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Dynamic Handover Optimization Protocol to enhance energy efficiency within the A-LTE 5G network's two-tier architecture

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ABSTRACT

Deploying small macrocell base stations, hence called femtocells, enhances the level of service provided to consumers inside as well as outside. However, the effective management of user mobility poses a significant challenge in their implementation. This paper focuses extensively on this challenge, specifically emphasizing a critical aspect of mobility management: handovers. Regarding macrocell femtocell 5G A-LTE two-tier networks, the decision-making process during handovers holds paramount importance. This research classifies and thoroughly examines decision algorithms concerning handovers, considering factors such as the speed of user equipment, financial considerations, interference, and received signal strength. Nevertheless, a significant number of these described decision algorithms overlook crucial aspects. Firstly, they often fail to account for cell selection when employing a scenario with just one macrocell and numerous femtocells; a hybrid access policy is used. Secondly, a significant number of those methods do not take the retention parameter for the user equipment into account, resulting in an increased occurrence of unnecessary handovers. To address these shortcomings, we propose a sophisticated handover decision algorithm. This novel approach considers various factors, including the individual's speed, received signal strength, time spent there, and the femtocell base station's access policy. Comparing our suggested algorithm to traditional decision algorithms that are only based on simulation, data shows that our proposed approach significantly lowers the frequency of unwanted handovers on received signal strength in the 5G network to improve the Energy Efficiency of the network by over 85%.

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1. INTRODUCTION

The escalating global usage of mobile applications has generated substantial demand for mobile data services, compelling mobile operators to explore innovative alternatives to traditional broadband services. Nowadays, mobile devices are utilized for a wide array of functions, spanning from accessing popular apps like Facebook and Twitter to streaming videos via platforms such as YouTube to making Voice over IP (VoIP) calls through applications like Viber, WhatsApp, and Tango [1]. They also extend to real-time medical applications such as Medscape and MicroMedex, among others. These diverse applications underscore the necessity for faster data speeds [2]. According to the Global Mobile Data Traffic Forecast Update for 2018-2023, it is projected that mobile data traffic will experience a significant annual growth rate (CAGR) of 87 per cent from 2018 to 2023, reaching a substantial 44.3 Exabytes per month by 2023. While femtocell base stations have proven to be invaluable, ensuring their optimal performance evolves in tandem with advancing technology remains a pressing concern and an area of robust research [3]. After all, the purpose of femtocells was to improve service to end consumers. This study focuses on the crucial decision-making process for handover in the two-tier macrocell femtocell LTE network for incoming mobility. During the handover procedure, the signal strength and frequency values of the currently serving cell and nearby cells are assessed [4]. The user equipment (UE) assesses these values and transitions to the cell with the highest signal quality. Typically, a predefined threshold parameter determines when and where this transition occurs. For seamless connectivity across cells, whether in scenarios of low, medium, or high mobility, the handover process must be smooth [5]. Achieving seamless handovers also necessitates considering the time required for the connection to establish or break. To address the challenges outlined above, a novel handover decision algorithm is proposed. This algorithm places a significant emphasis on factors such as UE velocity, residence time, cell search methodologies, received signal quality, and membership status [6]. The suggested approach addresses two important problems. It first deals with circumstances where a UE enters femtocell availability and leaves it quickly because of moderate or excessive mobility, leading to two needless handovers per femtocell availability: an incoming handover and an outgoing handover [7]. Notably, managing mobility poses a challenge within femtocell networks, encompassing both location management, which involves simultaneous UE tracking and reporting based on their locations, and handover management. Handover management, specifically, ensures seamless connections for nomadic users as they move across cells while transmitting data from their devices. Handover in this context encompasses various stages, with handover decision-making being a pivotal phase. The discussion will delve into a comprehensive exploration of various handover decision algorithms, culminating in the proposal of a specific handover decision mechanism.

