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Mobility Management in Next Generation Wireless Networks

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Abstract: Living in a modern society without smart devices is impossible now a days. Every sector related to human lifestyle is either smart or controlled devices which was rare a decade back. Expectations are not limited to network connection but extend to mobility as well. As a result, mobility management becomes an essential and challenging task to accomplish. The revolution in wireless technologies expects more scalability and flexibility in resource management. Handover is one of the vital parts of radio resource management. Execution with perfection and optimization of the handover technique increases the reliability of the system deployed to meet the requirement of high mobility. The cell became small as the wireless cell size adjusted with the revolution of relevant technologies like fifth generation (5G) and beyond. Traffic profile and its density are always in a growing trend. This pattern draws the attention of ultra-dense networks (UDN). The UDN of small cells requires an extra number of handovers with higher accuracy and less delay in execution. In this context, this paper proposed an algorithm where a cross-examination to reduce unnecessary handover that improves the handover performance in next-generation wireless networks.

Keywords: Mobility Management, Next Generation Wireless Networks, HetNet, Ping Pong Hand over, Wireless Communication

1. Introduction

In recent years, the evolution of internet of things (IoT) in wireless network domain has been more scattered and Long Term Evolution (LTE) implements hard handover and this break before make is creating major performance issues in mobility management [1]. Aside, the importance of wireless networks expansion, the mobility has become a prime demand from the user domain. The ongoing major identified areas are medical sector, education sector (i.e. distance learning), emergency fire fighting services, intelligent transportation systems, autonomous driving applications such as self-driven vehicles, drones, and many more. In next generations, wireless networks will experience a vertical hike in data rates as the controlled device management trend is rising state.

To adapt to these data-driven changes millimeter wave (mmWave) and high-frequency band like THz needs to be deployed. These higher frequency bands and small wavelengths and other environmental factors increase the penetration and path loss as a whole. To overcome these situations, it requires a massive small-cell implementation. As a consequence, the network will experience a huge number of handover cases. While mobility robustness is the vital demand, here comes handover and relevant processing in the picture to handle with perfection so that seamless service can be ensured to the end users. With the growing trend of such demands, wireless mobile networks are experiencing unpredicted change over time. Revolution in wireless technologies expecting more scalability and flexibility [2] as well. Handover becomes an important context of radio resource management day by day. Execution with perfection and optimization of handover technique increases the reliability of systems [3] that involved to support the requirement of high user density. It is always expected that there would be no interruption in a running call for a moving user irrespective of its movement speed and direction. It is assumed that improper handover decisions may cause the bad quality of running calls even service interruption sometimes. Also data-driven services face challenges to continue with a constant speed during intra-cell and intra-MSC handover. Intra-system handover is more crucial as all are living in the era of 2G, 3G, 4G, and 5G at a time. This increases system-level complexity and protocol compatibility issues. Apart from these, security-related tasks has to be maintained with priority. As a part of security process, authentication delay in the verification layer plays a vital role in the handover procedure, specially in time. Considering the current trend, there have a huge scopes to work for improving handover process to ensure call quality, system performance, and its security features.

2. Heterogeneous Mobile Network

The mobile network where user surrounded by a different types of cellular (macro, micro, femto etc) formation which may have a different range of cell radius respect to others according to their type. This formation type is termed as heterogeneous mobile network. The Distance between cell to cell varies in accordance with their type that have relation with antenna height. The network parameters also varies between them as they are not from same family.

Apart from the system performance security concern is higher in LTE heterogeneous mobile network (HetNeT) in contrast with traditional wireless mobile networks [4] as interoperability increases. Absence of efficient authentication process can cause performance degradation in heterogeneous mobile network that leads to additional delay in processing.

