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ADDRESSING CONSTRAINTS OF MOBILITY MANAGEMENT IN 4G NETWORK THROUGH HYBRID OPTIMIZATION TECHNIQUE

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ABSTRACT

This paper presents addressing constraints of mobility management in 4G network through hybrid optimization technique. Literatures were reviewed and research gap showed that despite the success of existing mobility management techniques, issues such as handover failure, signal degradation, and resource unavailability still persist in 4G networks. In this study, a hybrid optimization technique that combines Mobile-Assisted Handover (MAHO) and Network-Controlled Handover (NCHO) is proposed to address these issues. The developed technique was tested on a macro cell with load factor of 0.9, and the results show a significant improvement with 90.18% call handover success during 163 attempts.

Keywords: Mobility management; 4G LTE-A, Hybrid optimization technique, load factor

1. INTRODUCTION

Long Term Evolution Advance (LTE-A) supports spectrum flexibility by utilizing both time division duplex (TDD) and frequency division duplex (FDD) duplexing methods. This addition was implemented to enhance the system's functionality, as explained by Chen et al. (2015). The first version of LTE-A, called 'Release 10', was introduced to enhance the LTE standard by incorporating new features, such as coordinated multipoint (CoMP), relay node (RN), advanced multiple inputs multiple outputs, and carrier aggregation (3GPP, 2015; 3GPP, 2011). The distribution of controls in E-UTRA LTE-A occurs between the evolved NodeB (eNB) and user equipment (UE), through which the data transmission takes place. E-UTRA comprises four components: Mobility Management Entity (MME), Serving Gateway (S-GW), eNB, and UE (Tran et al., 2012).

The Mobility Management Entity (MME) is responsible for managing mobility, handling security, and admission control between the user equipment (UE) and the evolved packet core (core network). It serves as a control component (Akyildiz et al., 2010). The Serving Gateway (S-GW) is responsible for directing and forwarding data between the evolved NodeB (eNB) and user equipment (UE). It also functions as the mobility anchor for handover techniques. On the other hand, the eNB is responsible for connecting the UE to the MME/S-GW. The S1 interface is used to connect the eNB to the MME/S-GW, while the X2 interface is used to connect each eNB to the other. Additionally, management and control are distributed to each eNB without requiring intervention from the MME/S-GW (Volkan et al., 2014).

LTE-A offers several advantages, including high-speed mobility, wide coverage, and high data rates. It also supports switching compatibility with non-3GPP wireless systems, such as Universal Mobile Telecommunications Service (UMTS), General Packet Radio Service (GPRS), and Wi-Fi (Wiyim et al., 2014; Edward, 2015). Despite the aforementioned advantages, there are still challenges that researchers must address, such as mobility management, seamless handover, and resource allocation. These challenges need to be overcome to support the increasing demand for wireless technology.

"In the context of E-UTRA networks, the handover procedure is a critical component that enables user equipment (UE) connected to a base station to switch to the next base station or switch between sectors without disrupting the session. A seamless handover, which ensures uninterrupted connectivity, is essential for mobility, security, high quality of service (QoS), and user reliability in wireless systems (Miyim et al., 2014). With the LTE-A feature of supporting UE velocities of up to 500 km/h, the efficiency and accuracy of the wireless system may be reduced, making handover even more crucial (Márquez-Barja et al., 2011).

LTE-A relies solely on hard handover (HHO), where the UE breaks its connection with the serving base station before establishing a connection with the target base station. In HHO, data loss, buffering, and interruption time during handover are managed at the UE level, and data forwarding is managed by distributed controllers in the handover process, as opposed to centralized controllers used in soft handover, which is used in third-generation (3G) handovers (Zhou and Ai, 2014). The HHO procedure in LTE-A is primarily based on three parameters: received signal strength (RSS), hysteresis value, and Time To Trigger (TTT) period.

