ABSTRACT

With the increasing demand on data rate in 5G mobile networks, the deployment of small cells such as Femto Access Points (FAP) and device-device (D2D) communications in parallel with macro-cells have been adopted as key technologies for improving spectral efficiency to support the vision of 1000x capacity in 5G systems. One major challenge in the future heterogeneous wireless networks (HetNet) is the mobility and handover management of the increased number of users. FAPs alone cannot sufficiently support data rate to users’ equipment (UEs) in crowded areas. Such UEs may benefit from Device-to-Device (D2D) assistance from nearby devices. Moreover, the traditional handover decision may result in a large number of handovers and increased handover blocking probability. For these reasons, a Fuzzy TOPSIS algorithm is proposed for the handover decision and network selection in the context of LTE FAPs and D2D communications. The proposed algorithm determines whether to perform a handover or not and then selects the best candidate network based on the Quality of Service (QoS) and Quality of Experience (QoE) scores, respectively. The proposed algorithm showed reduced number of unnecessary handovers, blocking probability and improved user throughput.

KEYWORDS

HetNet; Femto; D2D; Fuzzy; TOPSIS; AHP

1 INTRODUCTION

Today, wireless communication technologies have become an essential part of people’s lives and businesses everywhere. Mobile data traffic is predicted to reach 49 Exabyte’s monthly in 2021 and expected to exceed the capabilities of the current 4G (fourth generation) and LTE (Long Term Evolution ) infrastructure [1]. To cope with this increasing demand and prevent network saturation occurrences, Heterogeneous networks (HetNets) are seamlessly integrated to ensure users’ satisfaction and provide wide coverage anywhere and anytime. Moreover, reducing the cell size and offloading data traffic through Femtocells has improved the network capacity in local areas [2]. However, small cells may be overloaded in crowded areas due to its limited capacity and low coverage. Thus, Femtocells alone cannot provide ABC (Always Best Connected) services to the user equipment (UE) while roaming. Device-to-Device (D2D) communication is used to solve this problem by enabling direct communication between two cellular devices without the eNB intervention to improve spectral efficiency and decrease end-to-end transmission delay. In such Heterogeneous Network, the mobility of the users from one network to another needs an efficient Handover (HO) decision to ensure the Quality of Service (QoS) and Quality of Experience (QoE).

User experience is influenced by the used access selection algorithm and depends on the throughput and delay for the used application(s). The traditional handover decision algorithm selects the access point (AP) which has the best Received Signal Strength (RSS) based on the nearest node estimated by the UE. Such method may end up with improper assignment since the target networks may not meet the QoS requirements of user’s services. This approach results in a large number of handovers and Ping-Pong due to continuous changes in AP association, high handover failure rate, and wastage of network resources. To solve this problem, QoS parameters need to be considered in the decision of handover in addition to RSS. In such context, Multi-Attribute Decision Making (MADM) algorithms, such as TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and AHP (Analytic Hierarchy Process), are proposed to rank the networks to make the handover decision [3]. AHP performs pair-wise comparisons that indicate the relative importance of each criterion and generates
normalized weights to the parameters. TOPSIS calculates the Euclidean distance between network priority degree to the positive and negative ideal solutions that maximizes the benefit criteria (such as bandwidth) and minimizes the cost criteria (such as delay), respectively. However, context information of some HetNets needs more advanced decision making algorithm to process the dynamic information. For this reason, some intelligence (such as Fuzzy logic) which adapts to the dynamically changing heterogeneous networks should be integrated into the decision function. Fuzzy logic applies inference rules to get Fuzzy decision output based on inputs parameters (handover criteria) like delay, jitter, available bandwidth and bit error rate (BER) [4]. The Fuzzy logic transforms the input parameters into Fuzzy sets (“Low, Medium, and High”) using membership functions, apply IF...THEN rules for obtaining the Fuzzy decision sets, and then pass the output Fuzzy set to the defuzzifier where the handover decision is taken.

This paper proposes a Fuzzy TOPSIS-based handover decision in D2D-enabled multi-tier LTE HetNet. The objective of our proposed handover scheme is to reduce unnecessary handovers through pre-selection function and utilizing Fuzzy TOPSIS decision algorithm for dynamic access selection. Hence, the proposed handover will ensure the QoS and QoE while enhancing the throughput.

The rest of the paper discuss the following: Section II introduces the related works on handover decision algorithms. Section III elaborate the system model and the proposed Fuzzy-TOPSIS handover process including discovery, decision, and execution. Performance study is presented in IV regarding number of forced HOs, number of executed HOs, blocking probability and overall network throughput.

