An Enhanced Algorithm for Load-based Handover Decision-making in 5G Wireless Networks.

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Abstract - *The handover process is one of the most important aspects of mobility management in 5G networks, it ensures a user's network connection continuity while moving from one location to another. It is also the cornerstone of achieving mobility load balancing under the name of the offloading process. The decision-making phase is one of the handover stages that need improvement to choose the appropriate station and accurately determine the handover parameters to select the proper time to execute the handover. In this paper, we proposed a Load-based Handover Decision-making algorithm based on fuzzy logic, considering the cell's load before implementing the handover decision to determine whether the candidate cell is suitable for the handover process to avoid problems resulting from handover to a heavily loaded cell. The results showed that the proposed algorithm provided an improvement in terms of the standard deviation of the load in the network, average throughput, packet loss rate, and handover failure rate.*

Key Words: **5G Networks, Handover, Handover Control Parameters, Cell Load, Fuzzy Controller.**

1.INTRODUCTION

Fifth-generation networks include many technologies that offer features for users. Still, at the same time, they may cause new problems, which refer to the deterioration of the service provided by the network due to a failure in a particular stage, such as when setting specific parameters[1]. Despite the significant benefit of small cells, they cause difficulties that lead to a deterioration in the quality of service, such as interference, unnecessary and frequent handovers, failed handovers, and Ping-Pong events[2].

Failure management [1] is one of the basic concepts in cellular networks, and given that the handover process is critical, especially in high-density networks that are accompanied by high mobility speeds, it is necessary to reduce failure cases during its implementation to mitigate the negative impact on the quality of service provided by these networks. The heavily loaded target cells are one of the reasons for the failure of handover operations since they are either unable to serve a new user or limited service provided. This will result in unsuccessful handover operations and lead to a deterioration in the quality of service in the network due to the loss of packets resulting from the connection interruption.

2. THE IMPORTANCE OF THE RESEARCH AND ITS OBJECTIVES

The importance of this research lies in proposing a solution that ensures the target station has sufficient resources to serve a new user before executing the handover decision, thereby ensuring that the user moves to a cell that can serve them first and provide convenient service for their requirements secondly. This ultimately achieves the research goal of improving service quality using the enhanced algorithm.

The research addresses the study of handover problems in 5G, shedding light on the concept of cell load and its impact on handover performance, and then proposes a modification to the handover decision-making algorithm that ensures not moving to a congested cell. We then follow with practical implementation, involving choosing the most suitable tool to simulate the required network, building the network, specifying the parameters, executing the simulation, and analyzing the results. Finally, the research concludes with recommendations that define the future direction of the research.

3. RELATED WORK

Several existing works were done in research to enrich the field of improving the handover process in the 5G wireless networks. In [3], an FL-based handover scheme was proposed for 5G UDNs, the proposed scheme can dynamically adjust two handover parameters, HOM and TTT, by using the SINR and horizontal moving speed of UE as inputs to a Fuzzy logic controller.

While the authors of [4] investigated various MRO (Mobility Robustness Optimization) algorithms for the 5G network at different mobility speeds and system setting scenarios to address Mobility Management (MM) issues during user mobility between cells to ensure a smooth connection.

On the other hand [5] presented the common types of Machine Learning and the techniques used from each type to optimize the HCPs of the MRO functions. Moreover, high-mobility-aware and network topologies are presented in the MRO function for further system enhancements. Besides, the survey further highlights several potential problems for upcoming research and provides future directions to address the issues of next-generation wireless networks.

In the paper[6] the effect of different HCP settings on 5G network performance was verified by analyzing fixed HCP settings in various scenarios to explain the need for applying more advanced technology in 5G networks. The proposed algorithm in this paper was used to assess the HCP settings. These optimization values were estimated according to the speed of UE's and loads of cells.

4. Background

4.1. Handover problems (handover failure):

The increase in deployment density of small base stations (SBS) is a solution to obtain high data traffic mobility in 5G wireless networks. However, it causes an increase in ping-pong events, accompanied by increased delay and handover failure. Ping-pong events occur when the serving cell hands over control of the mobile device to the target cell. Then, the target cell hands back control to the previous serving cell within a limited time after the last handover [7], causing high signaling due to the messages exchanged between network elements resulting from unnecessary handover operations. Therefore, reducing frequent and unnecessary handover operations saves network resources and improves overall system performance [8].