According to Khan and Han (2014), TTT period is a time duration during which the UE monitors the RSS of the target base station. If the RSS of the target base station remains above the hysteresis value for the entire TTT period, the UE triggers handover to the target base station. The TTT period can be adjusted to control the handover decision process, with longer TTT periods allowing for more stable signal measurements and fewer unnecessary handovers (Hosny et al., 2019).

During the HHO process in LTE-A, the UE breaks its connection with the serving base station before establishing a connection with the target base station. This can result in data loss, buffering, and interruption time during the handover process (Grech, 2017). However, these issues are managed at the UE level, and data forwarding is handled by distributed controllers, as opposed to centralized controllers used in soft handover in third-generation (3G) handovers. This distributed approach allows for faster and more efficient handover decisions and reduces the need for complex coordination between base stations during the handover process in LTE-A.

1. THE HANDOVER PROBLEM

Handover (HHO) procedure in Long-Term Evolution Advanced (LTE-A) network relies on three key parameters: received signal strength (RSS), hysteresis value, and Time To Trigger (TTT) period. However, the current HHO process in LTE-A can result in data loss, buffering, and interruption time during the handover process, as the User Equipment (UE) breaks its connection with the serving base station before establishing a connection with the target base station. This can lead to inefficient handover decisions and complex coordination between base stations, particularly in comparison to the centralized controllers used in third-generation (3G) handovers.

The current approach also relies on fixed values for hysteresis value and TTT period, which may not be optimal for all scenarios and may result in unnecessary handovers or delayed handover decisions. There is a need for an improved HHO procedure in LTE-A that minimizes data loss, buffering, and interruption time during handovers, while also providing flexibility in adjusting hysteresis value and TTT period for efficient handover decision-making. Additionally, there is a need to explore how distributed controllers at the UE level can further enhance the handover process, reduce the need for complex coordination between base stations, and improve overall handover performance in LTE-A networks. This paper will investigate some of the solution proposed to address the challenges and then make recommendation for the future.

2. LITERATURE REVIEWS

Selviand Sendhilnathan (2016) presented a fuzzy-based mobility management technique in 4G wireless networks. The fuzzy-based approach in the study aids decision-making in selecting parameters for proper handover during vertical and horizontal handover. The study reviewed the application of 243 rules for handover decision-making and found that a higher number of rules leads to better system performance and improved handover performance. Mukhtar et al. (2022) conducted research on mobility management solutions for future networks, considering challenges and compatibility. The study focused on identifying and discussing functional requirements for mobility management mechanisms through innovative qualitative evaluation. The assessment of these mechanisms considered adaptability, dependability, extensibility, and power consumption benchmarks for mobility management schemes. The mechanisms considered in the study included offload traffic flow in 3GPP, LTE Wi-Fi accumulation and dual connectivity, and LTE handoff. The results of the study identified that future research on mobility management should also consider security, assurance of low latency, massive handover numbers, context consideration, sensing, and network localization.

Jabbar et al. (2016) conducted research on the requirements for mobility management in diverse 5G wireless networks. The study emphasized the need to consider radio access networks that provide higher quality performance, reliable data transmission speed, and mobility that best suits multimedia applications with optimal performance at minimum cost. The system was developed using a hybrid vertical handoff algorithm based on forward and reverse procedures for vertical handoff. The results of the study showed that the technique reduced vertical handoff interruptions by 25% in the network. Alhammadi et al. (2022) presented a conflict resolution strategy for handover management in 4G and 5G networks. The study aimed to harmonize contradictions between mobility robustness optimization and load balancing optimization functions in a network. This was achieved by exploiting the received signal reference power, cell load, and user speed for adaptation of handover margin and time to trigger. The results of the study showed that the proposed technique reduced handover failure rate by 46% and interruptions by 58%. Shayea et al. (2022) conducted a survey on the management of handover for drones in future mobile networks. The study reviewed existing research on mobility management for communication in networked drones, focusing on drone networks and related works in the literature. The review highlighted major challenges faced in drone networks, particularly in the area of mobility management. The results of the review suggested that adopting intelligent handover schemes such as machine learning, deep learning, and other automatic robust processes could help reduce handover issues in drone networks.

