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Research Article

# Ad Hoc Wireless Networks With QoS Guarntees For LTE Femtocell-Macrocell Networks

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**ABSTRACT**

LTE analysis is this thesis' goal. Femtocell Network Implementation Indoor data traffic is predicted to dominate future data traffic. Using macrocellular coverage in high-traffic areas is difficult and expensive. Femtocells, low-power cellular base stations, can improve coverage and data throughput. A connected femtocell-macrocell network improves coverage, QoS, cost, and energy efficiency. In an integrated network, the number of Femtocell Access Points (FAPs) and macrocell-femtocell interference must be considered to ensure service quality. Control transfer, interference management, and resource allocation affect service quality. A seamless transition between macrocell and femtocell networks ensures service quality. Due to their small size, femtocells may handover often. Thus, effective decision methods are needed for smooth macrocell-femtocell transitions. One handover selection technique for macrocells to femtocells and another for femtocells to macrocells is provided. These algorithms consider numerous parameters, including UE velocity and RSS strength. Boosting throughput and spectrum efficiency while lowering packet loss ratio, handover latency, and packet delay can improve quality of service. Several quality of service measures were used to evaluate the handover strategy. LTE-compatible MANETs are another option. MANET topology management and routing techniques were studied in this work. GPSR routing and Boos flock topology management were used to build the network. Simulations are done using MatLab's "MONSTeR" model. The model is built with MatLab LTE system tools. Anyone can use the model on GitHub. This power-saving approach also affects user QoE in throughput and retransmissions. By training, testing, and validating our models using the KDD Cup 2015 dataset, we may improve femtocell networks employing mobile ad hoc network communication. The data show that switching from "always-on" to "on-when-needed" may sustain QoE

## 1. INTRODUCTION

The development of mobile networks has made significant progress during the past four decades. The era of mobile networks started in 1980. The Advanced Mobile Phone System (AMPS) and the Nordic Mobile Telephony (NMT) were developed during that time, specifically as first-generation (1G) systems. Several analog technologies were specifically created for voice services. The shift from analogue to digital technology was facilitated by second-generation (2G) systems such as Code Division Multiple Access (CDMA) and the Global System for Mobile Communication (GSM), often referred to as Interim Standard 95 (IS-95). Data transfers were initially implemented by second-generation telecommunication systems, but with significant limitations. High-Speed Circuit Switched Data (HSCD) enabled the achievement of data-rates of 14.4 kbps per time-slot. Following the first 2G system, advancements such as GSM networks with EDGE and GPRS were introduced, enabling faster data transmission rates. They continued to focus only on pricing for text-based services.The International Telecommunication Union (ITU) has lately emphasized the importance of high-speed data transfers for future growth, as outlined in its Manifest International Mobile Telecommunications for the Year 2000 (IMT-2000). The IMT-2000 aims to establish standards for third-generation (3G) networks. The UMTS, also known as the Universal Mobile Telecommunication System, was developed in response to these requirements. Several novel Radio Access Technologies (RATs), such as W-CDMA and High Speed Packet Access (HSPA), also surfaced concurrently. These specific requirements