Figure 1 represents a HetNet where user will face different handover behavior according to his movement to target cell as the target cell might not similar types. Also the frequency of handover process trigger varies according to their cell size. To support the rapid incremental traffic, HetNets could be in driving role as promising solution. Also appropriate energy efficient solution could be implement in HetNets. Coverage area and UE capacity of different cell types in HetNets are given below:

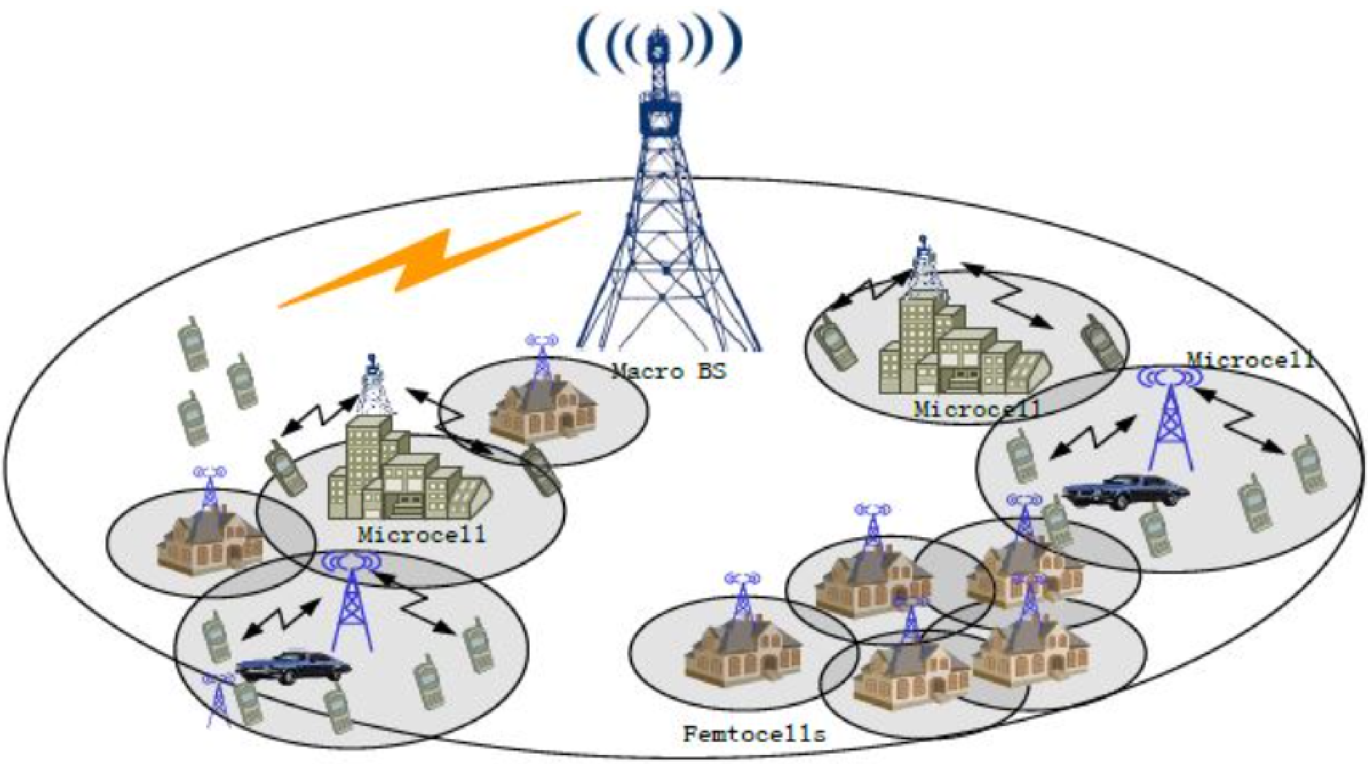

Figure 1. *Heterogeneous Mobile Network [3].*

Table 1. *Range with user capacity according to cell type [10].*

Cell Type	Range (m)	Capacity (UE)
Femto Cell	10-20	< 20
Pico Cell	200	20-40
Micro Cell	2000	> 100
Macro Cell	30000-35000	Many

3. Handover

Handover in wireless communication system is defined as the end user device changes its communication microwave link from serving base station to a target base station in the direction of user equipment (UE) movement. A basic handover model is shown in Figure 2.