2 RELATED WORK

In this section, we have classified handover decision (HOD) approaches to AP-based and D2D-based.

2.1 AP-based Handover Decision

Authors in [5] have used SINR-based scheme in which the HO is triggered when signal quality degrades as a result of user mobility, the limited network coverage, traffic congestion, radio propagation, or the user receives higher SINR level from an alternative wireless network. However, this approach provides a very large number of unnecessary HOs and high latency. SINR do not guarantee a reliable QoS, either. It also depends on the mobile user's speed, and the overall performance of the scheme degrades as the speed increases. In [6], an HO mechanism between Macrocell and Femtocell in LTE based networks is proposed. UEs are classified according to their speed to prevent high-speed users with non-real-time services from the HO to Femtocell because they will pass by the Femtocell in a short period. Reference [7] predicts the user mobility for possible HOs. The next position of the UE is estimated based on the UE’s location, speed, and QoS. The main purpose is to achieve the seamless HO and reduce the HO latency.

However, maintaining the QoS during the handover in HetNet needs an intelligent HOD algorithm that considers QoS parameters such as BER, delay, jitter, and bandwidth. Reference [8] dynamically obtain real-time network performance context and user preferences weights to apply an MADM algorithm for selecting the best network based on these parameters. Authors in [4] select the best network by utilizing the QoS parameters in a Fuzzy rule-based algorithm. The mobile UE periodically monitors available networks and communicate the collected information to the current network for executing the handover. Authors in [9] deployed an Adaptive Neuro-Fuzzy Inference System (ANFIS) capable of learning. The system calculates the Mean Opinion Score (MOS) based on QoS criteria. For lower MOS values, a handover procedure is triggered. Authors in [10] and [11] presented intelligent vertical handover decision algorithm that chooses the target network depending on predefined weights assigned to HO metrics using MADM. The Fuzzy inference system then evaluates the current and target network to initiate handover. Furthermore, the proposed work in [12] considers a Fuzzy TOPSIS method, as vertical HOD, which uses the output of the four Fuzzy controllers from different RATs (Radio Access Technologies) as inputs to TOPSIS, to determine candidate networks.
ranking score based on AHP weighting. The Fuzzy controllers are the received signal, QoS (delay and data rate), mobile speed and mobile battery level controllers. The AHP decision matrix that is of the same size has reduced the difficulty and delay for decisions when the parameters number or RATs number increase. When adding a new parameter, an inference rule is only added in the corresponding Fuzzy controller. Instead, authors in [13] used the Fuzzy logic system without defuzzification to reduce the computation and discovery time, avoid Ping-Pong and ensure QoS. The algorithm calculates the performance of WLAN networks and chooses the target network considering the current RSS, the forecasting RSS and available bandwidth as input network parameters into the Fuzzy login system.

2.2 D2D-based Handover Decision

A QoE-aware network management framework is presented in [14] for VoIP services in LTE-A networks that support D2D communications. Two parameters (the average delay and the packet loss rate) are collected, and then the MOS is calculated by the E-model. If the D2D receiver has a higher QoE than the current cellular link, then the UE switches to D2D and data are exchanged directly on the uplink, bypassing the eNB. A D2D-assisted handover scheme is proposed in [15], where D2D connectivity is utilized to improve the user handover between different BSs and enhance the overall link quality experienced by the UE. The procedure allows the UE, upon entering the overlapping region, to randomly select one of the D2D users at the intersection of its coverage and that of the target BS to start a direct D2D communication as a temporary relay. Reference [16] utilizes D2D communication with a nearby Femto UE (FUE) for load balancing and reuse the uplink resource of the corresponding FAP. Choosing which FUE to act as a D2D relay is based on the energy consumption, which is derived from the distance between the D2D sender and receiver. Authors in [17] enhance the QoE (in terms of ease of Internet access) through D2D-communications for both DL and UL transmissions in a multi-tier cellular HetNet. The proposed algorithm utilizes D2D relays for data communication when a connection cannot be established to overloaded eNBs around the UE. The eNB that has the best QoE is selected taking into account the Resource Block (RB) availability in nearby eNBs.

3 QoS/QoE-BASED FUZZY TOPSIS HANDOVER DECISION

3.1 System Model

We considered a single cell Long Term Evolution (LTE) with a hierarchical deployment of one eNB Macro base station, denoted by MBS, and some small APs (hybrid Femtocell), denoted by FAP. Femtocells are uniformly distributed around the edge of the reference Macrocell. Several UEs are randomly distributed among the coverage space as shown in Figure. 1. We assume three modes of operation for each mobile UE: Macro mode (MUE), Femto mode (FUE) and D2D mode (DUE). Only mobile UEs located near the MBS (at the inner region) operate in a Macro mode, while other UEs located at the cell edge operate in Femto or D2D mode. Cell edge UEs spend more power than others nearer to the center of the BS thus being the ones that should be associated to a smaller cell (FAP or D2D). Since FAPs are commonly deployed in local areas such as offices or campuses, we assume several UEs move at a constant low speed of $v$ m/s in a straight line.