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placed on mobile networks are precisely within their intended capacity to manage. 3G mobile networks prioritize speed while transmitting data. The primary Standard Development Organizations (SDOs) responsible for overseeing the publication of specifications and the coordination of research initiatives are the Third Generation Partnership Project (3GPP) in the United States and 3GPP2 in Europe. Releases, also known as Rel., serve as the authorized means for disseminating the 3GPP's recommendations. Each release signifies a distinct stage of development, and with every new release, there is an enhancement to the current technology, regardless of its magnitude. [1] After the launch of 3G in 1999, the 3rd Generation Partnership Project (3GPP) implemented a new numerical system. As a result, the schema is still being utilized in the present day, and the second release was referred to as Rel. 4 [2]. Following the standardization of IP Multimedia Subsystem (IMS) in Rel. 5, the mobile network-core started to integrate with all-IP networks [3]. The IMS ensures uninterrupted support for end-user service delivery across various networks and devices [4]. The Rel. 8 introduces both the Long Term Evolution (LTE) standard for radio access and the Home Node B (HNB) concept for new type base stations. HeNB, an enhanced version of HomeEvolved Node B, was introduced in Release 9 specifically for LTE networks. The LATO and GATO algorithms can reduce core network traffic by up to 90% [6]. The establishment of the core network (CN) also commenced concurrently. System Architecture Evolution (SAE) is the designated term used by the 3rd Generation Partnership Project (3GPP).The Evolved Packet Core (EPC) is the primary element of the System Architecture Evolution (SAE), which streamlines the structure of a network. An all-IP CN with EPC enables the use of many access technologies [7]. UMTS is capable of supporting both packet-switched and circuit-switched networks, whereas EPC exclusively supports packet-switched networks. IMS is utilized by EPC to deliver circuit-switched services. Because the LTE access network operates on packets instead of circuit switching like previous systems, VoIP calls are necessary for voice services to be implemented. The outcome was the establishment of the VoLTE (Voice over LTE) standard. It allows for phone calls with the ability of transmitting video on LTE networks [8]. Another option for voice over LTE is Circuit Switched Fallback (CSFB). This implies that the User Equipment (UE) will be removed from LTE and will be compelled to revert to a 2G or 3G network that is capable of providing circuit switched services [9]. Another way for transmitting voice packets over LTE is VoWi-Fi, short for voice over Wi-Fi. VoWi-Fi has the advantage of providing voice services in areas where there is no cellular signal coverage. It is an unquestionably complementing choice to VoLTE [10]. Upgrades the LTE network to LTE Advanced (LTE-A). In 2009, the 3rd Generation Partnership Project (3GPP) officially presented Long-Term Evolution Advanced (LTE-A) to the International Telecommunication Union (ITU) as the 4th generation (4G) mobile system, since it fulfilled the criteria set by the International Mobile Telecommunication Advanced (IMT-Advanced) standard. LTE-A's capability to aggregate signals from many carriers enables an augmentation in the available capacity. Achieving a downlink speed of 1.5 Gbps is possible with a bandwidth of 100 MHz, as the standard requires a peak spectral efficiency of 15 bit/s/Hz. The femtocell idea is continuously growing, encompassing collaboration with Wi-Fi networks as well. Prominent enhancements include M2M communication, which expands on Multiple Input Multiple Output (MIMO) technologies, In-Device Co-Existence (IDC), Heterogeneous networks (HetNet), and Coordinated Multipoint (CoMP) broadcasts. LTE-A Pro refers to Release 13 and later versions [13]. In addition to additional LTE-A extensions, LTE Unlicensed (LTE-U) enables the aggregation of secondary carriers in unlicensed spectrum, representing a significant advancement in Release 13. The integration of LTE-U with Wi-Fi networks has the potential to significantly enhance the total capacity of the network and is a feasible technology for Device-to-Device (D2D) communication. LTE-A is capable of supporting mobile networks, and there are further 4G technologies available. Several competitors participated, with WiMax and Ultra Mobile Broadband being the most prominent. The IEEE 802.16 and 802.16e standards specify two types of WiMax: mobile and fixed. WiMax was standardized by the IEEE. Despite prior standardization efforts, mobile operators have chosen to stick with LTE for their radio access networks, disregarding WiMax Phase 2 which was a competing 4G technology. Similarly, UMB technology, which has been suggested by WiMax and 3GPP2 as a replacement for CDMA2000, might be classified in the same category. The UMB research, however, was disregarded in favor of LTE.

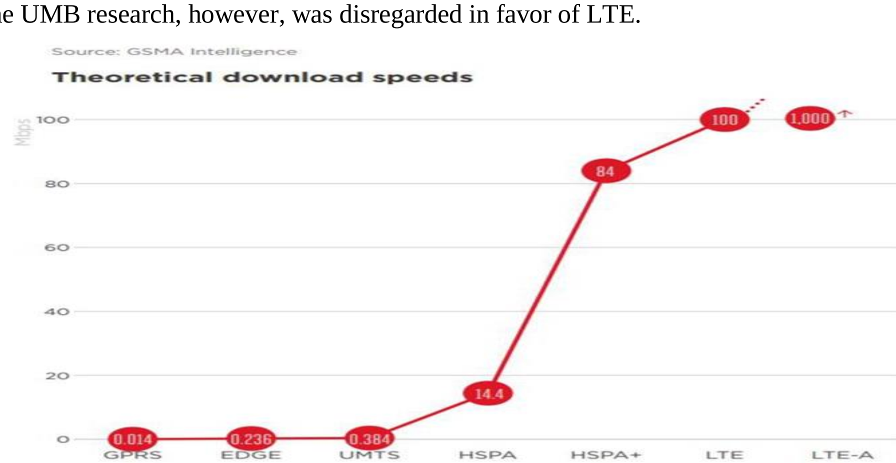


Fig. 1. Theoretical data-rates by different Radio Access Technology.[9]

### 1.2 Aim of Study

The objective of this article is to discuss the utilization of LTE Femtocell networks. Forecasts indicate that the majority of future data traffic will most likely come from indoor locations. Utilizing the existing macrocellular coverage in high-traffic scenarios is both costly and intricate. The objective of this thesis is to deploy LTE Femtocell networks. Forecasts indicate that a significant portion of future data traffic will most likely come from indoor areas. Utilizing the existing macrocellular coverage in high-traffic settings poses challenges and incurs significant costs. Another alternative for enhancing coverage while maintaining high data rates is the utilization of femtocells, which are cellular base stations with little power. The benefits of a coupled femtocell-macrocell network include enhanced coverage, improved Quality of Service (QoS), decreased expenditures, and energy conservation. MANETs, which stands for mobile ad hoc networks, might be beneficial in this scenario. For those who are now without electricity as a result of the tragedy, setting up a temporary wifi network presents an additional technical obstacle. The network will provide coverage to the affected areas, enabling individuals to connect wirelessly. Bandwidth and quality of service (QoS) may be ensured for phone, video, and text communications. The study primarily focuses on handover procedures in networks that have both integrated femtocells and macrocells. The suggested handover decision algorithm ensures a consistent quality of service (QoS) for the network. An efficiency comparison is conducted between the conventional system and the suggested system. My thesis primarily focuses on the detection and recognition of femtocells within wireless networks. Due to their status as the most advanced stage of development, LTE and LTE-A networks are the primary focus of my work. Alternatively, the physical radio access technology may utilize a portion of the discoveries autonomously. Another area that might benefit from these insights is the eventual implementation of 5G networks with ultra-dense networks. Cell densification is a key concept in 5G networks. In order to ascertain the need for a more intricate or uncomplicated approach, my research investigates the difficulties associated with PCI allocation and explores simpler alternatives. Moreover, it has the potential to serve as the foundation for similar issues in any networks that utilize tiny cells, not limited to just mobile networks.