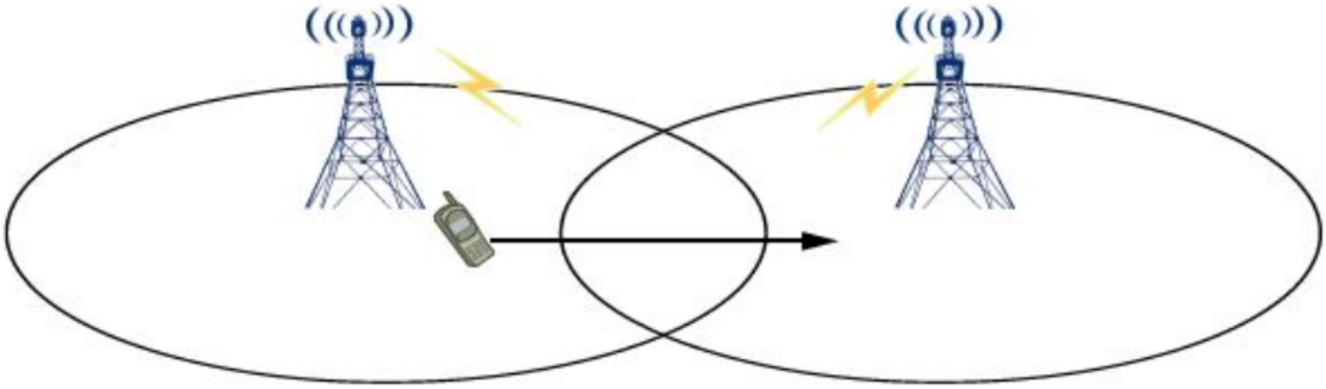

Figure 2. *Basic Handover [3].*

On completion of the measurement process here comes the handover trigger criteria, handover process initiation and execution. Performance parameters are measured after the handover execution. There are few parameter that could be taken in account to measure the handover performance such as handover rate, handover delay, latency, ping pong handover, wrong handover, early handover, handover failure, etc. Handover cases in heterogeneous wireless network shown below Figure 3:

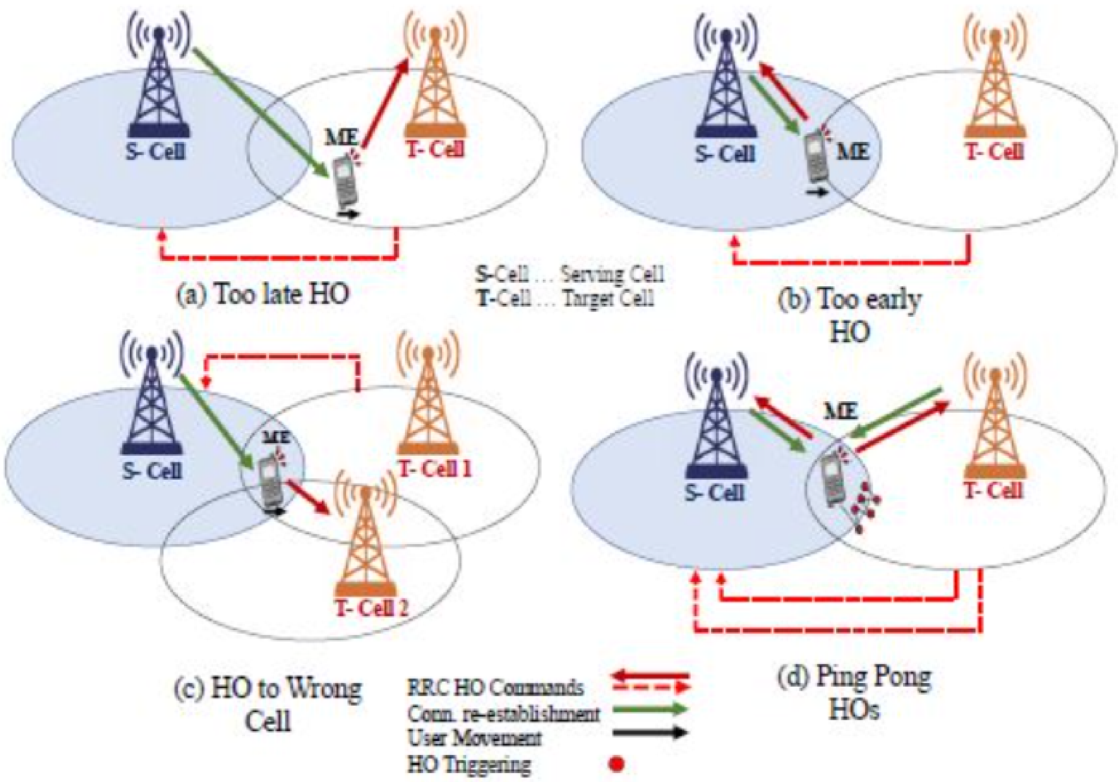

Figure 3. *Handover scenario in HetNets [10].*

Almost all the handover algorithm consider the receive signal strength (RSS) as criteria to decide handover triggering [5] as a primary concern. This paper also follow the same RSS measurement methods for handover triggering. The UE in moving state will experience more handover actions than the static one. The more speedy it is, the more handover cases will be faced by him. When UE receive a signal which have higher RSS than serving base station the handover process started. Basically RSS measurement took place when UE receives multiple signal form different base station. All such cases might not initiate handover trigger. Simple handover algorithm shown in Figure 4.