Mobility failure occurs when the user equipment fails to establish a radio connection in the source cell or complete the handover process in the target cell. There are different reasons for handover failure, either due to a problem in synchronizing the necessary signaling messages to complete the handover process between the source and target base stations or due to the loss of one of these signaling messages caused by a problem in the radio link. Moreover, attempting to move the phone to an already congested cell [2] can also result in call failure due to resource limitations, making the handover operation unsuccessful. If the call is completed later, this process will reduce the service quality provided to the existing users and the new user.

The timing of the handover process is critical. Therefore, the main challenge of Mobility Robustness Optimization (MRO) functions, which is the automatic adjustment of handover control parameters, is to avoid failure cases as much as possible. For example, reducing the values of TTT and HOM can cause an early and unnecessary handover, as there are types of errors that occur due to the user moving at different speeds, such as the Too Early Handover problem, which occurs when the signal strength of the target station is still weak [9], The early handover occurs due to the low values of the handover control parameters (HCP), which are then adjusted to high values due to poor connection, this causes failure to connect quickly when the handover process begins. As a result, the device will return to the previously served station, resulting in additional handover operations.

In addition to the Too Late HO problem, at high speeds, very late handover occurs due to the user passing through several cells within a short period. In this case, adjusting low values for the handover control parameters is essential to reduce the failure rate of the radio link [10].

4.2. Radio resources in the cell:

The smallest unit of radio resources is the physical resource block (PRB), which consists of 12 subcarrier frequency slots. The cell load is measured by the Resource Block Utilization Ratio (RBUR) [11], defined as the ratio of the reserved physical resource blocks (PRBs) by the cell s to the total number of available blocks in the same cell. The RBUR ratio directly determines the use of the resource block by the number of devices that can be served at a specific data transmission rate and with specific latency constraints. Equation (1) [12] expresses the average RBUR in the cell.

$$\overline{RBUR_s}\,(t) = \frac{\sum_{\tau\epsilon(t-T,t)} \sum_{j\epsilon J} I_{s,j} * N_{s,j}\ (\tau)}{T * PRB} \qquad (1)$$

Where:

- $I_{s,j}\,(\tau)$ is a binary indicator that takes the value of 1 if user j is served by cell s.
- $N_{s,j}\,(\tau)$ is the number of reserved physical resource blocks (PRBs) by cell s for user j during the period t.
- PRB refers to the total number of available resource blocks in cells, where all cells have the same maximum limit.

Therefore, the total number assigned by a cell at any given moment cannot exceed the value of $\sum_{j\in J} I_{s,j} * N_{s,j}(\tau)\mathbf{PBR}\ ,\forall \mathbf{s}.$ When the RBUR value reaches 1, the cell resources are exhausted, and any new user entering the cell will either have their connection dropped or will be served at a lower data transmission rate than needed.

5. Proposed Algorithm: Load-based Handover Decision-making algorithm (L-HD):

This study proposes a modification to a previously introduced algorithm [13], called (RHOT-FLC) , designed for handover decision-making and control parameter assignment based on fuzzy logic. The basic algorithm was observed to not consider the load value of the base stations before making the handover decision, which could result in user issues that affect service quality.

Also, the algorithm does not consider the case of a failed connection establishment with the target station. Therefore, it is necessary to add a condition to test the load value of the cell before deciding while also ensuring the possibility of connecting to an alternative station in case of a failed connection with the target station.

The following steps represent the stages of implementing the proposed algorithm (L-HD) , as shown in Figure 1:

1. Both the Radio Signal Quality (RSRQ), Radio Signal Power (RSRP), User Equipment (UE) velocity, and Cell Load are considered inputs to this algorithm.

2. The RSRP value for neighboring cells is extracted from measurement reports, sorted, and compared to the RSRP value of the serving cell.

3. The neighboring cell values are arranged according to the Cell Load value, which is calculated based on Equation (1) and takes values ranging from [0,1], where a higher value indicates a heavier load on the cell.

4. The condition for triggering the handover process is tested based on the $RSRP_s < RSRP_t$, where if it is met, the handover process is not executed since the mobile phone has not approached the cell boundaries, and the signal strength received from the serving station is still higher than that received from the target station. On the other hand, if the condition is not met, then there is a need to trigger the handover process, and since the A3 event is used in this algorithm, the fuzzy controller is relied upon to obtain the TTT & HOM values.

5. RSRQ, RSRP, and UE velocity are considered inputs to the fuzzy controller, which are divided into levels indicated in Table (1), where the values of these parameters are transformed into fuzzy sets, and the degree for each rule is calculated, resulting in obtaining the controller output which is both HOM & TTT values.