2. LITERATURE REVIEW

According to [8], For inward mobility in layered macrocell networks, a handover decision algorithm: The provided algorithm deals with a situation when a User Equipment (UE) is located inside the femtocell boundary, and there is only one macrocell and one femtocell present. This algorithm's main goal is to address the issue of inconsistent power transmission among macrocell and femtocell base stations. The algorithm uses a windowing function in addition to the measured RSS values from the individual base stations to reduce the rapid changes in Received Signal Strength (RSS). Reference Symbol Received Power (RSRP) and Referenced Symbol Received Quality (RSRQ) are the two categories under which RSS measurements fall. This approach establishes a windowing function based on the RSRP measurements for the served and target cells at period 'k' following the occurrence of a handover-triggering event. The UE then checks to see if the filtered RSS inside the femtocell base station exceeds a predetermined threshold. Additionally, it determines whether a certain combination parameter exceeds the sum of the fluctuation margin and the macrocell's filtered RSS or determines whether the RSS inside the femtocell base station is less compared to the sum of the fluctuation margin and the macrocell's filtered RSS. The link to the femtocell is made if the results of the checks are positive [9]. The UE, on the other hand, assesses that the modified RSS inside the femtocell at a specific time exceeds the total of the fluctuations margin and the filtrated RSS value at the supporting macrocell. As an alternative, it determines whether the altered RSS at the femtocell is reduced than the total of the serving macrocell RSRP, the femtocell RSRP, the predetermined RSRP threshold, and the hysteresis margin. The UE re-establishes contact with the macrocell if any of these circumstances are true. If none of these requirements are met, the handover decision process comes to an end. The choice of variables and the characteristics of the glazing function are covered in further detail. When it comes to controlling incoming mobility inside the two-tier macrocell femtocell network, this method offers several benefits. Firstly, it successfully resolves the issue of unequal differences in received signal strengths among both serving and destination base stations. Secondly, it offers a mechanism for balancing the risk of handover failure with the probability of handovers, given by the symbol, to optimize the weighting value. Eventually, the algorithm was thoroughly examined using a variety of performance measures and has been properly validated. The algorithm, which does not consider circumstances where the User Equipment (UE) has a choice of numerous femtocell base stations, was developed under the supposition of a single macrocell and a single femtocell [10]. There is a demand to develop an RSS-based handover decision algorithm which considers scenarios featuring multiple femtocell base stations because, in today's installations, buildings may host numerous femtocell base stations. Furthermore, user equipment velocities (UEV), interfering stages, bandwidth accessibility, and access restrictions are not considered by the basic single macro-femto model. As a result, the algorithm could not be compatible with the complexity of deployment scenarios in practice.

According to [11], Approach Based on Route Loss with Received Signal Strength: In this category, they use a suggested algorithm to decide on incoming mobility, specifically switching away from the macrocell to the femtocell, based mostly on assessed Received Signal Strength (RSS) and route loss. This method has similarities to algorithms that have been developed in earlier publications, and it can be used in situations when there is only one macrocell and one femtocell. Likewise, it has a window function that, as shown, is directly related to the assessment of Reference Signal Received Power (RSRP) in the base stations of both macrocells and femtocells. All these actions take place after a handover is completed, sparked by a preset handover-triggering event, which is important to note [12]. The User Equipment (UE) first determines if the filtered RSRP exceeds a predetermined RSRP threshold. If so, the algorithm moves on to the subsequent evaluation phase; if not, the UE stays inside the serving macrocell. In the second stage, it is determined if the RSRP at the target femtocell surpasses the total of the RSRPs at the macrocell and the hysteresis margin. The handover decision process is completed, and the handover is carried out if this requirement is satisfied. If otherwise, the algorithm moves on to assess the UE's route loss regarding the serving and goal base stations. If the UE experiences a greater loss of pathway from its serving macrocell, it assesses which path loss is higher and starts a handover to the intended femtocell [13]. Path loss and RSS data are successfully combined by this technique to produce a reliable combination that considers either route loss or signal strength at the time of handover. It is crucial to remember that this algorithm only considers a scenario with a single macrocell and a single femtocell, therefore unlikely in actual installations. It has not been fully examined how route loss and received signal power of transmission are calculated. The algorithm is still vulnerable to ping-pong handovers despite performance evaluations, particularly when considering the rapidly variable nature of path loss criteria.