## 2. METHODOLOGY

The objective of this research is to analyze issues related to automated PCI setting, such as collisions and confusion. As a result, I develop two topological models and evaluate their performance by simulating them in various scenarios presented in the chapter. The primary objective for femtocells positioned in close proximity inside a macrocell zone is to assess the probability characteristics and assign specific indicators to facilitate the allocation of PCI. All of them help the anticipated progression of mobile networks towards ultra-dense networks.A widely used method for simulation is referred to as network evolutionary growth. This implies that a fixed number of FAPs are augmented by an additional FAP. It is believed that a single macrocell encompasses all of these FAPs. It is hypothesized that the other cells are functioning and correctly set up, whereas the new FAP seems to be a recently activated cell.Since all deployed cells are assessed simultaneously for possible results, evolutionary progress is not limited to the specific situation. Although many FAPs are being supplied at the same time to enable self-configuration, none of the FAPs are active during the first setup phase of the deployment. Due to the simultaneous occurrence of several setup requests and the absence of neighbor ties, these approaches offer distinct perspectives on the problems.There are two distinct models available: the Dense Urban Model (DUM) and the Random Model (RANDM). Each macrocell has its own unique method for distributing FAPs. In order to provide a concise overview of all the simulations conducted, please take into account the following:

- Topology model (RANDM, DUM)
- FAP coverage distance (cell radius)
- Number of FAPs deployed inside macrocell

### 2.1 Adjacency

A femtocell topology may be represented as a graph $G(V, \text{D})$, where the FAPs are represented as vertices (V) and the connections between them are represented as edges (E). The determination of which edges connect any given pair of vertices (x and y, $(x, y) \epsilon V$) is based on the concept of adjacency, which varies depending on the model being used. In order to be classified as direct neighbors, one-hop neighbors, or first-level neighbors, FAPs must meet the requirements of the adjacency criterion. Regarding data packet forwarding, it may function as a reference point for the GPSR algorithm. As for topology maintenance, it can be utilized by the Boids-Flock algorithm. Subsequently, the Boids-Flock algorithm is utilized, incorporating three key parameters—separation, alignment, and cohesiveness—to ensure that the nodes remain linked and move harmoniously, hence preventing collisions. The GPSR position-based routing algorithm was chosen as the greedy forwarding option because of its effectiveness and simplicity. GPSR may utilize shortest pathways with restricted directional flooding, which results in little overhead.

Illustrated by the associations formed between the corresponding vertices in the network. A cluster of adjacent residents within close proximity, N1H(v), can be expressed as:

$$N_{1H}(v) = \{U: e_{uv} \in E\} \quad (1)$$

If an edge e links vertices u and v, then E represents the set of all possible edges described by the neighborhood relation function. Included are also the neighbors who, in my perspective, are neighbors of neighbors, occasionally referred to as second-level or two-hop neighbors. A FAP is considered a two-hop neighbor when it has a neighborhood relationship with both its one-hop neighbor and its direct neighbor, and when the one-hop neighbor also has a neighborhood relationship with the FAP. All nodes that are at a distance of two hops from node w , N2H(w), can be expressed as:

$$N_{2H}(w) = \{V: e_{uw} \in E \bigwedge e_{uv} \in E \bigwedge e_{vw} \in \emptyset\} \quad (2)$$

where euw and evw are edges that connect vertices u and w, respectively, and v and w, and E is the set of all possible edges formed according to the neighbourhood relation function. Figure 2 illustrates the visual representation of one-hop and two-hop neighbor notation. The three one-hop companions of the FAPA in the graphic are FAPAA, FAPAB, and FAPAC.

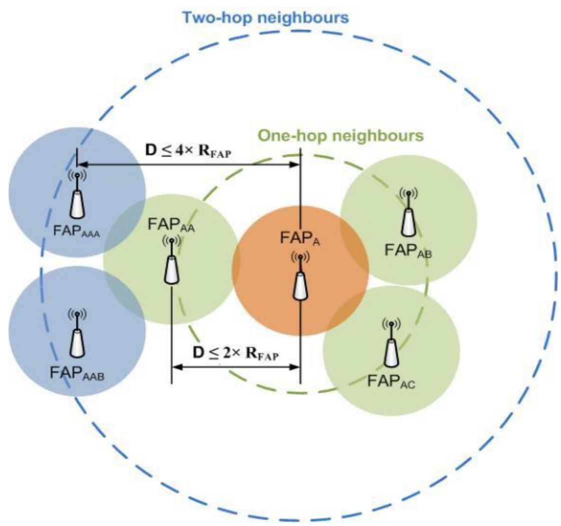


Fig. 2. One-hop and two-hop neighbors.[10]