6. If the condition of equation (2) is not met the handover process is not executed, and the current cell remains the serving cell. However, if the condition is met, the Cell Load value of the candidate cell is tested, and if it is capable of serving a new user (Meaning the value of BRUR did not exceed 0.9), the handover decision is executed. Otherwise, the handover process is executed at the second-best base station.

$$RSRP_{target} > RSRP_{serving} + HOM \tag{2}$$

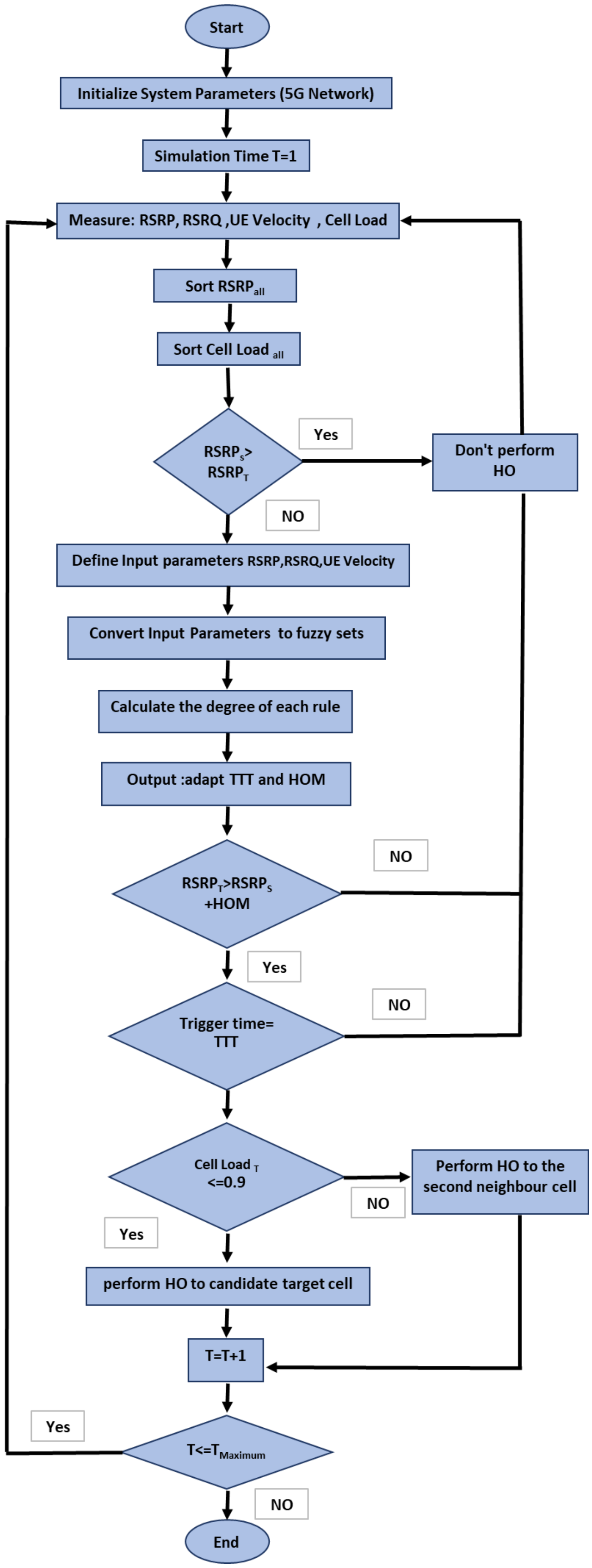

Fig -1: flowchart of the proposed algorithm

Table (1) shows the number of levels of input and output[13]:

Table -1: input and output levels

Input	Degree	Range
UE Velocity	Slow	0 to 30 km/h
	Moderate	25 to 70 km/h
	High	65 to 135 km/h
	Very high	130 to 160 km/h
RSRP	Weak	-160 to -95 dBm
	Medium	-100 to -73 dBm
	strong	-80 to -20 dBm
RSRQ	Poor	-60 to -18 dB
	Good	-22 to -12 dB
	Very good	-14 to -6 dB
	Excellent	-10 to +20 dB
output		
TTT	v. small	0 to 220 ms
	Small	210 to 380 ms
	Average	370 to 520 ms
	Large	510 to 640 ms
HOM	v. small	0 to 0.3 dB
	Small	0.2 to 0.5 dB
	Average	0.4 to 0.8 dB
	Large	to 1 dB 0.7

6 . Performance Evaluation

6.1. Simulation Setup:

It was decided to implement the practical section using MATLAB 2022a, relying on the 5g toolbox [14] [15] [16], which provides functions compatible with the established standards for fifth-generation wireless networks. In addition, it includes reference examples for modeling, simulation, and verification of communication systems.