Abolade et al. (2017) presented an overview of handover in mobile wireless communication networks, including handover types, commonly used parameters, and methods applied for handover. The study also discussed fuzzy logic-based self-adaptive handover techniques. The results emphasized the need for seamless handover in networks through the selection of appropriate network parameters. Nasrin (2018) proposed an adaptive mobility management scheme for next-generation small cell networks. The study introduced handoff decision algorithms for closed and open-access femtocell networks, secure target cell selection operations, and a model for analyzing the total cost of the handoff signaling process. The study also presented a power control scheme for mobility management to address issues in heterogeneous system radio femtocells. The joint handoff and offloading decision technique reported in the study aimed to reduce service migration rates and radio network congestion, and was deemed sufficient for adapting to current challenges in femtocell networks. Siddiqui et al. (2022) conducted a comprehensive review of issues and solutions in mobility management for 5G and beyond networks. The study focused on traffic routing using a flat network design and the effectiveness of distributed mobility management in wireless networks. The review identified limitations, challenges, and future research directions to enhance mobility management in 4G, 5G, and upcoming network communication technologies. The study serves as a review article that can be applied in the design of mobility management for 5G and beyond wireless networks.

Alotaibi (2022) presented key challenges in mobility management and handover processes in 5G HetNets. The study aimed to identify major challenges in mobility management and handover operations in heterogeneous networks, including power consumption, mm-WAVE usage, signaling, security, load balancing, and energy efficiency challenges. These challenges are critical considerations for improving mobility management and handover processes in networks using any technique. Obajuluwa et al., (2017) conducted research on the application of adaptive fuzzy logic for mobility management in a heterogeneous network. The work utilized a technique called the Order of Preference Algorithm, which is a multi-criteria decision model used to grade the performance of a wireless network. The network selection operation was performed using the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) algorithm. The factors considered for evaluation in this work were the handover time and network performance. The results of the study showed that the 4G operation of 493 handover nodes took an average of 0.003710 seconds for the operation. Jouini et al., (2016) presented an adaptive handover technique based on mobility load balancing in downlink Long-Term Evolution (LTE) self-organizing networks. The work first applied elementary procedures for the initiation and reporting of resource status using the X2-application protocol for load management in the network. Then, the mobility load balancing based on adaptive handover algorithm was implemented to enable the configuration of the adaptive handover operation. The results of the study showed that the applied load balancing technique improved the network performance by enhancing the overall throughput, packet loss ratio, and fairness while reducing handover overhead.

Khan (2019) conducted research on mobility management in 5G heterogeneous networks, with a focus on investigating techniques for accommodating low-latency applications in nodes of a network moving at the speed of a vehicle. The work was implemented as a constrained multi-objective optimization problem. The results of the study showed that the applied technique outperformed existing solutions. Assefa et al., (2018) presented a local mobility management based on software-defined networking with X2-interface in femtocell networks. The software-defined networking architecture presented in the work was integrated into the X2-based mobility management scheme in a femtocell network enterprise. The performance was mathematically analyzed by developing a closed-form expression of the applied technique in order to minimize signal overhead and handover latency. The results of the study showed that the technique reduced the signaling cost of handover by reducing the number of signals exchanged between the nodes.

Zaidi et al., (2020) conducted a survey on the future research directions and outlook of mobility management in emerging ultra-dense cellular networks. The work started by surveying the common challenges of ultra-dense mobile networks and presented the key mobility risks of legacy networks, as well as key findings from previous studies. The study also highlighted the technical challenges and potential opportunities associated with mobility in the area of emerging ultra-dense networks. The authors also applied machine learning techniques for the prediction of network behavior, achieving a regression result of 0.99. Mollel et al. (2021) presented a survey on the application of machine learning in handover management in 5G and beyond, with the aim of revealing the current state of cellular networks and providing a review on mobility and handover management in 5G network technology. The study then presented the application of machine learning in handover management, considering visual and network data for operation. The work concluded by identifying the need to consider various requirements for future research development, such as dataset availability, privacy and security, centralized or distributed deployment, and offline learning.