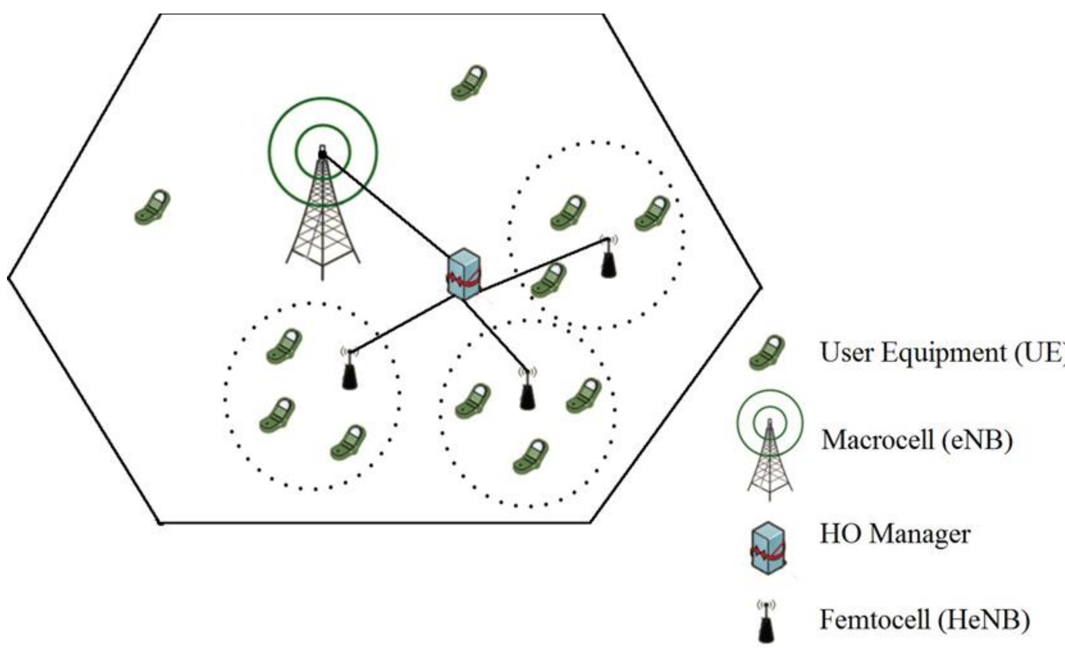


Fig. 3. Network Architecture [11]

## 2.2 Hardware and Software Requirements

The LTE-Sim network simulator is designed and operates seamlessly in a Linux environment.

## 2.3 Functional Requirements

The system is required to enhance QoS during handover in integrated Network

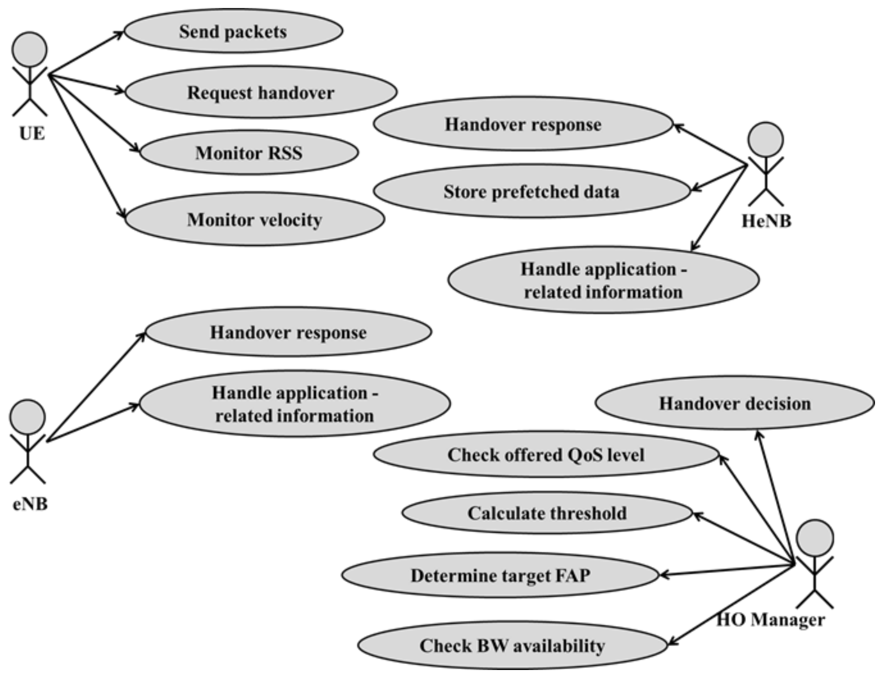


Fig. 4. Use case specification [12]

Figure 4 illustrates the functions performed by the different entities in the integrated

## 2.4 Non-Functional Requirements

The handover decision process is within the jurisdiction of the HO Manager's system. Determining appropriate the system managed by the HO Manager supervises the handoff decision procedure. In order to ensure successful handoffs, it is crucial to establish threshold values that consider the user's preferred service type and other quality of service parameters. Our motion prediction technique also aids in selecting the most advantageous target cell after the handover decision has been made.
Threshold values are determined based on the user's intended service type and the QoS parameters to ensure that QoS remains unaffected during handovers. In addition, we provide a motion prediction technique to assist in selecting the optimal target cell after making the handover choice.