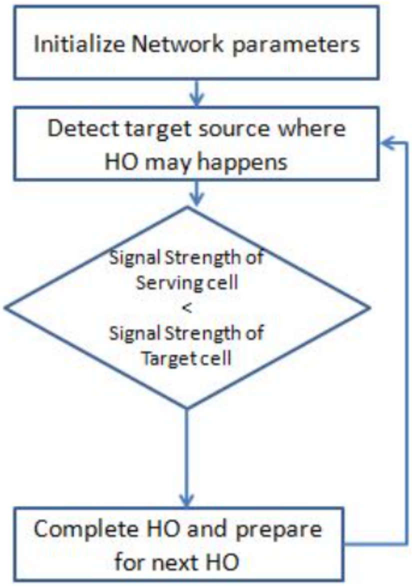

Figure 4. *Generic handover algorithm.*

4. Related Works

In coming years with the evolution of IoT, wireless networks will be more scattered and as LTE implements hard handover, this break before make will create major performance issues in mobility management. Issues like scalability, flexibility, admission and call drops becomes major challenges to current strategies [6]. Apart from that the flaws in RSS measurement can cause frequent switching between cells that impact handover performance directly. Also this will add performance degradation in the overall system as frequent switching consumes additional system resources in both access and core layers.

Among the popular LTE handover algorithm "Power Budget Handover Algorithm" [7] consider two parameter HOM (Handover Margin) and TTT (Time to Trigger) to take decision of handover. Where HOM is the received signal strength deference between serving and target cell of the user. TTT is the time interval that ensures HOM and timely handover to reduce unnecessary handover that termed as ping pong handover.

Inappropriate handover parameter can cause handover failure [8]. Ping pong and continuous handover is considered as unnecessary handover. Optimization in this area or reduction of unnecessary handover will improve the mobility robustness and system efficiency. With the rising trend of user demand of accessing wireless system which provides flexible mobility, the complexity of HetNets increses. To overcome resource scarcity over the demands, wireless access network will use mmWave and high frequency bands. Such rises in frequency and less size wave will ask to reduce cell size. Wireless cells will be compacted. This may termed as ultra dense network (UDN) [9]. Among the different types of handover, inter and intra cell, inter and intra radio access technology handover (RAT) [10] could be classified in broad head. During the handover process few parameters are compared between serving and target base station. On successfully completed measurement here comes the handover trigger criteria then handover process initiated and execution process initiated.

In many studies it is shown that the mobility prediction (MP) [11] in wireless network could reduce a significant amount of unnecessary handover. In this methodology user movement profile will be register and used for next handover trigger for others. Self optimization in handover decision could improve success rate. Establishment a relation between mobility robustness optimization (MRO) and Artificial intelligence (AI) approaches [12] may provide better result in handover success rate. Large number of handover processing produced from diversified traffic such as IoT, drones which could be handled in a better way with evaluation comparison of handover probability (HP), ping pong handover probability (PPHP) and outage probability (OP). With this the systems and services with automatic self optimization (ASO) [13] provides solution which that consider user experience.

Deployment of small cells to support incremental traffic has a major challenge in designing Ultra-dense network (UDN). Generated unnecessary and frequent handover between target and present serving eNB (e node B) or serving and immediate left over eNB which may termed as ping pong handover that consumes a significant amount of system resource as well energy [14]. This consumption may lead to call drop, admission blocking and handover failure which extends to overall poor service quality. Wireless mobile network experiencing chronic change in cell size and density of cells. This leads a huge number of handover. Among the generated handover cases few are unnecessary that is just wastage of resource and sometime impacting service assurance. The growth in handover cases creates additional load in central handover processing system sometime it cross the processing capacity. To overcome overloading issue and time delay in processing, the handover processing can be distributed zonal basis or any other suitable manner. This mobility management technique termed as distributed mobility management (DMM) [6]