Abdulraqeb et al. (2019) researched self-optimization of handover control parameters for mobility management in 4G HetNets. The study used dynamic handover control parameters for the classification of handover failure into separate categories, including wrong cell, too early, and too late. The handover control parameters were adjusted simultaneously based on the dominant handover failure. The system used various metrics for evaluation, such as handover ping-pong, interruption time, mobile network speed, and radio link failure. The results showed that the system optimized the handover control parameters for optimal performance, reducing the rate of interruption by approximately 44.94%. Prakash et al. (2016) presented the application of TOPSIS for optimized network selection of heterogeneous networks using a multi-attribute intuitionistic fuzzy group decision method (IFDM). The fuzzy group decision method that used TOPSIS was a scalable technique capable of handling a vast variety of networks with a large quantity of attributes in the network. It used special parameters, such as intuitionistic fuzzy index or hesitant degree. The results of the study showed that the multi-attribute IFDM had a lower decision time quality than the fuzzy-TOPSIS method.

Sun and Kim (2017) presented an analysis of the gap in the application of a distributed mobility management model in 4G/5G mobile networks. The analysis focused on the gap between the IP-based distributed mobility management architecture IETF and the 3GPP mobile network. The gap analysis was conducted to describe the technology requirements for the extension and acceptability of technical interoperability among standardization organizations. The work identified that the application of distributed mobility management models could be applied to all 4G architectures using technologies defined in the standardization documents, but not the same for 5G architectures. Baynat and Narcisse (2016) presented a study that took into account intra and inter-cell mobility of users using a performance model for 4G/5G networks. The work investigated how the intra and inter-cell mobility of users influenced the performance of 4G/5G wireless networks, such as LTE and LTE-A networks. The study presented a multi-class Processor Sharing (PS) queue model, which was used to capture the mobility of users in a network zone between cells. The results of the model used reported that user and cell performance mobility could be improved to enable the gain as a function of network speed.

Choi et al. (2019) researched mobility management in 5G networks among various access networks. The work used the multiple access protocol data unit concept session for the control of transmission of large data in 5G network architecture. It also proposed the application of anchoring mobility management between access networks. With the application of the proposed model, it would assist 5G networks in providing an optimal network environment that ensures efficient and seamless communication service to users. Edward (2016) implemented a WiMAX/LTE HetNet handover algorithm using Session Initiation Protocol (SIP) before handover and cross-layer design using Media Independent Handover (MIH) service to reduce the re-setup of the session in a WiMAX/LTE HetNet. The algorithm minimizes the number of SIP message exchanges during the vertical handover process, resulting in a reduction of IP multimedia subsystem session resets. The system implementation reported an 18% improvement in handover performance. Mohammed et al. (2013) presented an algorithm that uses a Fuzzy-based self-adaptive handover algorithm for mobile WiMAX. Fuzzy logic is used to determine whether handover should be initiated based on two criteria: Received Signal Strength Indicator (RSSI) and velocity of the mobile service. The study showed that the technique improved handover performance by 27.8% compared to conventional techniques.

Malathy and Muthuswamy (2015) applied the knapsack-TOPSIS technique to improve vertical handover in a heterogeneous wireless network that includes WiMAX and WLAN networks. The study considered network-controlled handoff models based on received signal strength and network traffic as network metrics. The results showed that the technique reduced unnecessary handovers by 24%. Ali et al. (2016) presented a handover avoidance algorithm that uses neural networks to prevent handover to base stations that encounter undesirable radio propagation conditions such as obstacle-induced coverage holes. The user equipment uses the neural network to learn from past experience and make the best cell selection for handover based on quality of experience. The study reported an accuracy of 93% in avoiding wrong handover transmissions.