## 2.5 System Design

The handover choice process is influenced by the system's functional and non-functional needs. The network architecture comprises user endpoints (UEs), femtocell access points (FEAPs), and macrocells. Femtocells cannot establish direct communication with the macrocell base station.

The speed and Received Signal Strength (RSS) of the UE are constantly checked. If a handover (HO) is required, the entity initiating the handover operation will get a HO-Required signal. If the user's device is already connected to the macrocell network, the signal will be transmitted to the macrocell base station.

The handover selection technique in Figure 5 considers the speed and received signal strength (RSS) of the UE.When the user equipment (UE) is connected to the macrocell network and the received signal strength (RSS) is decreasing, data is preloaded to nearby femtocells in order to minimize the time it takes to switch between cells. The threshold value is established by analyzing the service class and the application type.

During a handover or switch from a larger cell to a smaller cell, data is preloaded to each smaller cell located near the user endpoint (UE). The physical transfer of control occurs exclusively at the designated femtocell, whereas the preloading of data happens in the immediate vicinity of the user equipment (UE).

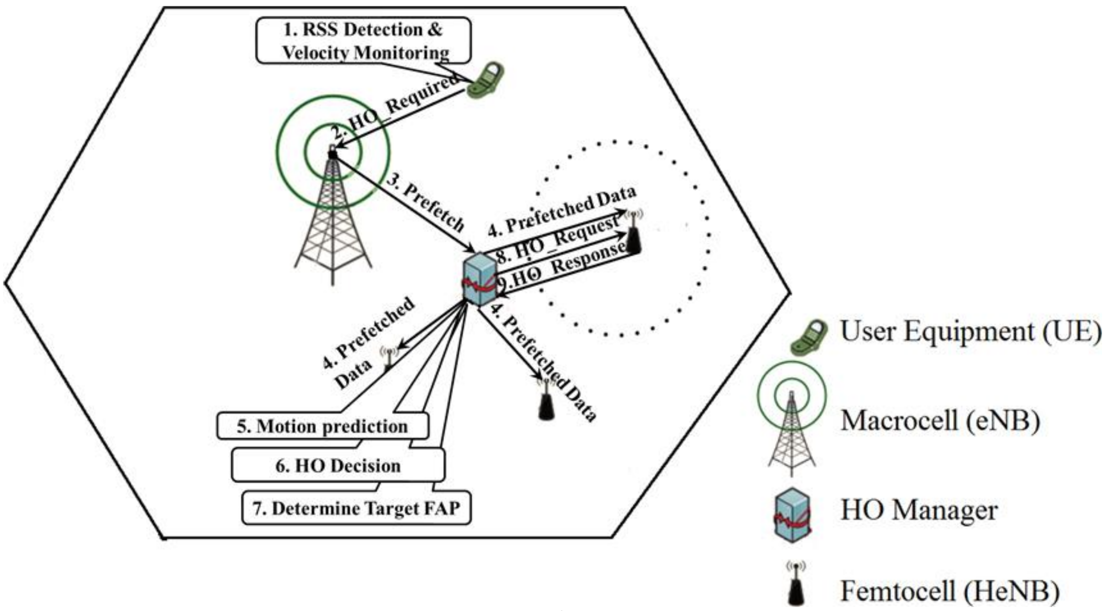


Fig. 5. Macrocell to femtocell handover [13]

To assess the need for a handover, the Received Signal Strength (RSS) and the velocity of the User Equipment (UE) are checked against predefined threshold levels. The threshold values are determined by considering the size of the femtocell, the typical pace at which the network performs handovers, and the anticipated value of the user equipment's time spent in the cell.
The hand-off process, known as femtocell to macrocell handover, starts when the UE transmits the HO-Required signal to the HO Manager, which then carries out the handover determination procedure. The User Equipment (UE) is handed over to the macrocell whenever its velocity falls below the preset threshold. Observe the dispersion mechanism depicted in Figure 6. To settle for a lower service class when there is little bandwidth available.