In addition to many other approaches for improving handover success rate and overall quality an optimized handover algorithm is proposed based on user QoS (Quality of Service) [15]. In this method the serving system is designed to select suitable target cell among the availables. When the received signal strength indicator (RSSI) of any access point (AP) is comparatively better with the evaluating AP, then this AP will be transferred to that better AP's connected to system. To avail high data rate in LTE, WiFi, WiMaX user must have the capability to connect with multiple interface. Seamless service assurance requires seamless switching between AP's inside heterogeneous network. Such seamless transfer of connected session from one AP to another AP is known as vertical handover [16]. The scanning process to identify available or best suitable AP will consume additional energy.

Apart from handover optimization in GSM (Global System for Mobile Communication) networks, several studies conducted to optimize handover performance in 802.11 (WiFi) network [17]. The study emphasises in reduction of IP address fetching delay using several methods via DHCP (Dynamically Host Configuration Protocol) relay. with evolution of wireless network generation, vertical handover scheme [18] added with the traditional horizontal handover scheme. In simple when handover happens between heterogeneous network architecture its called vertical handover and if handover happens with same access networks it is called horizontal handover. From the beginning of the journey of wireless network it experience several changes over the time. The evolution of wireless networks given in below table:

Table 2. *Feature Comparisons in different generations of wireless communications technologies [18].*

Generation	Year	Handover	Sub Generation
1G	1980	HO	1G Only
2G	1991	HO	2.5G, 2.7G
3G	2001	HO, VHO	3.5G, 3.75G
4G	2008	HO, VHO	4G Only
5G	2021	HO, VHO	5G

5. Methodology

With the available optimization cases, tools and techniques this paper will concentrate on ping pong handover optimization. Optimization in ping pong handover have a significant impact on reduction of the handover failure in broad head. In detail it will reduce handover count which actually not required. This reduction has direct impact in system performance and QoS. As the part of ping pong handover optimization, re-evaluation of handover scenario will happen where user intend to move towards the cell from where it comes before. If the result in re-evaluation is same as previous, then it will be considered as the user really wants to do so. This will help to reduce unnecessary handover caused from inappropriate handover calculation that might introduce near cell boundary or from expansion of cells caused by cell breathing.

6. Preparation

In the simulation using MATLAB, consider a set of user movement in random direction inside heterogeneous network. This network has been designed in way that user must face handover in random pattern. As heterogeneous network describes, the height of serving and target cell antenna and radius might be different. Also the distance between center to center of cells varies in accordance with its dependent parameters (i.e effective antenna height). The design of this cell footprint done in a way so that it satisfy the heterogeneous network criteria. The received signal of an UE will be impacted with different types of losses in its travel path. Among the losses this study will measure propagation loss with respect to UE and its serving cell, UE and its target cell. The measurement procedure of signal propagation loss follows the Okumura-Hata model.

7. Handover Algorithm

From the UE point of view when the receive signal strength from any adjacent cell is higher than serving cell then there calls a handover action initiation. On successful handover completion the session of UE has been transferred to new base station or eNB. In all situation, mobile station continuously measure and compare the receive signal strength of its serving cell with the receive signal strength of other cell of its movement direction or stationary position. Whenever the strength of received signal from target cell is higher than the receive signal of serving cell, then handover process initiated. As there is a direct involvement of UE in handover process, this types of user device initiated handover is known as mobile assisted handover (MAHO).

With the increase of frequency demanded by user growth, cell size becomes small day by day. Smaller cell increases dense network that rises handover cases for the UE and system simultaneously. Among the handover cases a significant amount of handovers are not necessary. Actually these are wrongly trigger handover events which may termed as unnecessary handover or ping pong handover. To be more clear a handover that is happens with a user frequently between two adjacent cell. To reduce unnecessary handover in the next generation wireless network, proposed algorithm could be a good choice to achieve the targeted improvement in handover optimization. Proposed algorithm has been designed to re-evaluate any handover scenario where ping pong handover is detected. Where target cell id matches the cell id which is in its history of immediate left over cell id, handover re-evaluation process will be initiated as per proposal.