The network was built in a standalone mode based on previous studies showing better handover performance in standalone architecture [17]. In addition, the Fuzzy Logic Toolbox [18] was relied upon as it provides functions and applications for analyzing, designing, and simulating fuzzy logic systems. The fuzzy logic controller was designed as shown in Figure 2,

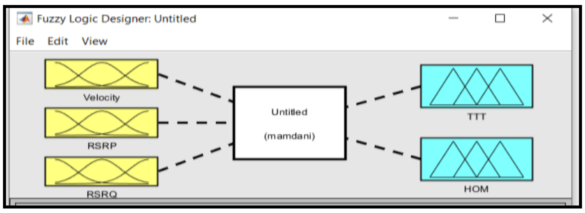

Fig -2: fuzzy logic controller

and the parameters shown in Table (2) were adopted, which were chosen based on [13] and according to standards.

Table -2: Simulation parameters settings

Parameters	values
# of gNB	50
Cell radius	150 m
T_x Power of UE	23 dBm
T_x Power of gNB	46 dBm
Number of Measured UE	10 UEs
Maximum Number of UE per Cell	10
Channel bandwidth	400 MHZ
Path loss mode	Log-normal path loss model (path loss exponent=3.0)
Fading Model	Friis spectrum propagation loss model
Mobility model	Constant velocity mobility model
Carrier frequency	25 GHz
UE velocity	Up to 160 km/h
TTT range	Adaptive: 0 ms ... 640 ms
HOM range	Adaptive : 0db ... 1 dB
Simulation time	30 s

6.2. Result analysis:

The performance of the proposed algorithm (L-HD) was evaluated by comparing it with the (RHOT-FLC) algorithm for three different values of user equipment velocity in terms of several metrics, including quality of service and handover performance. Because improving the handover performance contributes to improving the network's overall performance [19].

6.2.1. Standard deviation of load:

The standard deviation of the load indicates the load balance level in the network cells and is calculated as follows in equation (3):

$$\sigma = \sqrt{\frac{\sum_{s\in S}(\overline{RBUR_s}\,(t) - RBUR_{Net}(t))^{\,2}}{S}} \quad (3)$$

Where

- $PBUR_{Net}(t)$: the average load in the network consisting of S cells during a period t .
- S: the number of active cells in the network.
- $RBUR_s(t)$: the average load in cell s at time t. The value of σ ranges from 0 to 1, and the closer the value is to zero, the more balanced the network is.

Chart 1 shows the performance evaluation of the algorithm in terms of the standard deviation of the load. The proposed algorithm (L-HD) performed better than the (RHOT-FLC) algorithm since it ensures that the target cell's average load does not exceed 0.9 or it transfers the user to the second-best station, thus contributing to load distribution between cells and reduces the difference between them.

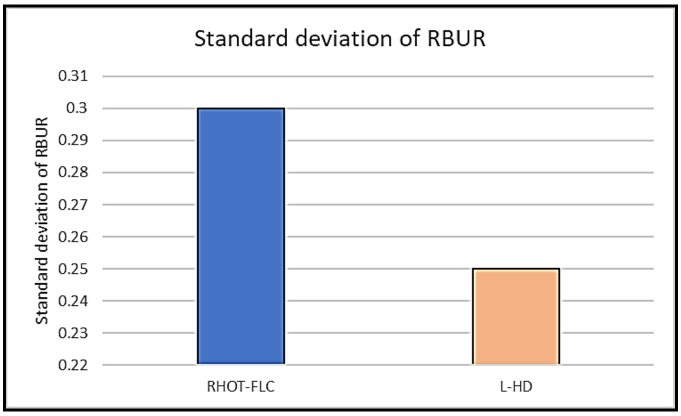

Chart -1: standard deviation of load

6.2.2 Average throughput :

The comparison of the two algorithms in terms of average throughput is shown in Chart 2, for three different user equipment velocities (10, 60, and 100 km/h). The proposed algorithm (L-HD) gave a higher throughput than the baseline algorithm since it guarantees the user's transfer to a cell capable of serving it with sufficient resources. In case of failure to transfer to the candidate cell, there is an alternative cell to complete the handover process, resulting in a reduced probability of connection interruption between the user equipment and the cell. Moreover, since it contributes to load balancing between cells, it increases the utilization of resources, resulting in higher throughput.