Cao et al. (2019) researched the application of deep reinforcement learning for the development of a handover decision system for unmanned aerial vehicle (UAV) networks. The technique aims to prevent unnecessary handovers while maintaining a stable and reliable network communication. The model uses the UAV state as input for policy optimization and develops an RSSI-based reward function for learning UAV handover decisions. The technique resulted in a 76% reduction in unnecessary handovers compared to Q-learning and greedy handover decision techniques. Bilen et al. (2017) researched the management of handover in software-defined ultra-dense 5G mobile networks. They presented a Markov chain-based handover management technique that selects and allocates the best eNodeB to mobile nodes before establishing a connection, considering available resources and transition probabilities. The study showed a 21% reduction in handover failure and a 52% reduction in delay.

3. MOBILITY MANAGEMENT PROBLEM

One existing technical problem of mobility management in 4G (Fourth Generation) wireless communication networks is handover or handoff failure (Kumar et al., 2012). Handover refers to the process of transferring an ongoing call or data session from one cell (base station) to another as a user moves from one coverage area to another. Handover failure occurs when the handover process is not executed successfully, resulting in call drops, data loss, and degraded user experience. There are several reasons why handover failures may occur in 4G networks, including;

1. Signal degradation: When the signal strength of the target cell is weak or the quality of the signal is poor, handover may fail as the user moves from the source cell to the target cell. This can result in call drops or data loss (Dulari and Bhushan (2019).
2. Interference: Interference from other devices or networks can disrupt the handover process, leading to handover failures. This can occur due to interference from neighboring cells, overlapping coverage areas, or co-channel interference (Dulari and Bhushan (2019).
3. Resource unavailability: Handover requires resources, such as time slots or frequency channels, to be available in the target cell. If the target cell does not have sufficient resources, handover may fail, resulting in call drops or data loss (Jana et al., 2011).
4. Incorrect handover decision: Handover decisions are typically based on various parameters, such as signal strength, signal quality, and network load. If the handover decision is incorrect, for example, due to inaccurate measurements or wrong algorithms, handover may fail (Dulari and Bhushan (2019).
5. Network congestion: High network congestion can impact the handover process in 4G networks. If the network is heavily loaded with high user traffic, handover failures may occur due to resource unavailability or delays in processing handover requests (Kumar et al., 2012).
6. Handover triggering threshold: The threshold used to trigger handover in 4G networks may not be optimized, leading to handover failures. If the threshold is set too low, handovers may occur frequently, leading to unnecessary disruptions. If the threshold is set too high, handovers may be delayed, resulting in call drops or data loss (Kumar et al., 2012).
7. Mobility parameters: The configuration of mobility parameters, such as handover hysteresis, time-to-trigger, and time-to-reselect, can impact the handover process in 4G networks. Incorrect configuration of these parameters can result in handover failures (Dulari and Bhushan (2019).

Efficient and effective mobility management is critical for providing seamless connectivity and a high-quality user experience in 4G networks. Addressing these technical problems related to handover failure requires careful optimization of network parameters, accurate measurement and decision-making algorithms, effective resource management, and appropriate handling of network congestion to ensure smooth handover transitions for users.

4. PROPOSED SOLUTION

Mobile Adaptive Handoff (MAHO) and Network Coordinated Handoff (NCHO) are two techniques used in wireless communication systems to address handover failure and mobility management issues. They are considered as hybrid solutions to the problem statement because they combine aspects of both network-controlled and mobile-controlled handoff techniques. As already predefined, handover failure can occur when the handoff process is not executed properly, leading to call drops or degradation in service quality. Mobility management involves managing the movement of mobile devices between cells to maintain continuous connectivity and optimize network resources.

MAHO is a mobile-controlled handoff technique that allows the mobile device to measure the signal strength and quality of neighboring cells and make handoff decisions based on this information. MAHO enables the mobile device to take an active role in the handoff process, as it can scan and report the measurements of neighboring cells to the serving cell. This information is then used by the network to make handoff decisions.

NCHO, on the other hand, is a network-controlled handoff technique where the network actively coordinates the handoff process. The network monitors the signal strength and quality of neighboring cells and determines when and where handoffs should occur. The network then commands the mobile device to handoff to the target cell.