According to [14], Intra-cell switching of femtocells taking RSS and SINR difficulties into account: A handover decision algorithm built on the idea of intra-cell handovers with a focus on dealing with interruption and the possibility of several densely deployed femtocells. Transitions within the same kind of cell, specifically femtocells, are known as intra-cell handovers. User Equipment (UE) is switched across a single channel to another throughout the same cell category since these handovers take place inside the same cell type. The suggested technique is best suitable for situations where a UE encounters interference from several femtocells, regardless of whether it is covered by macrocells or linked to another femtocell. The system evaluates the signal-to-noise in addition to the interaction ratio (SINR) of the UE concerned and compares it to a specified SINR threshold to start an intra-cell handover. If the influence ratio is below this limit, the handover process continues; if not, the handover decision step is aborted [15]. A list of prospective candidate cells is compiled by the macrocell once all measurements of received signal strength (RSRP) have been collected. Appropriate RSRP for each macrocell at period 'k' must not be more than the total of the RSRP of the identical eligible cell and the handover fluctuation margin for this list to be formed. Only when this list of candidate cells is empty does the handover decision-making procedure come to an end. If not, before assigning any resources to the UE, the macrocell carefully examines both its communication channels and operating bandwidth lists. This denotes that the decision-making process for the handover is finished [16]. The macrocell examines its list of intervening femtocells and contrasts it to the preceding list of intervening femtocells if the list is not empty. The handover decision procedure halts if the output is unfavourable (signifying the existence of a new conflicting cell in the list). The macrocell recognizes the unallocated channel and notifies the femtocell to carry out an intra-cell handover if the output is negative (indicating that the number of overlapping cells has increased) [17]. The procedure is then repeated to look for any more inconsistencies. Alternatively, the macrocell executes the power regulation in the impacted femtocell and reconsiders the list if the output is still positive, suggesting that the list has not changed. This iterative process continues until a successful intra-cell handover. This technique is excellent for cases featuring a single macrocell and numerous femtocell base stations because it efficiently handles interference from surrounding cells and lowers the likelihood of handovers [2]. However, it potentially lengthens the entire turnover process by adding a second delay brought on by signalling operations in the handover decision step. When shifting interfering femtocells to different channels, there is also concern about possible increases in interfering levels in nearby femtocell base stations or UEs.

3. METHOD

To tackle the challenges mentioned above, a novel handover decision algorithm has been developed. This algorithm places its focus on several factors, including the velocity of the User Equipment (UE), the duration of residence, methods employed for cell searching, the quality of received signals, and the membership status of the UE, as seen in Figure 1. The suggested algorithm tackles two main problems. Firstly, it deals with situations at the point a UE approaches the coverage area of a femtocell but promptly for reasons of moderate or high mobility to improve Energy Efficiency. This scenario often results in two unnecessary handovers: one going in and one going out. The program compares the UE's velocity versus a predetermined speed threshold to correct this. The target femtocell's coverage area is measured using a fixed UE duration of residence parameter, and the intensity of the signal that was received is compared to a predetermined threshold. This algorithm's second goal is to fix scenarios in which an UE departs from the coverage area of its serving macrocell to enter a femtocell area with multiple femtocell base stations. In such cases, determining which femtocell to connect to becomes a challenge. To address this, the algorithm leverages the proximity estimation feature, which combines information about UE membership and the list of neighbouring cells, as seen in Table 1.

Table 1 shows the variables used during the simulation and their measurement to ensure smooth flow of the UE.

