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GRT Golden Research Thoughts

A ROBUST HANDOVER OPTIMIZATION BASED ON VELOCITY-AWARE FUZZY LOGIC IN 5G ULTRA-DENSE SMALL CELL HETNETS

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ABSTRACT:
Handover (HO) management becomes complicated in 5G networks and beyond due to frequent user transfers across narrow coverage zones. Additionally complicating HO decisions and possibly resulting in suboptimal resource utilisation is the presence of small cells (SCs). We present an intelligent technique based on a fuzzy logic controller (FLC) approach that leverages previous knowledge to dynamically change the handover margin (HOM) and time-to-trigger (TTT) in a 5G ultra-dense SC heterogeneous network (HetNet) in order to optimise this process. FLC enhances TTT in reaction to movement by adjusting it according to the user's velocity. It adjusts HOM simultaneously by taking into account inputs such cell load, user equipment (UE) speed, and reference signal received power (RSRP). The suggested method improves HO choices, which raises system performance as a whole.

KEY WORDS: *fuzzy logic controller; HCP; heterogeneous networks; handover; ultra-dense small cell networks; 5G.*

INTRODUCTION:

The rapid proliferation of mobile devices is driving up demand for data traffic. By 2028, mobile data traffic is expected to exceed 329 exabytes (EB) per month, according to the Ericsson Mobility Report. When compared to the need for data traffic in 2022, this indicates a growth factor of 3.5% [1]. The capacity and coverage of legacy networks need to be increased in order to meet the growing demand for data traffic. Using higher frequency bands and placing a large number of small cells (SCs) inside the existing cells' coverage area are two possible solutions [2]. An environment of heterogeneous networks, or HetNets, is therefore created. HetNets are made up of SCs and MCs, which can connect to various radio access networks.

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Mobility robustness optimization (MRO) is a significant function of self-organizing networks (SON) introduced by the third generation partnership project (3 GPP) [8,9]. Its purpose is to find the appropriate HO trigger for the optimal target cell to automatically optimize the HO control parameters (HCPs), such as TTT and HOM. The aim of the MRO algorithm should aim to mitigate UHO, RLF, and handover rate (HOR), which are significantly affected by the adjustment of HCPs [10]. For example, setting a long TTT at high speeds decreases UHO but increases RLF and vice versa. In addition, setting a low value for the HOM at high speeds can result in an early HO which in turn leads to RLF. Therefore, determining the optimal TTT and HOM to optimize the KPIs is still a challenge. Numerous methods have been suggested in academic research to address the issue of estimating TTT and HOM in long-term evolution (LTE) and 5G HetNets.

This study proposes a system for developing an algorithm that utilizes a fuzzy logic controller (FLC), and its notable contributions can be summarized as follows:

Development of an intelligent FLC framework that separately handles TTT and HOM. The proposed framework utilizes critical system parameters such as RSRP, UE speed, and cell load to optimize the tuning of the TTT and HOM settings. These settings vary based on different input conditions, with the TTT being specifically set to longer for lower UE speed scenarios and shorter for higher UE speeds to ensure optimal performance.

Optimization of the TTT and HOM settings involves applying the FLC rules based on previous expertise to determine their optimal values. This expertise includes an iterative process of applying different TTT and HOM values with varying ranges of input parameters to minimize RLF and HOPP. Specifically, different UE speed categories were considered for TTT optimization. It is crucial to set TTT and HOM in a manner that minimizes both RLF and HOPP levels simultaneously. Long TTT values may reduce HOPP occurrence but can lead to RLF due to serving signal deterioration and HO delay. Similarly, high HOM values can have the same effect. Conversely, a short TTT and low HOM may reduce the RLF but increase the overhead signaling and HOPP probabilities. This approach balances the mitigation of RLF and HOPP issues while ensuring the overall quality of service (QoS).

We present an algorithm that facilitates efficient HO decision-making in ultra-densely deployed SC HetNets, resulting in optimized KPIs compared to existing methods in the literature, with a focus on simultaneously mitigating RLF and HOPP levels.

Significantly, the UE speed thresholds considered in this study surpass those docu- mented in prior literature. The carefully selected UE speeds are reflective of real-life scenarios, thus enhancing the practical applicability of this research.

The remaining sections of this paper are organized as follows. Section 2 provides a summary of the relevant literature concerning the adjustment of HCPs, specifically focusing on TTT and HOM. Section 3 defines the system model used in this study, provides an overview of FLC, and explains the proposed algorithm. Section 4 lists the simulation parameters and presents a thorough discussion of the KPI results. Finally, Section 5 serves as the conclusion of the paper.

Related Works

To tackle the problem of HO management and optimize adjustments to HCPs, re- searchers have taken various approaches. There are two main options for configuring the HCPs: fixed and adaptive. However, it is common practice to combine both fixed and adaptive settings into a single configuration for HCPs, harmonizing them together.

the authors proposed an HO algorithm considering signal-to-interference-plus-noise ratio (SINR) and time-of-stay (ToS) parameters to balance the load between the cells and improve the throughput in HetNets. They assigned specific values to TTT and HOM based on the mobility of the UEs. The algorithm has a maximum speed limit of 70 km/h.