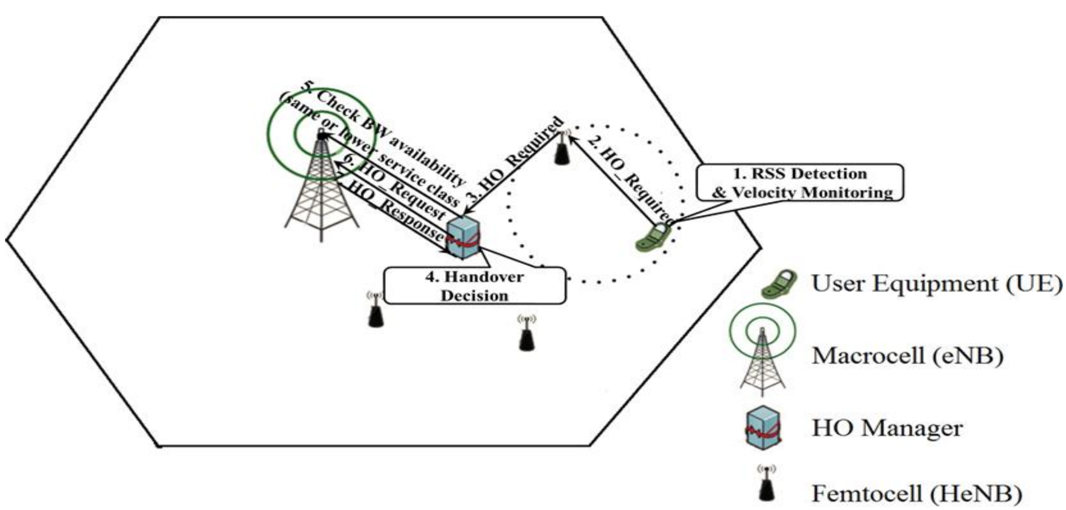


Fig. 6. Femtocell to macrocell handover [14]

## 3. RESULTS

In order to implement the suggested system, Matlab is employed. There is a single, predetermined number of macrocells in the scenario. There are a total of fifteen user endpoints (UEs) that are stationary within the macrocell. The quantity of user endpoints (UEs) within a femtocell is consistently 3. Furthermore, the applications currently running on each User Equipment (UE) are categorized as continuous bit rate (CBR), voice over internet protocol (VoIP), video, or best effort (BE). The distribution and speed of the UEs in the network are not fixed. The handover method is influenced by the distance between the User Equipment (UE) and the serving cell. To assess performance, the suggested system is compared to the conventional system in terms of efficiency. Analyzing the QoS parameters is facilitated by averaging the data received from 10 runs.

### 3.1. Experimental Setup

Their accuracy in measuring time using seconds and percentages is impeccable. The experiment is executed using Matlab R2019a for Windows on a system equipped with a 32 GB RAM and a 2.8 GHz Intel Core i9 CPU. Following extensive utilization of the Wireless Adhoc Network in several research endeavors, we have made the decision to make all of our data available on this platform. We improved our data collection by employing techniques derived from wireless ad hoc networks. A total of 13,583 records, which is equivalent to twenty percent of the full data, were utilized to carry out the test procedure. All tests were conducted on a system equipped with two 12-core AMD Magny Cours CPUs, fourteen Streaming Processors (each containing 32 cores), and an NVIDIA graphics processing unit (GPU).
The default simulation is based on a network topology that includes one macro eNB and four micro eNBs. A Manhattan grid layout provides a 500 m x 500 m area with buildings that vary in height from 20 to 50 meters. The user equipment (UE) is positioned 1.5 meters above the ground.Table 1 displays the setup of the eNB.

TABLE I. MONSTER ENB CONFIGURATION

| eNB type | $N_{TRX}$ | Hight[m] | BW [MHz] | Carrier Frq. [MHz] | $P_{max}$ [W] | $P_0$ [W] | $\Delta_p$ | $P_{sleep}$ [W] |
|---|---|---|---|---|---|---|---|---|
| **Macro** | 1 | 35 | 10 (UL/DL) | 1747.5 (UL)<br>1842.5 (DL) | 20 | 130 | 4.7 | 75 |
| **Micro** | 4 | 25 | 5 (UL/DL) | - \|\| - | 6.3 | 56 | 2.6 | 39 |
| **Pico** | 2 | 5 | 1.4 (UL/DL) | - \|\| - | 0.13 | 6.8 | 4.0 | 4.3 |

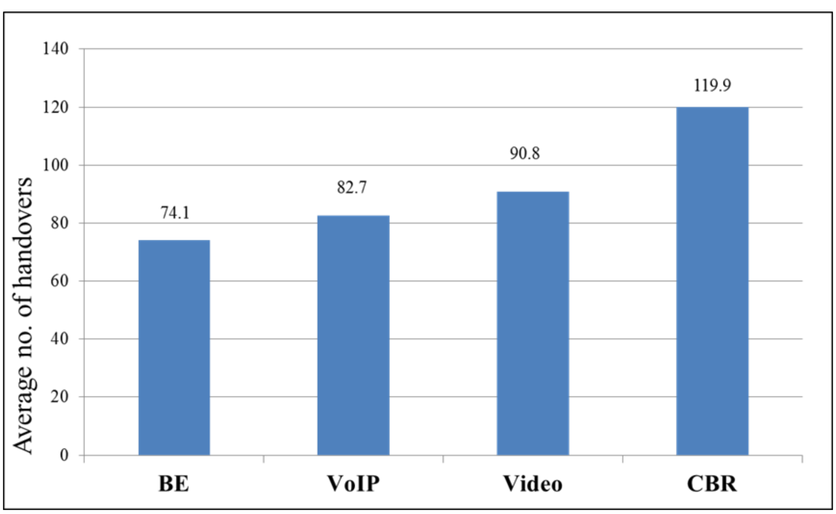


Fig. 7. Average Number of Handovers for each Application[17]

We evaluate the performance of suggested and traditional handover strategies in terms of packet delays across several application types. By eliminating unnecessary handoffs, the need for packet retransmission is removed as the likelihood of packet loss decreases. The outcome is a decrease in the time it takes for packets to be delivered.

