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Mobility management in 5G heterogeneous networks

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USE OF THESIS

Abstract

In recent years, mobile data traffic has increased exponentially as a result of widespread popularity and uptake of portable devices, such as smartphones, tablets and laptops. This growth has placed enormous stress on network service providers who are committed to offering the best quality of service to consumer groups. Consequently, telecommunication engineers are investigating innovative solutions to accommodate the additional load offered by growing numbers of mobile users.

The fifth generation (5G) of wireless communication standard is expected to provide numerous innovative solutions to meet the growing demand of consumer groups. Accordingly the ultimate goal is to achieve several key technological milestones including up to 1000 times higher wireless area capacity and a significant cut in power consumption.

Massive deployment of small cells is likely to be a key innovation in 5G, which enables frequent frequency reuse and higher data rates. Small cells, however, present a major challenge for nodes moving at vehicular speeds. This is because the smaller coverage areas of small cells result in frequent handover, which leads to lower throughput and longer delay.

In this thesis, a new mobility management technique is introduced that reduces the number of handovers in a 5G heterogeneous network. This research also investigates techniques to accommodate low latency applications in nodes moving at vehicular speeds.

Declaration

I hereby declare that the project does not:

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(iii) Include material without acknowledging the actual authors.

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Date: 20/03/2019

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List of Publications

List of submitted and unpublished manuscript from this research:

1. M. A. R. Khan, I. Ahmad and D. Habibi, “A New Handover Management Scheme for 5G Heterogeneous Networks,” Revised manuscript under second round of review (Editor has requested for revisions following the first round of review), Computer Communications, Elsevier Science. .
2. M. A. R. Khan, I. Ahmad and D. Habibi, “Reducing Delay for Delay Sensitive Application Vehicular Communications” Manuscript in preparation for a journal publication.

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Abbreviations

1G = First Generation

2G = Second Generation

3G = Third Generation

4G = Fourth Generation

5G = Fifth Generation

3GPP = Third Generation Partnership Project

AAA proxy = Authentication, Authorization, and Accounting proxy

AHP = Analytic Hierarchy Process

ANN = Artificial Neural Networks

AP = Access Point

BE = Best Effort

BS = Base Station

CBD = Central Business District

CBR = Constant Bit Rate

CCDF = Complementary Cumulative Distribution Function

CIS = Context-aware Information Server

DoS = Denial of Service

DSL = Digital Subscriber Line

EIS = Enhanced Information Server

FBMIS = Fuzzy-Based Multi-Interface System

FDMA = Frequency Division Multiple Access

FLC = Fuzzy Logic Controller

GSM = Global System for Mobile Communications

GVLL = Generic Virtual Link Layer

HetNet = Heterogeneous Network

HHO = Hard Hand-Over

HO = Handover

I2V = Infrastructure-to-vehicle

ICT = Information and Communication Technology

IEEE = Institute of Electric and Electronics Engineers

IMT-2000 = International Mobile Telecommunication 2000

IINR = Interference to other-Interferences-plus-Noise Ratio

IT = Information Technology

LMA = Local Mobility Anchor

LTE = Long-Term Evolution

LTE-A = Long Term Evolution-Advanced

MAC = Media Access Control

MADM = Multi-Attribute Decision-Making

MANET = Mobile Ad-hoc NETwork

MBS = Mobile Base Station

METIS = Mobile and wireless communications Enables for Twenty-twenty information Society