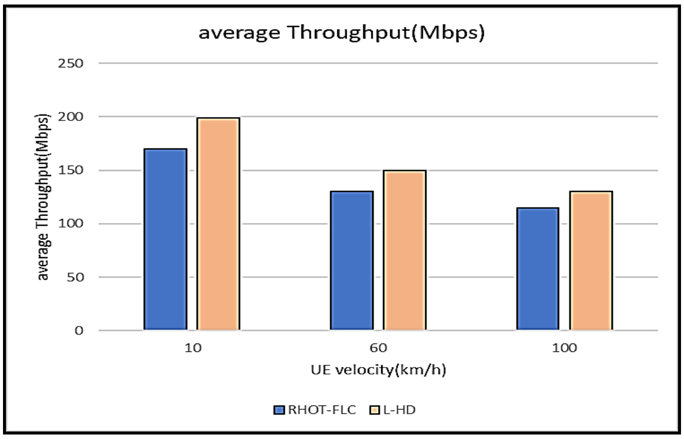

Chart -2: average Throughput

6.2.3 Packet Loss Rate (PLR) :

Chart 3 shows the evaluation of the proposed algorithm (L-HD) in terms of packet loss rate, which showed improvement over the baseline algorithm (RHOT-FLC). The improvement ensures a reduction in the probability of connection interruption resulting from the inability of the target cell to serve the user.

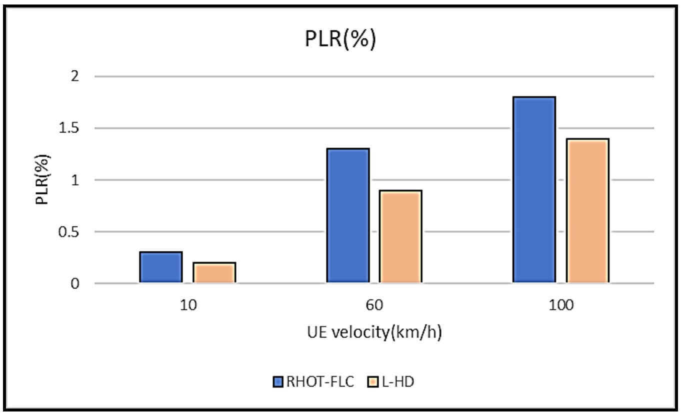

Chart -3: Packet Loss Rate

6.2.4 Handover failure :

Chart 4 shows the evaluation of the proposed algorithm in terms of the failure rate of handover processes. The improvement in (L-HD) contributed to a decrease in the handover failure rate due to a reduction in the unsuccessful handover process. The improvement is evident at low speeds since high speeds cause an increase in the handover rate per second, which increases the likelihood of handover process failure.

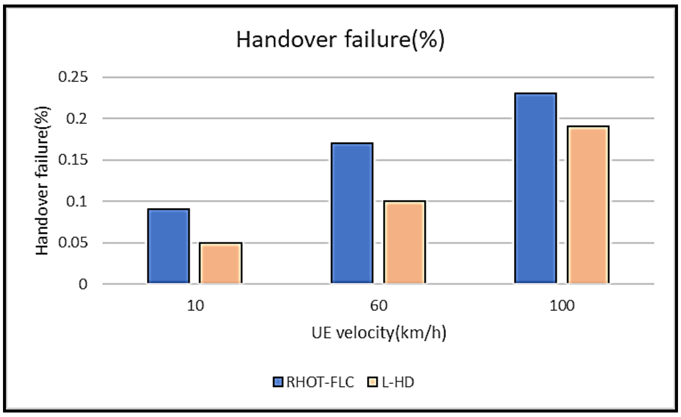

Chart -4: Handover failure

7. CONCLUSIONS

This research focuses on improving a previously proposed algorithm for making handover decisions and selecting control parameters for handover. The improvement includes a test that is applied before making the handover decision, in which it is verified whether the candidate cell can serve a new user. If it is unable to do so, the handover operation is executed to the second-best base station. This improvement reduces the probability of establishing a failed connection with a congested cell and improves network balance since the phone involved in the handover operation will be transferred to the second-best cell, thus distributing the burden among cells. The results have shown that the proposed algorithm (L-HD) improves the standard deviation of the load in the network, average throughput, packet loss rate, and handover failure rate. Based on the results obtained, the focus will be on improving the solution to increase the network load balancing ratio with the shortest possible latency.

ACKNOWLEDGEMENT

The authors wish to acknowledge the Faculty of Information Engineering at Tishreen University for their support of this research.

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