Table 1. Performance evaluation

Variables	Measurements
Bandwidth in order	15MHz
strength of Macrocell	25dBm
strength of Femtocell	15dBm
Quantity of buildings	3
condominiums per building	16
Rooms in each condominium	3
Nodes	10

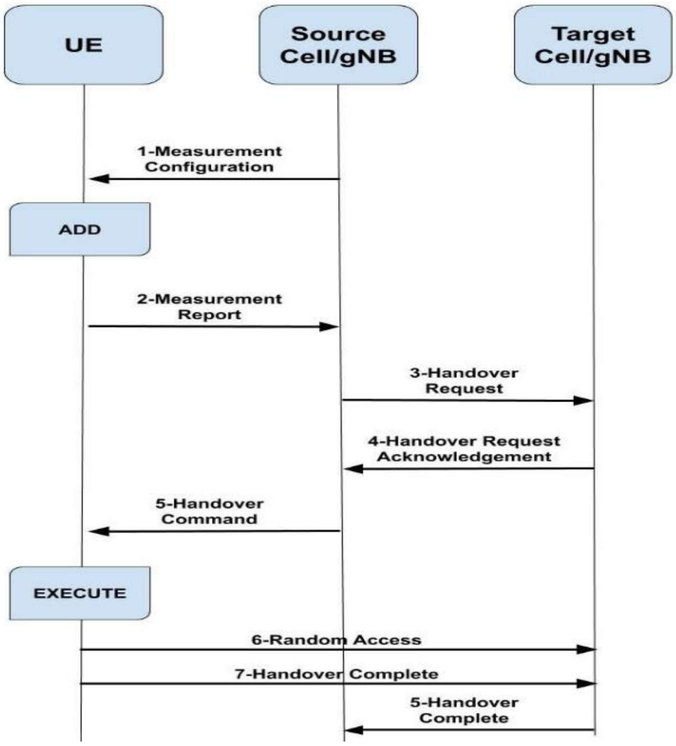

Figure 1. Methodology flow chart of the algorithm

4. RESULT AND ANALYSIS

The simulation commences by having User Equipment (UEs) move in random directions within the coverage area of a macrocell, which includes multiple Femtocell Access Points (FABs), as seen in Figure 2. To accurately simulate UE adaptability, the simulation system gives each cell and UE a special identification number and establishes their initial positions and configured velocities. Subsequently, it continually observes and records each UE's movement at 1-millisecond intervals. It documents the UE's Geometric coordinates; it is a special identification number and the name of the performing cell. Any time a handover event takes place in the simulator, it transmits only recorded data to a cell that has just started to serve and takes away the outdated data associated with the previous serving cell.

In each simulation, we gathered data regarding the count of handovers that occurred relative to the number of User Equipment's (UEs) in motion at that specific moment from Eq 1. Furthermore, we conducted simulations of the latest suggested approach with the standard power-based handover technique. Being an analogous example for a Received Signal Strength (RSS)-based handover determination method in Eq 2, the power-based handover algorithm was chosen as the approach to be utilized in Eq 3.

LS ½64$_1$þ o ð1Þ $where\ S$ ¼ $N = HO$ (1)

$$xk + 1 = Axk + Buk + wk \quad (2)$$

$$yk = Cxk + vk \quad (3)$$

Where Ls is a low signal, þ is performance, o union, ð is UE speed, S is serving cell and N is the network. Also, x is the power based, k is the constant, A is the throughput, B is the determinant, u is the coordinate, w is the performing cell, y is the NCL, C is the RSS, and v is the velocity.