MIH = Media Independent Handover

MIP = Mobile Internet Protocol

MM = Mobility Management

MN = Mobile Node

mBS = microcell Base Station

PDC = Personal Digital Cellular System

PPP = Public Private Partnership

QoS = Quality of Service

RSS = Received Signal Strength

RSSI = Received Signal Strength Indicator

SC = Small-Cell

SDN = Software-Defined Networking

SCNs = Small Cell Networks

SHO = Soft Handover

SINR = Signal to interference Noise Ratio

SIP = Session Initiation Protocol

ToS = Time of Stay

UE = User Equipment

UMTS = Universal Mobile Telecommunications Service

URS = User Request Security

V2V = Vehicle-to-Vehicle communication

VBR = Variable Bit Rate

VHD = Vertical Handover Decision

VHO = Vertical Handover

WLAN = Wireless Local Area Network

WiMAX = Worldwide Interoperability for Microwave Access

List of Symbols

ξ	The set of microcell
P_M	Macrocell transmission Power
P_m	Microcell transmission Power
UE	User Equipment
ψ	Categories of UE
V	The set of the vehicle user
U	The set of the pedestrian user
F	The set of the fixed user
D	Total user Demand
α_M	Path loss component for the Macrocell
α_m	Path loss component for the microcell
C	The Coverage probability
n_m	Number of deployed microcell
P_t	Total power consumption
γ	The average association preference
N_v	Total number of vehicle user
N_u	Total number of pedestrian user
N_f	Total number of fixed user
B_M	Bandwidth for the Macrocell
SE_M	Spectral efficiency for the Macrocell
B_m	Bandwidth for the microcell
SE_m	Spectral efficiency for the microcell

Φ	The handover cost
S	Speed for the high mobility user
T_M	The throughput of macrocell users
A_m	The probability of being served by mBSs
Γ	Distance
L	Latency
B_l	Bandwidth of the link
ς	Packet delivery ratio

Chapter 1

1 Introduction

Information and communication technology (ICT) has become a major industry that plays a transformational role across various economic sectors including business and service delivery. Wireless communication is one of the most successful technologies in the field of Information and Communication Technology (ICT) with its penetration rate reaching over 90%. In developed countries, the share of the population using wireless technologies such as smartphones has increased threefold in the last five years. This share is expected to continue to increase in the near future.

In recent years, there has been a significant increase in the usage of mobile communication systems for data transfer, generally using web-based data or multimedia data. This expansion is related to the increase in the number of cellular devices, particularly smartphones, and tablets, and a rise in the number of web-based services, for instance, video streaming and cloud computing. According to a recent Cisco report [1], mobile data usage is expected to increase exponentially in coming years, and the most notable applications, including video applications, web applications, and social networking applications, will require more data at a much lower latency.

Such an increase in demand (Figure 1.1) presents some major technological challenges for network service providers. Some of these challenges include spectrum shortage, increase in energy demand and energy related cost, delay consideration for low latency applications, and network security naturally, the expectation from the next generation of wireless communication systems is very high. The fifth generation (5G) infrastructure public private partnership (5G-PPP) working group has been working very hard to address the challenges and the 5G system is expected to include some major technological innovations.

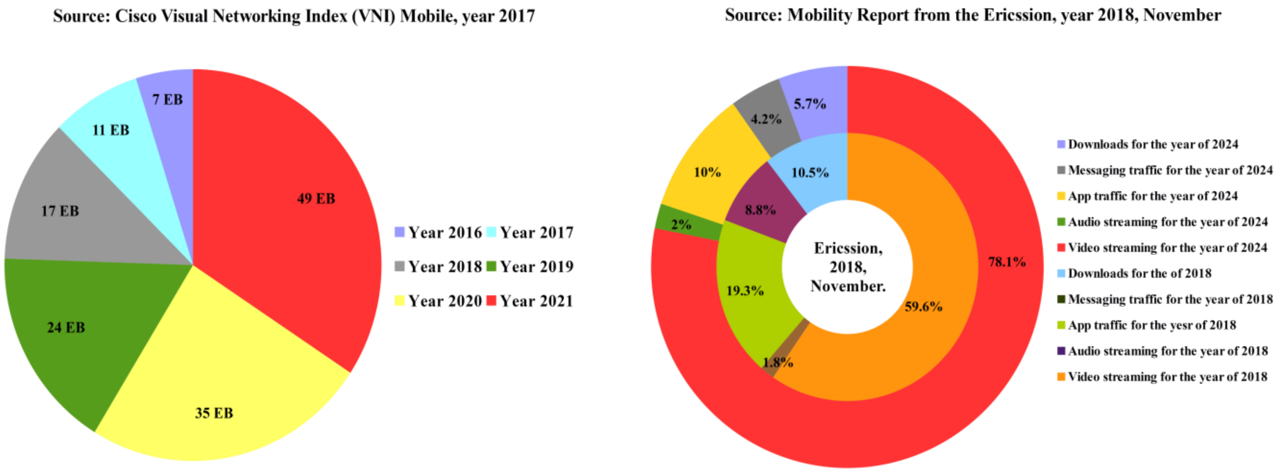

Figure 1.1: (a) The demand for mobile data traffic by the year of 2021, (b) Evolution of the average smartphone user's data consumption for the year of 2018 and 2024.