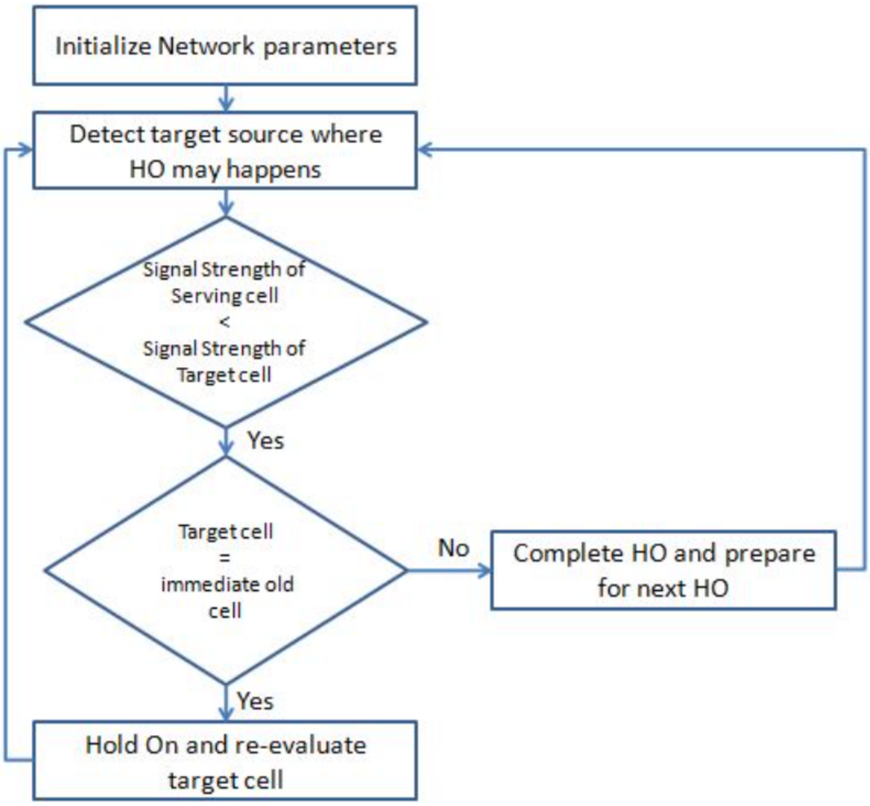

Figure 5. *Proposed Handover algorithm.*

7.1. Implementation

Consider a user is moving in a urban area inside the footprint of a service provider where different types of cell exist in its movement path. The shapes of the cells are hexagonal. Consider few adjacent cells of different size and to meet the heterogeneous network criteria. The antenna of every cell are designed and deployed accordingly. The site to site distance is obviously related to effective antenna height. The transmitted signals propagation loss from transmitting and receiving eNB for the user can be measured from below equation:

$$\text{Ł}(dB) = 69.55 + 26.16log(f_c) - 13.82log(h_te) - a(h_re) + (44.9 - 6.55log(h_te))log(d) \quad (1)$$

Where fc in the urban environmental frequency, hte is height of transmitter antenna, hre is the receiver antenna height and d is the distance between serving and target cell antenna. The distance could be measured from bellow equation:

$$d = 3.57(\sqrt{Kh_1} + \sqrt{Kh_2}) \quad (2)$$

Where h1 and h2 are the respective antenna height. K is the adjustment factor to account for refraction and the value is 4/3.

7.2. Procedure Details

In regular handover cases, once the receive signal strength from a cell is higher than the received signal strength of its serving cell then handover process initiated. After handover trigger and successful execution, the user attached with new radio system for further communication. This signal measurement is a continuous process and happens repeatedly. The hole process of a handover consumes significant amount of radio resource collectively. Wrong measurement or variation in received signal strength from different base station can produce unwanted handover which leads to processing resource consumption and finally performance degradation occurs. This might happens due to cell breathing and user near to cell boundary and other factor.

Each and every handover in wireless network can be tracked using unique radio cell id and user handover history recording. In every handover intention it will check user movement history from record if it is trying to move back again to its lastly left over cell, this handover execution will halt and system will re-initiate signal strength measurement. This time if same situation occurs, consider this one as a real movement of the user and allow handover to execute following other required criteria and process.

The stated re-evaluation in handover process reduces unwanted handover significantly. The process of simulation in different scale using MATLAB and received some positive vibes reflection in result.