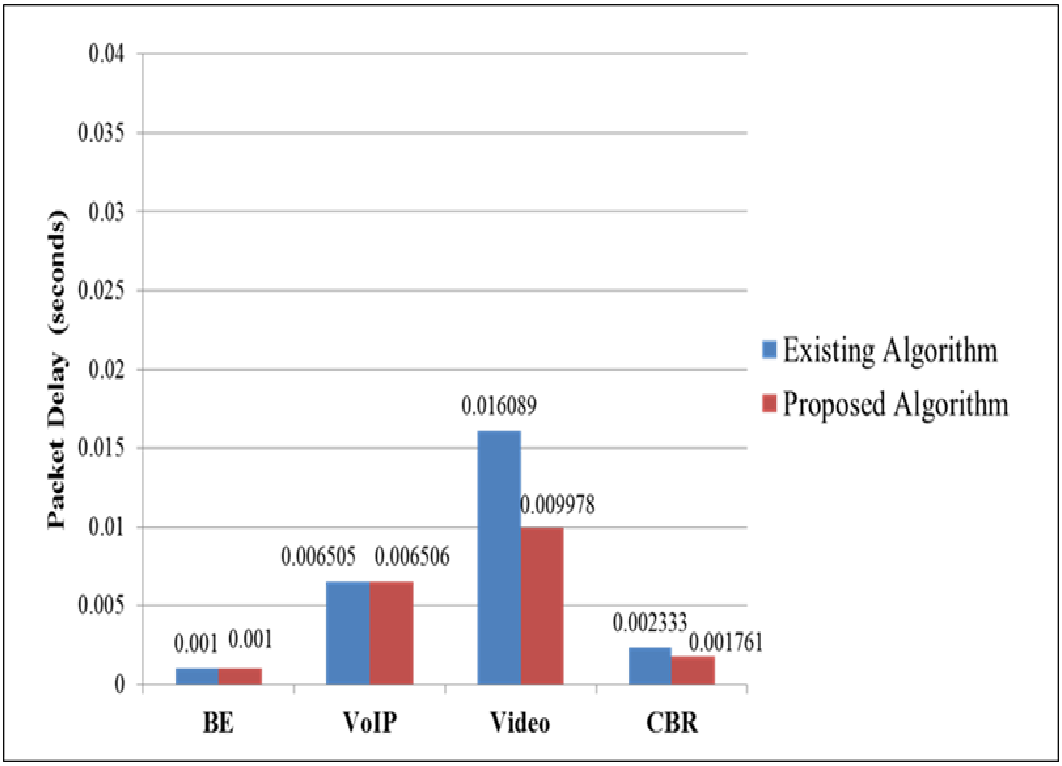


Fig. 8. Packet Delay for each Application[18]

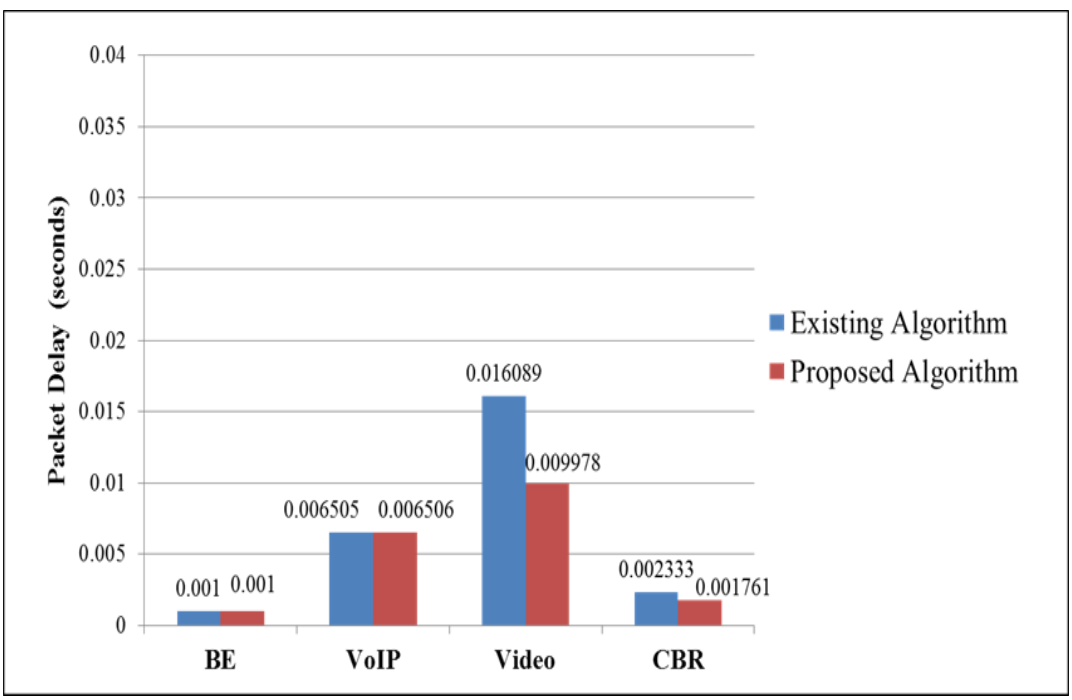


Fig. 9. Packet Delay for each Application[19]

Figure 10 demonstrates that the spectral efficiency of the integrated network rises proportionally with the number of femtocells. Increased femtocell density and reduced user density per cell lead to improved spectral efficiency. The suggested method's effective management of hand-in and hand-out directly leads to enhanced spectrum utilization.