The 5G-PPP has the technical vision to provide improved wireless zone capacity and diverse service abilities. The 5G-PPP also aims to save up to 90% of energy per service provided, and provide a secure, reliable and low latency connection [2]. In order to achieve the goals, researchers have targeted some specific areas of wireless communications including the dense deployment of small cells, multiple input multiple output (MIMO) antenna technology, mmWave and free space optics technology, modulation techniques etc.

The concept of small cells is likely to be a major enabling technology in 5G (Figure 1.2) [3]-[5]. The key idea behind small cells is to use cells with a much smaller coverage area than a traditional macrocell and, where possible, to backhaul the local data using high capacity wired links such as optical fiber. This enables high frequency reuse per unit area [6], [7].

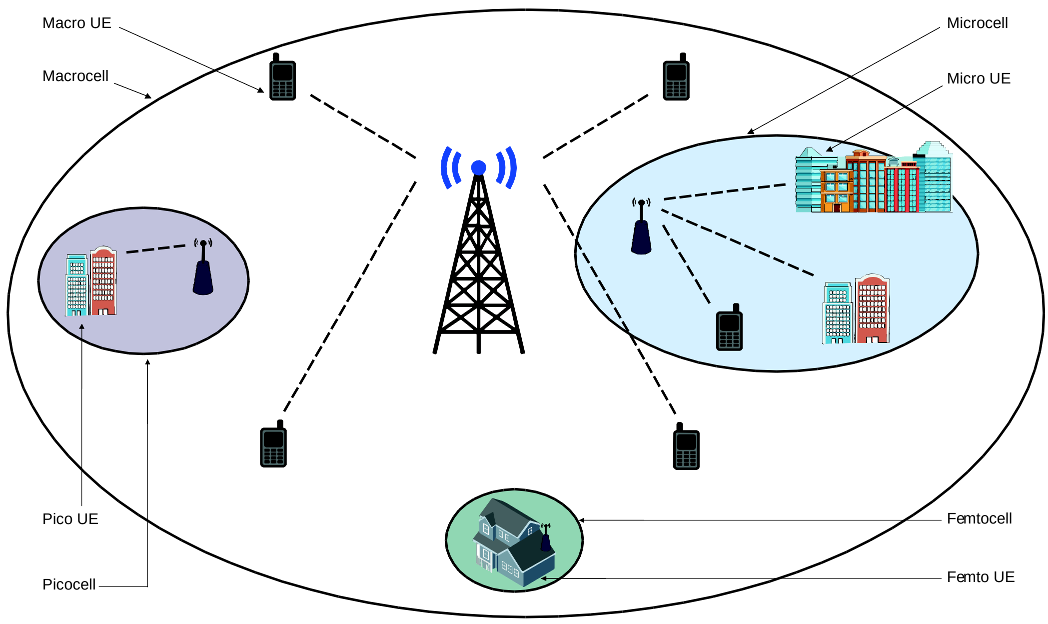

Figure 1.2: Small cells in next generation networks.

The concept of small cells, however, presents a major challenge for mobile nodes as the coverage area per small cell is much smaller than the coverage area of a macrocell. Small cells would cause frequent handovers and connection drop-outs [8], [9] if resources are not carefully managed. This problem is further aggravated by the fact that vehicular communication (e.g., between roadside units and vehicles) is predicted to become increasingly popular in the next few years because of the increasing popularity of automated cars, augmented dashboards, and other safety-critical applications [10] - [12].

Vehicular applications are often time critical and demand very low latency. Current wireless technologies are not equipped to meet such demands. As a result, network service providers expect a lot from the 5G standard to facilitate vehicular communication services. In this thesis, the frequent handover problem in a 5G heterogeneous network is investigated, and two promising solutions are presented in Chapter 3 and 4 to address the challenges arising from the densification of cells.

1.1 Significance and Motivation

The technical vision of 5G is significantly different from the technical vision of the fourth generation (4G) of communication systems. The main driving force comes from the exponential increase in the number of portable devices and the new applications demanding higher bandwidth [13].

Apart from the raw speed, 5G aims to include benefits such as low latency and high capacity. Furthermore, it is anticipated that 5G will facilitate dense employment of wireless communication links, which will help connect more than seven trillion wireless devices used by more than seven billion people. A significant portion of these user groups will be using portable devices to connect to the core network, and users may want to access the network even when they are on the move. As a result, mobility management would become more challenging than ever before.