In this simulation, a number user to travel within a set of cells. During their movement it will faces so many handover as expected. Among the handovers it identifies the cases while user come back to its immediate leftover cell as early handover or unnecessary handover or ping pong handover (PPHO). Once

PPHO detected, handover evaluation method again initiated for the case. This re-evaluation can give same result again, this case it can be consider that the user is coming back to its previous cell willingly.

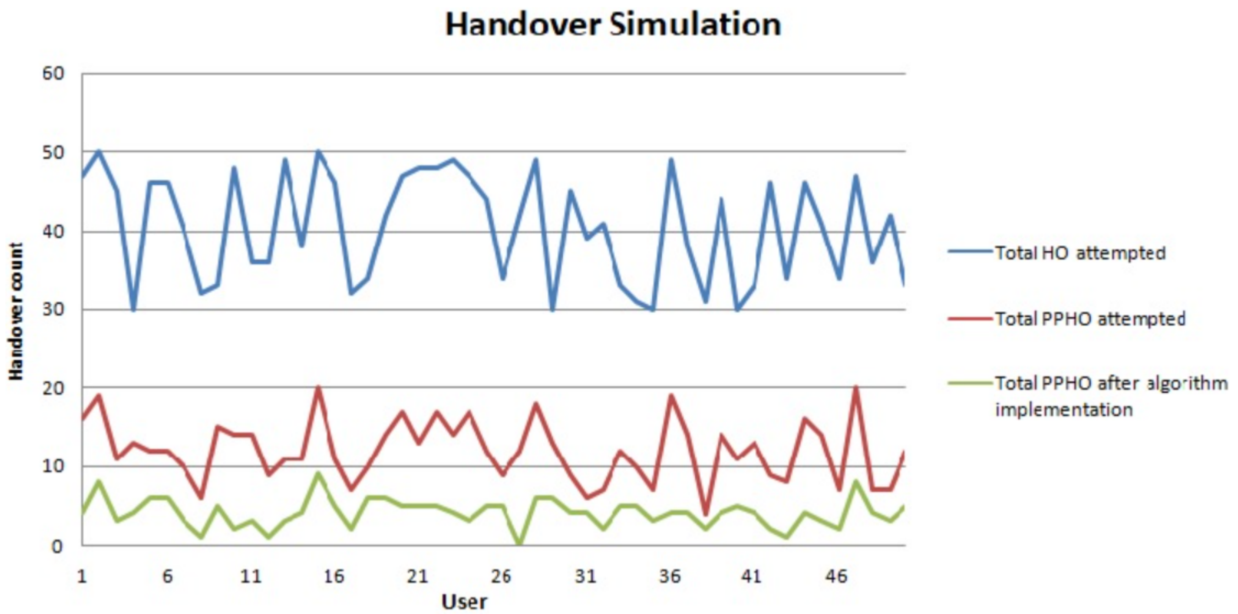

Figure 6. *Handover simulation.*

Handover process with and without optimization shown in Figure 6. Here a remarkable differences after re-evaluation algorithm implementation has been found.

8. Result Discussion

The simulation result shown in Figure 6 represents the total number of handovers experienced by a user in a cycle along with the probable ping pong handover (PPHO) count. As the target to exclude the unwanted ping pong handover which might be introduced from the wrong handover trigger initiated from wrong measurement data in HO decision, cell breathing, and other subsequent factors, then call the re-evaluation process for such handover cases. After re-evaluation, result shows a significant reduction in ping pong handover (PPHO) cases. For more contrast, more data should be gathered. To do so the study went through few more simulation scenarios with the same process and different data sets, the summary of results shown in Figure 7.