Since energy consumption is one of the main challenges in D2D communication as the UEs devices are equipped with a limited battery, our solution assumes that a network mobility management server is deployed in the evolved packet core (EPC) of the network (at the MME or in an access router such as S-GW/F-GW). The server assists in handover discovery, minimizes scanning delay and energy consumption [7] [18]. It maintains a database about each possible target cell, including small cells and D2D UEs.

3.2 Proposed Handover Decision Process

As a result of the UE’s mobility, an alternative network selection and HO decision is performed as follows:

1. The server preprocess target selection based on SINR and Rate threshold.
2. The server applies a Fuzzy algorithm that ranks the available networks in terms of QoS (including bandwidth, delay, jitter
and BER) to decide on a possible handover.

3. The UE selects the target network based on QoE score (in terms of MOS, direction, and battery) using TOPSIS and AHP weighting.

This process is illustrated in Figure 2. We have divided the HO process into four phases: Handover Trigger, Handover Discovery and Information Gathering, Handover Decision, and Handover Execution. Figure 3 shows the proposed sequence diagram of the signaling messages exchanged during the handover from an MBS to a FAP or D2D relay. The detailed signaling procedure in each phase are described as follows:

**Handover Trigger:** this phase starts when the UE detects within the current network a decrease in signal strength or data rate. Moreover, we assume that the server has a list of surrounding APs. Therefore, if an AP is found in the UE’s current location, it will trigger the UE to measure the link SINR and Rate as shown in Figure 3.

**Handover Information Gathering:** this phase includes the discovery of neighboring networks, in a periodical manner or upon request. If an HO is triggered, the UE will generate a request to the server to enquire about available Point of Accesses (PoAs) with better QoS, as shown in Figure 3. The server then obtains the real-time SINR and the cell traffic load of the corresponding available FAP and DUE relays. The server performs network pre-selection based on SINR$_{\text{min}}$ and Rate$_{\text{min}}$ thresholds to eliminate unreachable and congested PoAs. The pre-selection will avoid activating unqualified networks to reduce the unnecessary handovers. Afterward, it gathers/calculates other handover parameters values of the qualified networks including delay, jitter, and BER.

**Handover Decision:** this phase is made initially by the server which evaluates qualified networks in terms of QoS score using the Fuzzy QoS controller. The QoS controller takes into account

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**Figure 1:** A Femto/D2D multi-tier cellular network

**Figure 2:** Proposed handover decision

**Figure 3:** Proposed handover signaling from Macro to Femto/D2D
four input parameters: bandwidth, delay, jitter and BER [4]. The Fuzzy membership functions for those parameters as well as the QoS score are given in Figure. 4. The input Fuzzy sets are fed into the Fuzzy system. IF-THEN rules are applied to obtain the Fuzzy decision sets. Some of the QoS rules in VoIP services are defined as follows:

IF delay is low, BER is low, jitter is low, and bandwidth is high, THEN network quality factor is high.

IF delay is low, BER is medium, jitter is low, and bandwidth is high, THEN network quality factor is medium.

IF delay is low, BER is medium, jitter is medium, and bandwidth is low, THEN network quality factor is low.

If the output QoS score is greater than a QoSmin threshold (0.5) [10], the handover is initiated. However, if the QoS score is less than the threshold, handover will not be executed as long as the SINR is above the threshold. As per Figure. 3, the network server replies to the UE’s request with a list of candidate PoAs. The UE then determines its direction, the Battery level and MOS of the candidate networks. Based on these parameters and their weights determined by AHP method, the UE ranks the candidate networks using TOPSIS where the QoE scores are calculated [12, 19]. Finally, the network with the highest QoE score is selected as the target network.

**Handover Execution** where the UE access the new network and switches all its connection according to the 3GPP standardized procedure in the last phase. We assumed that the server allocates orthogonal frequency bands for MUE and FUEs and each user occupies one of them for VoIP communication. However, the server is considered to allow DUEs to reuse the available resources (e.g., RB) in an underlying manner as long as the interference remains below a given threshold.