By combining elements of both network-controlled and mobile-controlled handoff techniques, MAHO and NCHO aim to improve handoff performance and mobility management. The figure 1 and 2 presented the flow chart of the MAHO and NCHO techniques.

The figure 1 presented the MAHO which stated the monitors the load on the base station considering parameters such as traffic density (TD), call drop (CDR) and call arrival rate (CR) and then determine the signal strength of the base station. Other parameters considered for the Signal Strength (SS) determination are the interference (NF) and network load factor (NLF). The equation 1 was used or the signal strength determination;

$$SS = \frac{(CR - CDR)}{(TD + NF + NLF)} \quad (1)$$

The equation 1 was used to determine the condition of the cell and then when overload is detected, the neighboring cells are generated for HO preparation and eventual HO with the NCHO technique in figure 2. The NCHO check the availability of the generated cells and then select the Select the best considering equation 1 again and then start the HO process.

MAHO allows the mobile device to actively participate in the handoff process, which can help in making more informed handoff decisions based on local measurements. NCHO provides centralized control from the network, which can help in optimizing handoff decisions based on global network conditions. The hybrid approach of MAHO and NCHO can help address handover failure and mobility management issues in wireless communication systems.

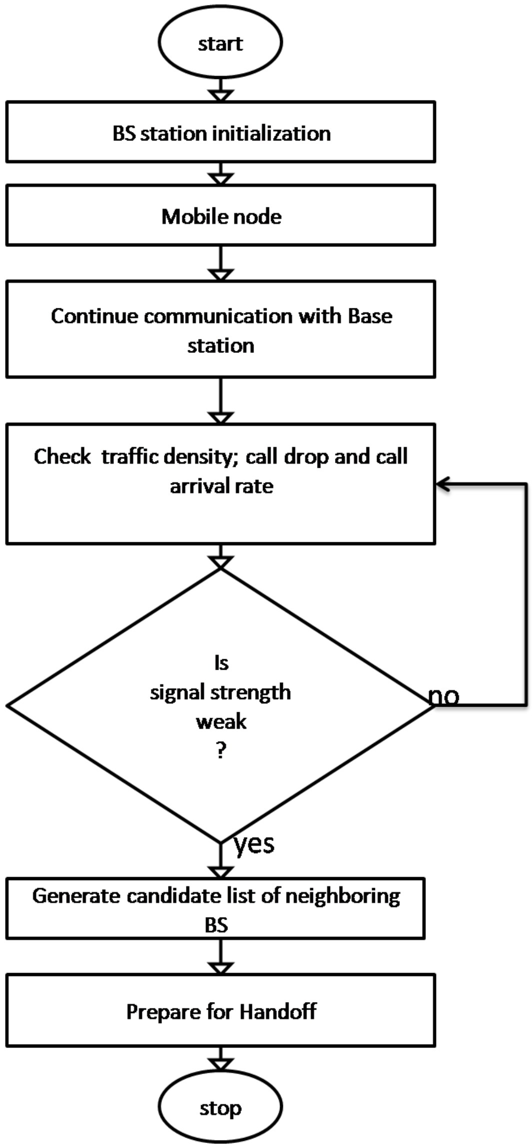

Figure 1: MAHO Flowchart

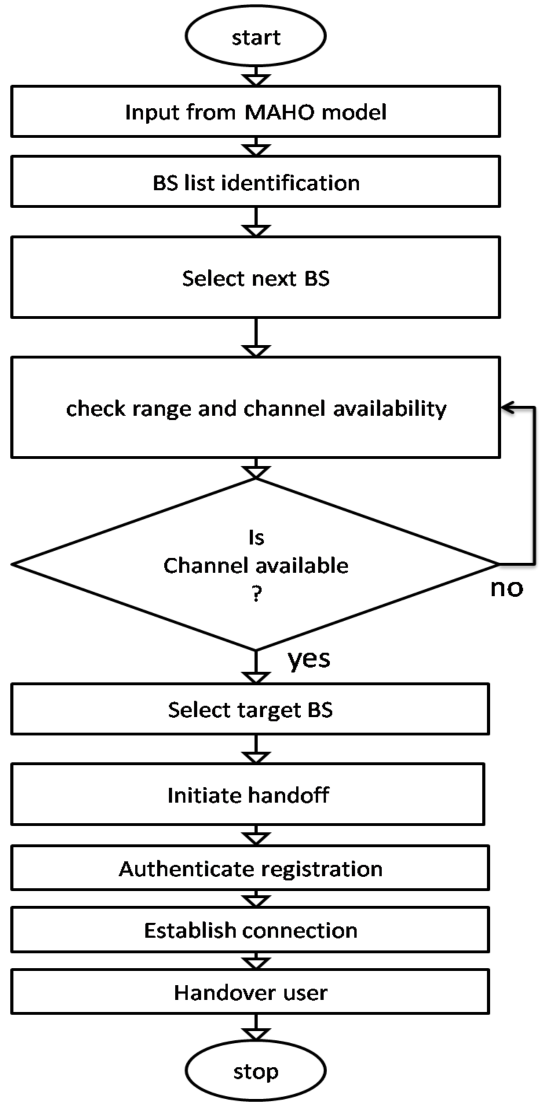

Figure 2: NCHO flowchart

5. PERFORMANCE EVALUATION AND RESULTS

To evaluate the performance of the hybrid techniques developed, simulation approach was used to test the model on a three tier heterogeneous network, with the macro cell network load factor set to 0.9 which implied congestion at the initial point before the model simulation. The result were evaluated considering handover success rate, handover failure and call drop probability considering an average of 163 handover process. The analysis of the results were reported by the author in a sister paper title “Enhancing mobility management in 4G network using hybrid of mobile and network assisted handoff technique". The results indicate that out of 163 handover attempts, 147 were successful while 13 failed, resulting in a handover success rate of 90.18%. This means that approximately 90.18% of the attempted handovers were successful.