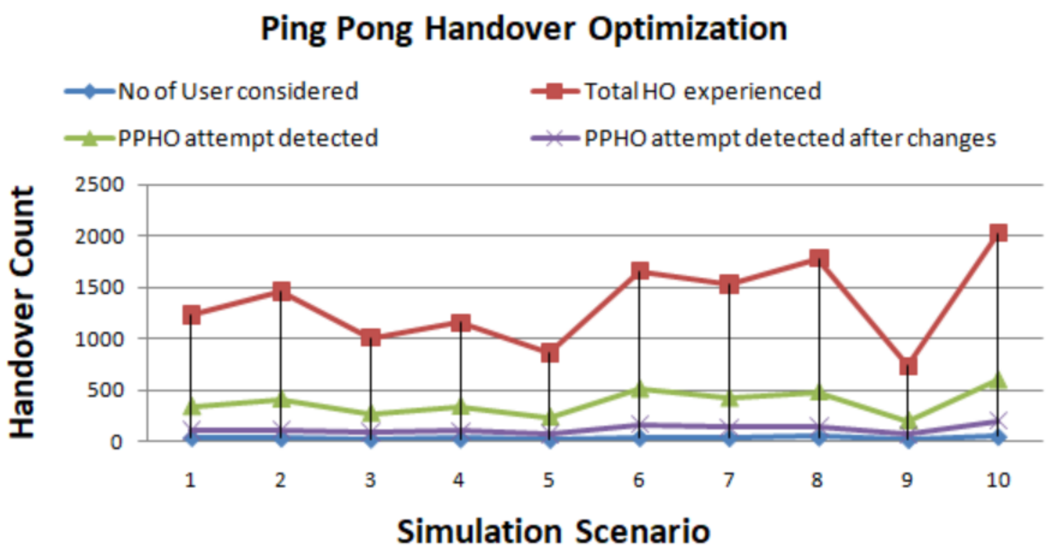

Figure 7. *Handover simulation Scenarios.*

The gathered data set has different patterns in the PPHO reduction rate. Assumed that this is happening because the probability of unnecessary handover varies and can be said as ubiquitous. Since this can not be predicted, any rate or pattern cannot be plotted rationally. However, it is obvious that once ping pong handover is detected and a re-evaluation technique imposed and this produces positive results. The data set received as a result of optimization can be used as history data in a central or, distributed mobility management system. Where the system gets to match any handover anomaly it can use its stored data for reference. This data storing can be done with supervised machine learning [19] or unsupervised machine learning[20] technique. The data set can be used for deep learning-based mobility prediction where the system will let you know that there is a probability of ping pong handover. Intelligent UE or user can decide to change his movement accordingly. This will allow the user to set the priority of the connected session.

Performance comparison of the simulations shows huge improvement but not eliminate the unwanted handover because there is a probability of wrong measurement, wrong trigger, or wrong assumption that is causing another unwanted handover. In this proposal, re-evaluation process starts once only. In another context, this re-evaluation process consumes additional wireless resources to complete its scope as per definition. The beneficial part of this algorithm is it will reduce the probability of unwanted handover which reduces call drop rates later on. Here unwanted process execution is reduced, and systems resource is optimized. Overall the system performance and quality will improve significantly with the changes implemented.

9. Conclusion and Future Work

This paper explained a way to reduce unwanted handover which may termed a ping pong handover. The workout is, that the algorithm will detect unwanted handover situations and process to reduce them with a re-evaluation of its measurement. The assumed data set and its analysis focused on received static parameters that may not be sufficient to stop unwanted handover triggering second attempts and onwards.

Future work will focus on storing the history data against unique cell identification numbers in the handover management module. This data is gathered using machine learning (ML) techniques, and artificial intelligence is used to predict mobility on accurate prediction of overall handover scenarios in next-generation wireless networks. Moreover, the focus will be on the directional movement of the user in addition to the current algorithm which will help to identify static users residing near to cell boundary for whom the handover process is not supposed to trigger.

Abbreviations

5G	Fifth Generation
AI	Artificial intelligence
AP	Access Point
ASO	Automatic Self Optimization
DHCP	Dynamically Host Configuration Protocol
DMM	Distributed Mobility Management
eNB	e Node B
GSM	Global System for Mobile Communication
HetNet	Heterogeneous Mobile Network
HM	Handover Margin
HP	Handover Probability
IoT	Internet of Things
LTE	Long Term Evolution
MAHO	Mobile Assisted Handover
ML	Machine Learning
mmWave	Millimeter Wave
MP	Mobility Prediction
MRO	Mobility Robustness Optimization
PPHO	Ping Pong Handover
PPHP	Ping Pong Handover Probability
QoS	Quality of Service
RAT	Radio Access Technology Handover
RSS	receive signal strength
RSSI	Received Signal Strength Indicator
TTT	Time to Trigger
UDN	Ultra Dense Networks
UE	User Equipment

Conflicts of Interest

There have no known conflicts of financial interests or personal relationships that could have appeared to influence the work of this paper. The authors declare no conflicts of interest.

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