The authors in [12] introduced an algorithm that adaptively adjusts the HOM based on the UE's position within the cell in an LTE environment. They clarified that the HOM decreases as UE moves toward the cell edge. The algorithm considers two UE speeds: 30 km/h and 120 km/h. In [13], an algorithm was developed based on enhanced mobility state estimation to optimize TTT and HOM. The algorithm takes into account the speed of the UE and different types of HOs (MC to MC, MC to SC, SC to MC, and SC to SC) in HetNets. In the study, the authors combined the adjusted TTT values with adaptive HOM adjustment in SON. The maximum speed of the UE considered is 120 km/h. In addition, it is recommended to set lower TTT values for UEs with higher mobility speeds. This will help prevent late HOs that could lead to RLF. In [14], the authors proposed an algorithm using a weight function tailored for carrier aggregation within the LTE-A environment to adaptively estimate HOM. The algorithm dynamically fine-tunes the HOM level by employing an adaptive function that relies on the weighting functions of SINR, cell load, and UE speed. The evaluation of the system's performance involved measuring the SINR received by the UE, the throughput at the cell edges, and the probability of experiencing an outage. The maximum UE speed was set to 150 km/h. In reference [15], the authors extended the approach introduced in [14] and proposed a method to estimate the TTT and HOM parameters for each UE in a 5G network. The estimation was performed dynamically based on the UE's experience. This method takes into account cell load, SINR, and UE speed as inputs to execute bounded functions. The outputs of these bounded functions are then used as inputs to another function that estimates the TTT and HOM parameters. The performance of the proposed method was evaluated using RSRP, HOR, HOPP, and RLF. The maximum UE speed considered in the study was 140 km/h. In a similar manner, the authors of [16] presented an algorithm that estimates both TTT and HOM in an LTE/5G HetNet. This algorithm adjusts the TTT and HOM by considering factors such as RSRP, cell load, and the speed of the UE. The performance of the network was evaluated using metrics such as HOF, HOPP, and InT. The maximum speed of the UE was set to 140 km/h. Furthermore, the use of FLC has been extensively documented in the literature as a means of dynamically adjusting TTT and HOM. Some studies have used FLC to estimate either TTT or HOM, whereas others have used FLC to estimate both. In [17], a method has been developed for LTE HetNet environment that uses FLC to dynamically set the HOM. This method considers parameters such as reference signal received quality (RSRQ), UE speed, and the current HOM threshold. The maximum speed for the UE was set to 90 km/h. The study focused on system performance based on HOR, RSRQ, and HOM levels but did not consider KPIs such as RLF and HOPP, which are important for measuring system quality. The authors of [18] proposed a method that uses FLC to dynamically adjust the HOM based on three different rules in an LTE network. They considered the HOR and call dropping rate (CDR) as inputs to the FLC. TTT was applied using a fixed set of values. The method was analyzed for various traffic loads and UE speeds. The system's performance was evaluated in terms of HOR and CDR, but other KPIs were not considered in their evaluation. The maximum speed for the UE was set at 50 km/h. In reference [19], the authors proposed an algorithm based on FLC that uses RSRP, RSRQ, and UE speed to dynamically determine HOM in an LTE HetNet. The algorithm's effectiveness was assessed by employing KPIs such as HOR, RLF, and HOPP. The speed of the UE was taken into account within the range of 0 km/h to 80 km/h. Additionally, the impact of various inputs on FLC was studied individually, including HOR, HOF, HOPP, and the average time spent by the UE inside an SC. In [20], an HO algorithm that uses FLC has been introduced. This algorithm dynamically determines the HOM by considering both the current received SINR and the expected future SINR values for the UE in a 5G network. The authors claim that future SINR values can be predicted based on the SINR variations in the previous.

Handover Ping-Pong (HOPP)

HOPP refers to a wireless network scenario where UEs experience frequent and repetitive HOs between two BSs. Instantaneous variations in signal level due to shadowing, especially in UEs located at the cell edge, cause HOPP. HOPP is one of the vital performance metrics that shows the UHO. HOPP may occur due to inappropriate settings of HCPs in automatic configuration and low value setting to HCPs in manual configuration. In both the automatic and manual configurations, the minimum value settings to HCPs cause early HO and, in turn, lead to an increase in HOPP probability. HOPP significantly degrades the QoS of the network, wastes network resources, and results in excessive power consumption.