Due to the advancement in technologies such as autonomous cars, augmented dashboards, roadside safety equipment, and emergency applications, vehicular communication is expected to be a major part of 5G systems.

While the dense deployment of small cells provides numerous advantages, small cell networks offer some major challenges [8], [14]-[16] for vehicular communications. When nodes travel at high speeds and the area covered by a base station becomes smaller (i.e., small cells), frequent handover would be needed to maintain reliable connections in vehicular nodes. In literature, researchers have highlighted the importance of the problem and discussed the significance of possible solutions. This provides the motivation for this research work in which we investigate and present solutions to the frequent handover problem.

1.2 Aims

The aims of this research include:

[1] developing resource management techniques to reduce handover rates in 5G heterogeneous networks. As mentioned earlier, the deployment of small cells will significantly increase the number of handover per unit area. The first objective of this thesis is to present a resource management technique that reduces the total number of handover in a 5G network.

[2] developing solutions to improve latency in vehicular communications. Latency is a major issue for vehicular communications in 5G heterogeneous systems that are likely to support real-time high-speed emergency applications for the high speed movement of emergency mobile user (such as ambulance, police car, fire-service). The second key goal of this thesis is to introduce a new solution to improve the latency.

1.3 Research Contributions

In this thesis, we present our proposed models and solutions to address the high handover and latency challenge in 5G networks. In Chapter 3, we present a mechanism to allocate resources among vehicular, nomadic and fixed users in a heterogeneous network so that the handover cost and the power consumption can be minimised. We introduce a new term in the form of association preference factor, which is considered as one of the two objectives in the optimisation model. The other objective keeps the power consumption low, meaning less carbon footprint and reduced energy bill for the network provider. Simulation results suggest that the proposed solution significantly outperforms existing solutions. In a bid to find a robust solution, we also introduce a heuristic solution, which performs reasonably well compared to the optimum solution.

The second contribution of this thesis in presented in Chapter 4. We address the low latency challenge for the emergency vehicular communications in 5G heterogeneous networks. Simulation outputs confirm that the proposed solution reduces latency and increase throughput in emergency vehicular nodes.

1.4 Organization of Thesis

The remainder of this thesis is structured as follows:

(i) Chapter 2 presents the technical background of 5G heterogeneous networks. This chapter also presents the background of vehicular communications. Relevant existing work available in the literature are presented followed their advantages and shortcomings. The research gap is then identified and highlighted.

(ii) Chapter 3 presents the problem formulation and solution to the frequent handover problem in 5G networks. Numerical results are then discussed in Section 3.5.

(iii) Chapter 4 presents the problem formulation and solution to the latency problem, which is critical for emergency vehicular communications.

(iv) Finally, Chapter 5 summarises and concludes the contributions and significance of this research Suggestions for further research are also recommended in this chapter.

Chapter 2

Background and Literature Review

2.1 Background

Each decade has been characterized by developmental changes in mobile communications. The original generation (e.g., 1G) at the 1970s and second generation (2G) cell frameworks during the 1980s were utilized for the most part for voice applications and to help circuit-exchanged administrations.

The 1G framework relied on simple innovations; whereas 2G introduced more advanced frameworks, for example, the Global System for Mobile Communications (GSM), IS54 Digital Cellular, Personal Digital Cellular System (PDC), and IS-95 [17]. These frameworks existed across many countries for a reasonable period of time. Data rates for clients in these frameworks were restricted to approximately a few several kilobits for every second.

International Mobile Telecommunications 2000 (IMT-2000), which was introduced at the start of the 21st century, signalled the third generation (3G) cell framework [18], providing up to 2 Mb/s and 144 kbps in indoor and vehicular conditions, respectively. Nonetheless, even 3G infrastructure lacked the capacity to handle modern mobile working needs. The shortcomings of 3G were compensated for with the development of 4G systems. The infrastructure of 4G systems facilitated higher data support, and new data services. However, irrespective of these advancements, 4G could not met the increasing demands for spectrum as well as the associated energy consumption from current technologies. Naturally, a lot is expected from the 5G communication systems.