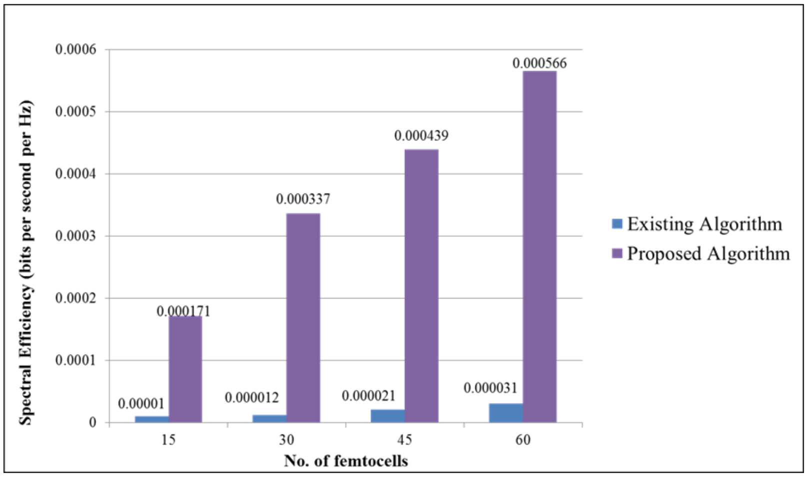


Fig. 10. Spectral Efficiency for each Application[20]

## 4. CONCLUSION

This study introduces the utilization of LTE femtocell networks to enable Ad hoc wireless networks. MANETs are crucial in facilitating long-distance communication. For the MANET to fulfill its objective, it is imperative that each node have the ability to communicate effectively and function independently within the network's framework. The suggested technique aims to enhance the performance of integrated femtocell-macrocell networks by prioritizing Quality of Service (QoS) during changeover. The switching between the femtocell and macrocell networks is determined by the signal strength of the user equipment (UE), the velocity of the UE, and the required quality of service for the current application. To alleviate the load on the macrocell, it is advantageous to evenly distribute the mobile devices throughout both the femtocell and macrocell networks.This document is a concise summary of the extensive assessment and analysis conducted to evaluate the performance of the system. The suggested handover selection method improves the rate of data transfer and the efficiency of using available frequencies. While the packet latency remains same, there has been a substantial reduction in the packet loss ratio. The handover decision algorithm takes into account quality of service (QoS) characteristics such as handover delay and cell usage. A threshold value is established to indicate the precise moment when a handover must be carried out. Traditional handoff techniques in integrated environments sometimes result in several unneeded handoffs. The ping-pong effect occurs due to the extremely tiny dimensions of femtocells. The network was constructed using a mix of the GPSR for routing and the Boos flock for topology management. The KDD Cup 2015 dataset is used for the purposes of training, testing, and validation. The MatLab model "MONSTeR" is utilized for constructing the simulations. The model is constructed using the MatLab LTE system toolkit. The model is available to everyone on GitHub. Moreover, the impact of this power-saving technique on user quality of experience (QoE) in terms of throughput and retransmissions. With the use of technology advancements and Mobile Ad-hoc Network connection, we may contribute to the progress of femtocell networks. Based on the findings, it is feasible to transition from the traditional "always-on" approach to a "on-when-needed" model without sacrificing the quality of the user's experience. The suggested method prevents superfluous handovers between femtocells. The transmission of data from the current serving cell to the destination cell after the decision to handover takes a very long period. The suggested solution minimizes this latency by pre-fetching the data before initiating the handover.The suggested methodologies are implemented to enhance the performance of integrated femtocell-macrocell networks, by considering a wide range of quality of service factors.

## 5. FUTURE RECOMMENDATION

Additional quality of service elements, such as jitter, location update cost, allocation priority, and retention priority, can be used to improve the handover mechanism. In order to simulate UE movement, it is possible to create models for various forms of traffic. As an illustration, the node is restricted to moving solely along roadways within MANeTs because of the constraints imposed by the simulator. Thus, a simulator designed specifically for MANETs or drones would have the capability for mobility. Subsequent efforts on this project might entail implementing it in more practical situations, such as a simulation of a major European metropolis, in order to assess the performance features of its deployment and assign specific values to key indicators. In order to conduct this type of evaluation, it is necessary to have uniform criteria, as the precise values of the indicators are depending on the technology being used. By employing the techniques described in Chapter 2.4 and having access to the indicator data from the research mentioned in the previous paragraph, it would be feasible to fully simulate the automated PCI assignment procedure. When transitioning between suboptimal choices, this would enable the evaluation of overall effectiveness. It is impractical to proceed with this task until the aforementioned.

## Conflicts Of Interest

No competing relationships or interests that could be perceived as influencing the research are reported in the paper.

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