Figure 12a displays the HOPP probabilities as the average of all UEs with varying UE speed scenarios. It illustrates that HOPP probabilities vary across different methods and speed limits. For instance, A3 exhibits unpredictable HOPP probabilities for different UE speeds. On the other hand, greenFLD [25] shows an increasing HOPP probability from 5 to 80 km/h, but it decreases for speeds above 80 km/h. In contrast, greenAWF [15] has higher HOPP probabilities for lower UE speeds, but these decrease as UE speeds increase. In comparison, the proposed algorithm has lower HOPP probabilities for low UE speeds and higher HOPP probabilities for higher UE speeds. The occurrence of the HOPP probability is related to how HCPs limits are applied in algorithms. Some algorithms have more reactions with UE speeds, whereas others do not.

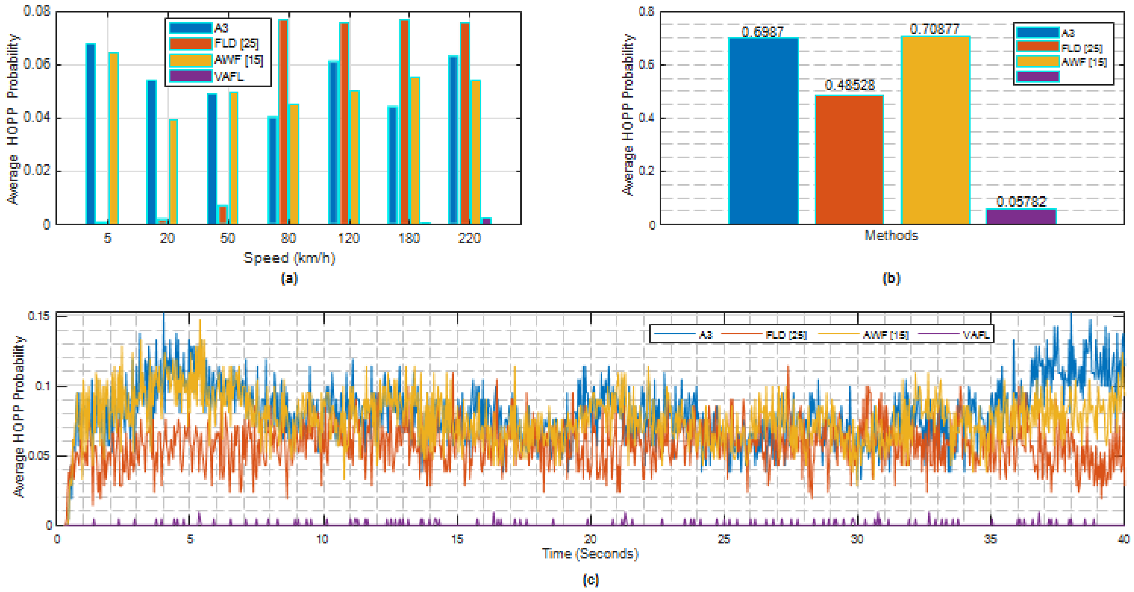

Figure 12. Figure 12 depicts the average HOPP probability for the methods under consideration across different scenarios: (**a**) for all UEs versus UE speed scenarios, (**b**) for the overall system, and (**c**) for all UEs versus simulation time.

Figure 12b presents the HOPP probabilities for all the considered methods as the average of all UEs across the various UE speed scenarios. Similarly, Figure 12c shows the HOPP probability for all UEs versus time. In these illustrations, it is evident that the proposed algorithm offers a substantial reduction in the HOPP probability compared to the other methods considered. The proposed algorithm achieved reductions of 91.72%, 88.09%, and 91.85% in comparison with the A3, FLD [25], and AWF [15] methods, respectively. This reduction is attributed to the optimization of HCPs and the effectiveness of the algorithm presented in this work.

Conclusions

In this study, we proposed a system that uses FLC to estimate HCPs, such as TTT and HOM, and based on the proposed system, we developed an algorithm which optimizes the KPIs by making efficient HO decisions in a 5G ultra-densely deployed SCs HetNet environment. The FLC utilized in the system leverages prior expertise and considers factors such as RSRP, UE speed, and cell load as input metrics. It adapts to different UE speeds and adjusts the TTT and HOM in a separate manner inside the FLC framework. The rules for both parameters differ significantly, while TTT is directly ruled by the UE speeds, a concept is referred as 'velocity-aware', HOM operates under distinct rules. Importantly, our proposed algorithm customizes the HCPs for each UE independently, eliminating the blanket impact on all UEs. We validated the HCP settings across a range of speed scenarios from 5 km/h to 220 km/h and assessed the algorithm's performance using various KPIs such as HOR, HOF, RLF, and HOPP. The results undeniably demonstrate that our proposed algorithm surpasses the performance of compared methods in the literature, ensuring a balance between RLF and UHO by minimizing the average RLF probability to 0.0069 and the average HOPP probability to 0.057 in an ultra-densely deployed HetNet environment, which serves as compelling evidence of its efficacy and superiority. This clear advantage positions our algorithm as a prime candidate for implementation in 5G networks, offering tangible benefits in terms of performance optimization and operational efficiency. In addition, future research can explore the validation of our proposed method, considering other metrics with different scenarios.

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