old cell (Told cell).

$$\text{Handover Delay} = T_{new}\,\text{cell} - T_{old}\,\text{cell} \quad (3)$$

The proposed methodology runs the HO process with very little time compared to the existing work. Figure -7 shows how much the number of milliseconds is reduced using the proposed methodology.

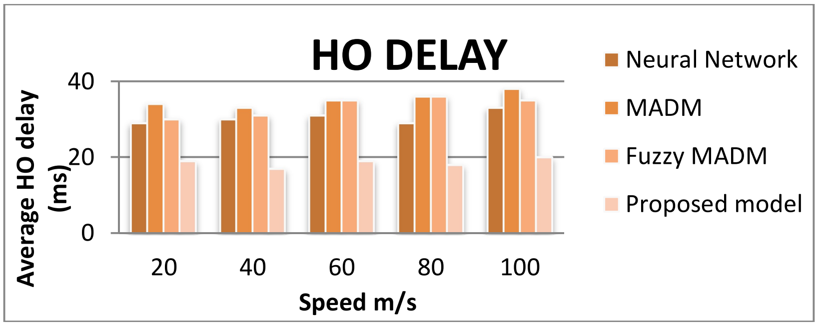

Fig.7. Average HO delay

Selecting the right cell is crucial for achieving the highest data transfer speed, known as throughput, which ensures fast data delivery. Existing methods can sometimes achieve higher throughput when they pick the best cell. If not, they might provide average throughput based on old techniques. Lower throughput can lead to delays in transmitting data. However, the proposed method for cell selection always picks the best service provider, ensuring optimal throughput.

6. CONCLUSION

The importance of Handover (HO) management lies in maintaining Quality of Service (QoS) for End User (EU) applications during mobility, ensuring better coverage and capacity for mobile networks. This translates to improved service quality and customer satisfaction. As 5G and future technologies continue to advance, offering higher data rates and lower latency, efficient mobility management becomes crucial for seamless data delivery with minimal latency.

Existing methodologies handle network performance estimation and score calculation when HO is triggered by the EU, leading to time-consuming target cell selection processes. In our recommended model, Handover Control Parameters (HCP) play a significant role in executing the process with minimal latency. HCP collects performance history from service users, forwarding Network Download Rate (NDR) to the EU for cell selection. Based on this information, the EU selects the target cell and communicates the selection to the source cell, which then initiates the HO process.

In future research, we aim to explore predictive algorithms for HO management across heterogeneous networks, spanning 4G, 5G, and even 6G. Our primary objective is to propose a new model that reduces the number of unnecessary HO processes, thereby enhancing network efficiency and user experience.

Acknowledgment

The first author sincerely acknowledges the financial support (University Research Fellowship) provided by the Department of Computer Science, Periyar University under the grant: **PU/AD-3/URF Selection Order/016175/2020.**

REFERENCE

Saad Ijaz Majid , Syed Waqar Shah , Safdar Nawaz Khan Marwat , Abdul Hafeez , Haider Ali and Naveed Jan, "Using an Efficient Technique Based on Dynamic Learning Period for Improving Delay in AI-Based Handover" Mobile information systems, 2021.

Xiaonan Tan, Geng Chen and Hongyu Sun, "Vertical handover algorithm based on multi-attribute and neural network in heterogeneous integrated network" EURASIP Journal on Wireless Communications and Networking, 2020.

Michael S. Mollel, Attai Ibrahim Abubakar ,Metin Ozturk, Shubi Felix Kaijage, Michael Kisangiri, Sajjad Hussain, Muhammad Ali Imran, And Qammer H. Abbasi, "A Survey Of Machine Learning Applications To Handover Management In 5g And Beyond" IEEE Access, Mar 29, 2021.

Jawad Tanveer, Amir Haider, Rashid Ali and Ajung Kim, "An Overview of Reinforcement Learning Algorithms for Handover Management in 5G Ultra-Dense Small Cell Networks" Applied Sciences, Jan 3, 2022.

Noura Aljeri and Azzedine Boukerche, "A Two-Tier Machine Learning-Based Handover Management Scheme for Intelligent Vehicular Networks" Ad Hoc Networks, Jun17, 2019.

Imad El Fachtali, Rachid Saadane, Mohammed El Koutbi, "Improved vertical handover decision algorithm using ants' colonies with adaptive pheromone evaporation rate for 4th generation heterogeneous wireless networks" International journal of Wireless and Mobile Computing, Vol. 12, No. 2, 2017

G.A.Preethi, P.Gauthamarayathirumal, C.Chandrasekar, "Vertical Handover Analysis Using Modified MADM Method in LTE", Mobile Networks and Applications, 2019.

Mouad Mansouri and Cherkaoui Leghris, "A Use of Fuzzy TOPSIS to Improve the Network Selection in Wireless Multi access Environments", Journal of Computer Networks and Communications, Jul 2020.

Najam Ul Hasan, Waleed Ejaz, Naveed Ejaz, Hyung Seok Kim, Alagan Anpalagan, And Minho Jo, "Network Selection and Channel Allocation for Spectrum Sharing in 5G Heterogeneous Networks", IEEE Access, mar 23, 2016.

Fan Jia and Xiaolin Zheng, "A Request-Based Handover Strategy Using NDN for 5G", Wireless communications and Mobile Computing, Aug 8, 2018.

Ioannis Chamodrakas, Drakoulis Martakos, "A utility-based fuzzy TOPSIS method for energy efficient network selection in heterogeneous wireless networks", Applied Soft Computing, Feb 5, 2011.