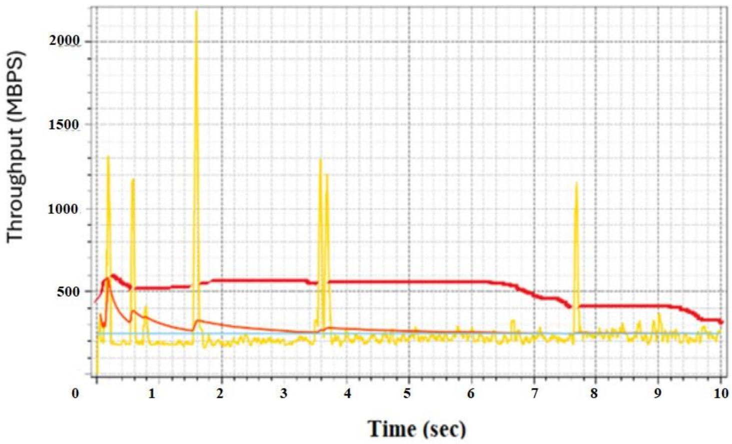

Figure 2. Moving UE

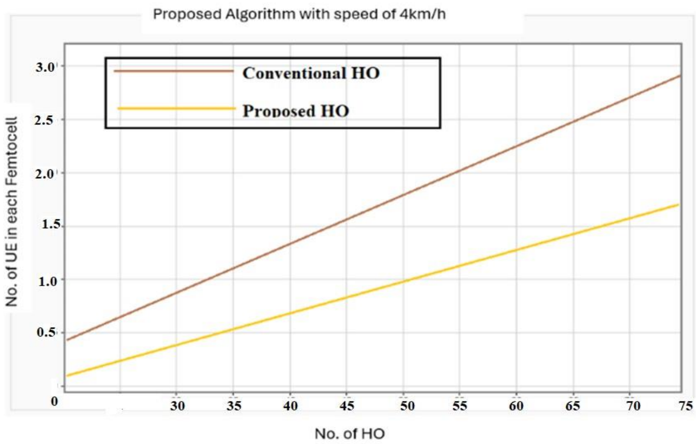

Figure 3. The algorithm has a speed of 4km/h

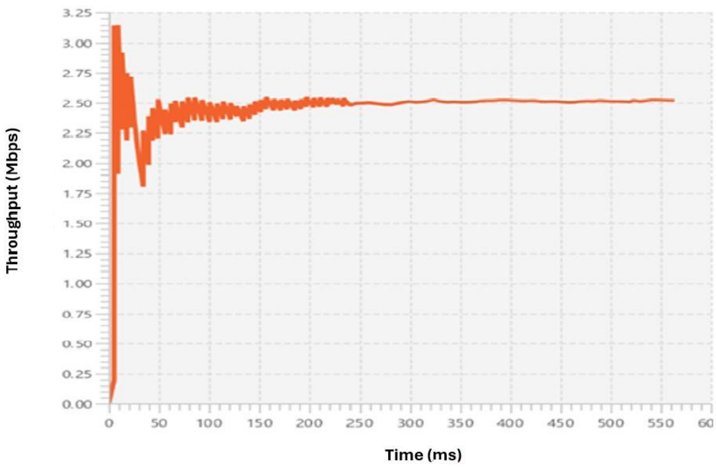

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Figure 4. Mobility in UE

Based on the findings presented above, it becomes clear that the period introduced, denoted as "Ti," exerts a substantial influence on the frequency of pointless handovers. Figure 3 shows the traditional power-based handover choice algorithm in this context. As the number of User Equipment's (UEs) increases, the count of unnecessary handovers escalates into the thousands. This phenomenon arises from the fact that mobile UEs are moving swiftly and are forced to transfer control to every femtocell base station they encounter in Eq 4. In essence, for every passing femtocell station, two pointless handovers transpire. Comparatively, when we assess the proposed approach in addition to the standard power-based one, we observe a noteworthy reduction in the occurrence of unnecessary handovers. This reduction stems from the time interval "Ti," which mandates that the UE must remain in its current state for a minimum duration before triggering the handover phase in Eq 5. Additionally, in Figure 2 and Figure 4, the results demonstrate that the proposed handover decision algorithm consistently yields a lower count of unnecessary handovers. Notably, this observation holds true for scenarios with different velocities, specifically 4 kilometres per hour and 16 kilometres per hour. The reduction in unnecessary handovers in these instances is attributable to the UE's residence time, which is set at 4 seconds.

$$HS4\ (CTðaidÞðHidÞo\ , CTCido\ )CT1 = MM \quad (4)$$

$$Li\ ¼\ ENRSAðRi_{1Þ} = TT \quad (5)$$

$$MSjþ1\ ¼\ Rjþ1 = CTjþ1 \quad (6)$$

Where H is the handover, MM is the mobility management, TT is the time to target, and CT is the cross target.