### 4 NUMERICAL RESULTS

The above-described system model has been simulated using MATLAB. The simulation parameters are provided in Table 1. The mobile users move horizontally within the macro cell area and handovers from one AP to another. By varying the devices’ locations, the signal strength of the current connection decreases. Each time, a list of candidates are discovered and the mobile UE chooses the AP with the highest QoE score to connect to. The implemented handover process is summarized in Algorithm 1. To evaluate the performance of the proposed scheme, we compare the proposed FUZZY TOPSIS scheme and the conventional SINR-based scheme with D2D and without D2D. The SINR-based algorithm selects the target PoA that has the maximum received SINR to associate. In each scenario, the total number of forced HOs, number of executed HOs, blocking probability, and total average user throughput is obtained. We consider 6 FAPs while increasing the number of users from 100 to 300.

Figure. 5 shows that the number of forced handovers in the SINR-based algorithm increases more than the proposed Fuzzy TOPSIS. This means that the UEs will need to switch between networks more frequently in order to maintain the required SINR. However,
in our approach, we consider the QoS requirement as well as the UEs’ direction in the HO decision, thus less HOs are forced. In Figure 6, by using the proposed algorithm with D2D, the number of executed HOs is significantly reduced as compared to SINR-based with D2D. In the SINR based algorithm, the mobile UE will decide a handover as soon as it detects a network in location and chooses the one with the highest SINR. However, the best network should be chosen based on the QoS at the UE to reduce unnecessary HOs. In the Fuzzy TOPSIS based scheme, handover is only initiated if the Fuzzy algorithm generates a score of 0.5, which is greater than the threshold [10]. As long as the UE is satisfied with the service, the handover will not be executed. Thus, the number of handovers is relatively constant. However, due to the limited range of D2D connections, more HOs will be performed to guarantee the QoS as compared to the no-D2D cases. When direct D2D connectivity is not available, fewer HOs are executed since there is a limited number of available PoAs, or the availability of free channels in the candidate networks cannot accommodate the request of handover due to lack of resources. In this case, the blocking probability will increase as the user density increases (Figure 7). Apparently, no balancing is considered without D2D, as most of the cell edge

Algorithm 1: Handover decision and access point selection

1: Consider AP List of FAPs and D2D relays (MUEs or FUEs) in UEs location
2: Consider i the index of the user location in x and associated to an MBS; moving in a low speed horizontally
3: Compute the user SINR and Rate
4: if SINR or Rate ≤ threshold then trigger Handover
5: Obtain data from server:
   for each AP i in AP List (FAP or D2D relay UE) in location
   Obtain information of available AP i information
   if SINR i > SINRmin && Rate i > Rate min then,
   in qualified_AP_List add AP i
   Obtain other HO metrics (delay, jitter, BER)
   end if
   end for
6: Compute QoS score using Fuzzy logic for each AP in qualified_AP_List (if exist)
7: for each AP; in qualified_AP_List
    if QoS score of AP ≥ QoSmin then,
    in candidate_AP_List for the UE add AP i
    end if
   end for
8: if the number of candidates in the candidate_AP_List=0
   Block the UE
   Release resources
   Continue;
   end if
9: if the number of candidates in the candidate_AP_List ≥ 1
   Consider MOS, direction, battery
   Compute QoE score using TOPSIS for each AP in candidate_AP_List
   Consider the AP that has the highest score as the target_AP for the UE
   end if
10: Obtain target_AP resources (RBs) from the server
    Release resources if UE already connected
    Allocate a resource block
11: Compute SINR, throughput, blocking probability, etc.
users are blocked especially when the number of users increases. On the other hand, by introducing the D2D in our consideration, the blocking probability in the proposed scheme is reduced as more D2D candidates are available. Figure. 8 plots the user’s throughput over the whole area, where it shows that using the Fuzzy TOPSIS with D2D, an enhanced throughput could be achieved with less number of handovers because of the inclusion of more parameters (QoS and QoE) in the decision process and the availability of candidate networks with D2D relaying.

5 CONCLUSION

This paper proposed a Fuzzy TOPSIS network selection and handover process between MBS, FAPs, and D2D. The algorithm first preprocesses target selection based on SINR and Rate threshold. Only networks meeting the SINR and Rate threshold can enter into the Fuzzy logic decision phase. Then, Fuzzy logic ranks the available networks in terms of QoS. Finally, the UE makes a decision based on QoE score using TOPSIS and AHP weighting. Our main observation is that the proposed algorithm can select the best network with a noticeably reduced number of handovers while guaranteeing the required QoS and throughput. Moreover, network performance is improved with additional overlay tiers (D2D) as compared to the performance achieved with the Macro/Femto-only networks. Therefore, we expect that multiple tiers and intelligent network selection will be integrated into the future 5G HetNets.

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