2.1.1 Emerging communication technology - 5G

With respect to increasing technological requirements, upcoming 5G wireless communication technology provides an integrated system that consolidated the current mobile communication systems, like LTE-A and Wi-Fi, within under a new air interface [19]. In this regard, a new framework is required to connect an ever expanding array of system devices that require very high traffic rates. As a result, Mobile and wireless communications Enablers for Twenty-twenty Information Society (METIS) has identified association of current 4G frameworks with the fundamental aspirations of the 5G systems [20], [21]. The significant aspects are,

i) that 5G will facilitate an increase in the volume per unit area by a thousand times as compared to 4G.

ii) higher rate of the accessibility of user data by ten to hundred times.

iii) an increase in the number of connected devices by ten to hundred times.

iv) improved battery life of low-powered devices by ten times.

v) reduced E2E latency "End-to-End" by five times, resulting in the attainment of 5ms with respect to the applications of road safety.

In addition to this, the system stability in terms of cost effectiveness, coverage area, and energy efficiency would also be achieved. It is clearly evident that the targets are ambitious, which requires a number of key innovations in 5G. One such innovation is the heterogeneous network, which is described in the following section.

2.1.2 Heterogeneous Network and Small cells

A heterogeneous 5G network incorporates two different kinds of cells namely macrocells and small cells. The primary operation of heterogeneous networks is that numerous smaller cells operate under the umbrella of macrocells to increase the coverage, promote frequency reuse, and enhance the ability to support high traffic rates for all areas [6], [22].

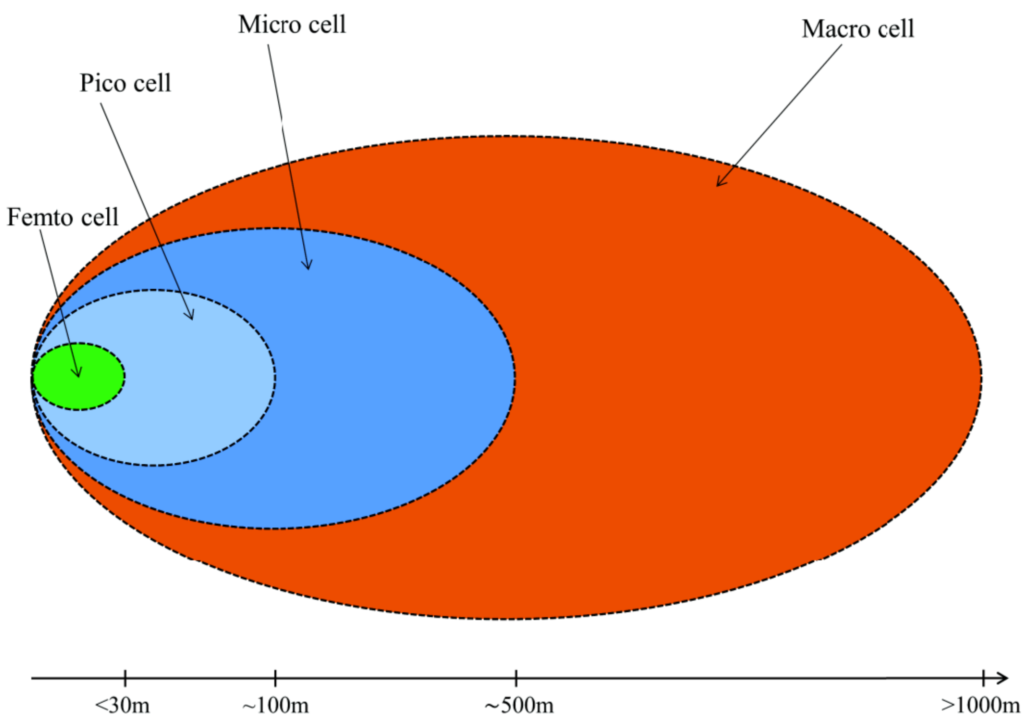

Figure 2.1: Difference types of small cells in an urban area.

Small cells are classified into microcells, picocells, and femtocells. The important features of macrocell and small cells for heterogeneous networks are as follows:

(a) Macrocell

The cell diameter for a macrocell may range from 1 km (about) within the city to more than 40 km within a non-urban environment. The base station of a macrocell requires the installation of powerful antennas on the top of a tall building or a tower at a height of at least 30 m or more. With respect to the transmission power of the antennas, the value also can be set by 46dBm [23]. Moreover, the transceiver equipment of the base station is located within the same tower or the building, maintaining the temperature of the surrounding area. More precisely, even these transceiver devices are placed in the proximity of the antennas based on the reduced sizes as a result of the recent advancements.