5. NOVELTY

In summary, the potential novelty of a Dynamic Handover Optimization Protocol (DHOP) to enhance energy efficiency within the Advanced Long-Term Evolution (A-LTE) 5G network's two-tier architecture needs the nature of 5G networks, the concept of a two-tier architecture, the process of handover, and the importance of energy efficiency in Eq 6. Also, 5G networks are the latest generation of cellular mobile communications, aiming to increase speed, reduce latency, and improve the flexibility of wireless services. They use a dense network architecture with more and smaller cells, allowing for a high rate of data transmission. Similarly, a two-tier architecture in 5G networks typically refers to the use of macrocells and small cells. Macrocells cover larger areas and provide the backbone of the service, while small cells cover smaller areas and are used to boost capacity in areas with high user density. Handover refers to the process of transferring an ongoing call or data session from one cell base station to another as a user moves through the coverage area. Likewise, effective handover is crucial for maintaining service quality, especially in high-speed mobile environments. Energy efficiency in 5G networks is critical due to the increased number of base stations and the inherent energy demand. Optimizing energy use while maintaining service quality is a significant challenge. In addition, the novelty of a DHOP in this context would lie in its ability to dynamically adjust handover parameters based on real-time data to optimize energy usage without compromising service quality. The protocol continuously analyzes network conditions, user mobility patterns, and energy consumption rates. Based on this data, real-time adjustments to handover triggers are made, selectively activating or deactivating small cells or adjusting their operational parameters to optimize energy use. In a two-tier setup, small cells usually consume less power but are deployed in greater numbers. A DHOP intelligently manages the activity status of these cells, perhaps turning off certain small cells during low usage times or in areas with low user density, thereby saving significant amounts of energy. Hence, by incorporating predictive analytics, the protocol anticipates areas of high demand and adjusts resource allocation proactively, ensuring efficient energy use while avoiding service degradation during peak times. Typically, by ensuring that handovers and cell activations are managed in a way that prioritizes maintaining a high-quality user experience, the protocol supports the core objectives of 5G networks. In the end, the novelty of the DHOP in enhancing energy efficiency within an A-LTE 5G network's two-tier architecture was characterized by its dynamic, predictive, and learning capabilities, which allow it to optimize handovers and manage the network's energy consumption intelligently. Lastly, this protocol represents a significant step forward in making 5G networks more sustainable and cost-effective, particularly in urban environments with variable user densities and mobility patterns.

6. CONCLUSION

The emergence of femtocell base stations is one example of how the rising demand for high-speed online access has sparked important technological advancements. These low-power, cost-effective, and small femtocell base stations serve to enhance signals obtained from macrocells. In the modern telecom sector, applying them has become routine. However, these deployments come with several difficulties, with mobility management emerging as a major issue. When it comes to mobility management, handover is of utmost relevance for femtocell installations in LTE networks. Making decisions about the timing and location of handovers is essential to this operation. This study looked at several alternative handover decision algorithm articles, with most of them being primarily designed for an instance featuring simply one macrocell and a unique femtocell. Given the rapid and frequently unforeseen development of femtocells in the past few years, this instance nevertheless falls short of accurately portraying the situation in actual life. The unveiling of an innovative decision algorithm created to thoroughly handle the previously noted difficulties is the main contribution of this paper. Inbound, outbound, along with intra-cell handovers are efficiently managed by this method regarding Close Subscribers Groups (CSG) and non-CSG component User Equipment's (UEs). Furthermore, it deals with the issue of cell finding by joining the NCL (Nearby Cellular List) with CSG data. Even though not all the method's components were exposed to simulation, the suggested approach underwent examination. Our findings indicate a 20.56% improvement over the 5.37%, 10.78%, and 16.91% performance of the prior handover choice algorithms. Regarding UEs with moderate to high levels of mobility, there is an addition of the time-to-trigger variable, specified at 4 seconds, significantly decreased the occurrence of repeated handovers. More work needs to be done in the future to secure the effectiveness of the network. Incorporating machine learning algorithms is an alternative for a better algorithm in the future.

DATA AVAILABILITY STATEMENT

The datasets are openly available for anyone to access and use at Github and CIS department, while others may be restricted due to privacy concerns, or proprietary information, by the organization that the data was collected.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest in this work.

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