In terms of quality of service (QoS), a handover success rate of 90.18% could be considered relatively high, indicating that the handover process is functioning effectively for the majority of attempts. A higher handover success rate generally implies better QoS, as it means that a large proportion of handover attempts are successful without disruption to the service being provided.

6. CONCLUSION

This paper investigated the state of the art algorithm for the management of mobility in 4G LTE-A network. From the outcome of the study, it was observed that the despite the success of the mobility management techniques, 4G network still suffers issues such as handover failure, signal degradation, resource unavailability, etc. this problem was addressed in this study using a hybrid optimization techniques that combines MAHO and NCHO. The result after testing on a macro cell with load factor of 0.9 recorded 90.18% call HO success during 163 attempts.

7. RECOMMENDATION

Further research on hybrid optimization techniques: The study used a hybrid optimization technique that combined Mobile-Assisted Handover (MAHO) and Network-Controlled Handover (NCHO) to address the mobility management issues in 4G networks. Further research could be conducted to explore and evaluate other potential hybrid optimization techniques or combinations of existing techniques to improve handover performance, reduce signal degradation, and enhance resource availability in 4G LTE-A networks. Real-world testing: The study conducted testing on a macro cell with a load factor of 0.9, which is a controlled environment. Real-world testing in different network conditions and scenarios could be performed to validate the effectiveness and performance of the proposed hybrid optimization technique. This could include varying load factors, network densities, and mobility patterns to understand the robustness and scalability of the algorithm.

8. FINDINGS

The findings reveal that the handover success rate of 90.18% out of 163 attempts indicates a relatively high level of effectiveness in the handover process. This suggests that the quality of service (QoS) for the majority of handover attempts is satisfactory, as disruptions to the service were minimal. A higher handover success rate is generally indicative of better QoS, and these results highlight the efficiency of the handover process in maintaining uninterrupted service delivery. Further research and improvements in the remaining 9.82% of handover attempts could potentially lead to even higher levels of QoS in the future.

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