In broadband wireless communication systems, a macrocell is regarded as the first element f used for facilitation, and blanket coverage of an inhabited area. As a result, macrocells serve two main objectives with the capability of blanket coverage whilst minimizing initial cost. Moreover, growth aspects of the network with respect to the inclusion of traffic and subscribers are also facilitated. Consequently, the radius of the macrocell is dependent on the following factors,

(i) Peak time facilitation regarding the management of the amount of the anticipated traffic.
(ii) Maximization of the coverage distance.

Peak time facilitation of traffic is associated with the anticipated density of the subscriber, where increasing subscribers require enhanced traffic capacity. Accordingly, the service capacity of each base station is limited to facilitating a set number of users at a particular time. In addition to this, the macrocell coverage area can be small for a densely inhabited area. With respect to the relatively small population density of rural and suburban areas, base stations are capable of facilitating the coverage of a larger area. Therefore, the range of the cell radius entails several “kilometres” for suburban areas, several “hundred meters” for densely populated urban areas, and several “tens of kilometres” for rural areas.

(b) Microcell

Compared to the macrocell, a microcell is smaller and possesses considerable differences in terms of requiring a smaller antenna with reduced power and power settings for transmission. These cells typically provide coverages up to 500 m [24] and can be deployed indoors or outside to fill gaps in terms of both capacity and coverage. For instance, developed urban areas often/may encounter problems of congestion in terms of weakened signals. Moreover, microcell system designs could also be used in highly dense areas such as stadiums or concert arenas, for increasing the capacity of the system [24], [25].

The base station of a microcell is generally directly interconnected with the central network. This connection is established using the link of an optical fibre. However, at certain times, increased traffic is routed by means of the base station of a macrocell, using a point-to-point wireless (Figure. 2.2). Microcells are classified into the following three types,

i) Hot Spots: These include poorly covered or areas with intense density of tele-traffic. The hot spot provides the service by means of being embedded in the larger cells’ cluster in an isolated manner.

ii) Downturn Clustered Microcells: Contiguous and dense areas, providing service to mobiles and pedestrians, are served by these microcells [24]. The coverage networks of urban areas of street canyons are served by these microcells with antennas located below the height of the building.

iii) In-Building 3D Cells: These cells are positioned to serve the requirements of pedestrians and office buildings. These cells are intended to eradicate the concerns of clutter dominance of these highly dense areas in terms of slow movement of the users. Thus, the consumption of power of portable units is also a strong concern that is managed by these cells.

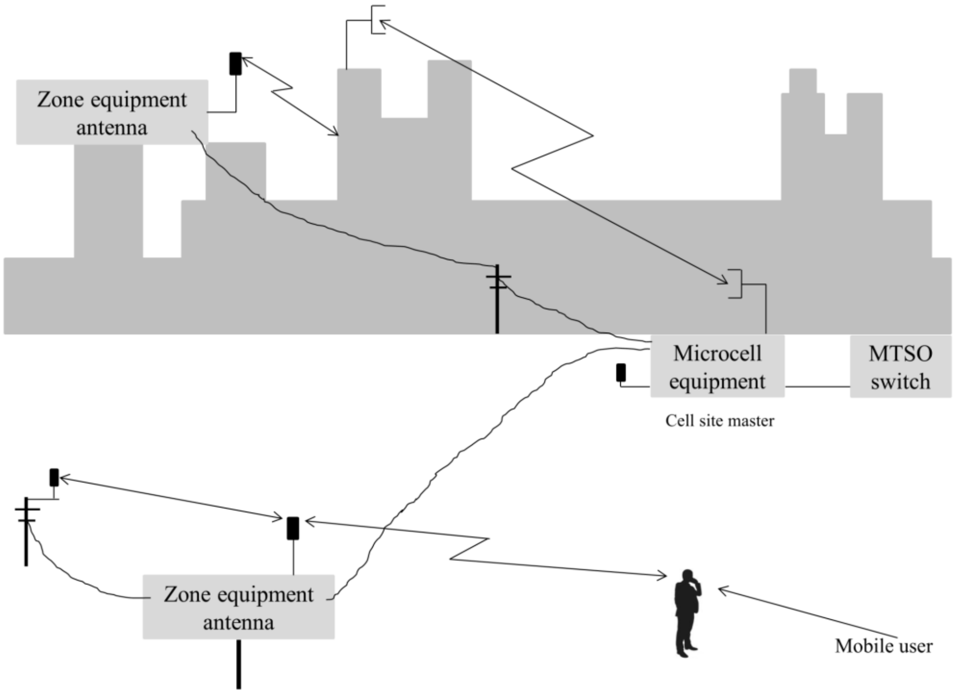

Figure 2.2: Microcell Installation concept.

(c) Picocell

A picocell serves as a wireless base station that is designed with very low power output for coverage of a very small area, like a single floor of an office building [26]. The cellular network of picocells tends provide of coverage extensions for indoor areas that face weakened receiving of the signals. Moreover, network capacity is also increased in the areas with dense usage of phones, like airports, train stations or the shopping malls. With respect to the effectiveness of picocells, extensive research has been carried out for enhancing their cost-related and coverage-related performance in serving unapproachable places in the world.

The following are applications of picocells:

(i) Coverage improvement of in-building: In-building coverage is improved mainly caused by the use of innovative techniques of construction along with special materials. Thus, picocells facilitate the coverage in such environments, including visitor centres, train stations, airports, museums and others along with the enhancement of network capacity.

(ii) Filling of Black-spots within the network: Non-existent or minimal coverage creates black spots on the network. The areas of the buildings with marginal coverage encounter sharp drifts in service quality resulting in “network busy” signals, dropped calls, distorted voice signals, and even slower data rates.

(iii) Extension of the capability of macrocells: It has been a global telecommunication challenge to facilitate the capacity availability in the peak hours to the users of highly populated areas. In this regard, operators have been modifying networks through bandwidth-intensive undertakings. Although the intended objectives are attainable through the deployment of macrocells, it would be cost-consuming. Thus, picocells are used as these cells maximize the re-use of the spectrum along with providing enhanced network capacity.

(iv) Applications associated with Satellites: Picocell can provide remote network to confined zones like provincial spots, marine, oil and gas organization, etc. where there is no broadband availability for backhaul. In these conditions, picocell is a feasible arrangement possessing satellite correspondences for backhaul.

(d) Femtocell

Femtocells are smaller in coverage size and transmit power compared to picocells, microcells, and macrocells. Femtocells can be used in a home or small office buildings. The transmit power of femtocells is often less than 100 mw [27]. Normally it can be seen that [28] the coverage range of femtocells is less than 30 meters. Through Ethernet, femtocells are capable of using the cable modem or even a DSL (digital subscriber line) for backhauling data and voice calls within the range of the operator's network and the internet connection of the consumer [29]. Hence, the mobile network of the operator is extended by means of using the internet connection of the consumer.

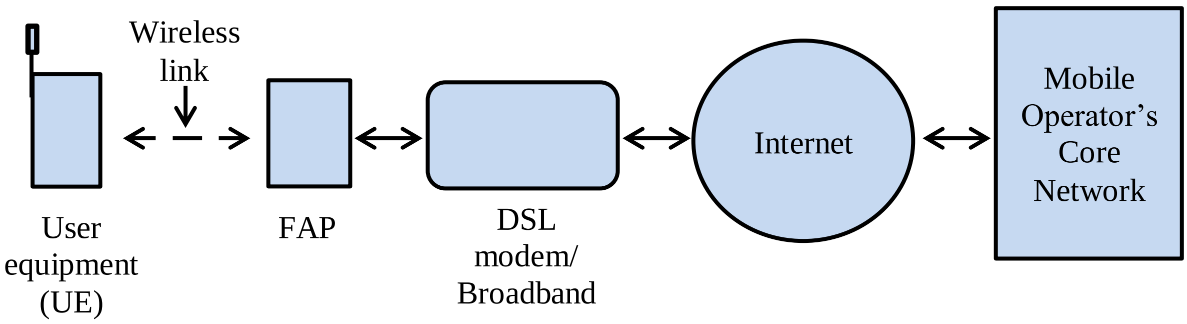

Figure 2.3: User Equipment (UE) linked to an operator's central system in a femtocell.

2.1.3 Vehicular communication, types, and future applications

Vehicular communication is becoming increasingly popular. Digitization of products and services used in automobiles is playing a key role for the popularity of vehicular communications. Vehicular communications can be categorised into five broad classes [10], [30]:

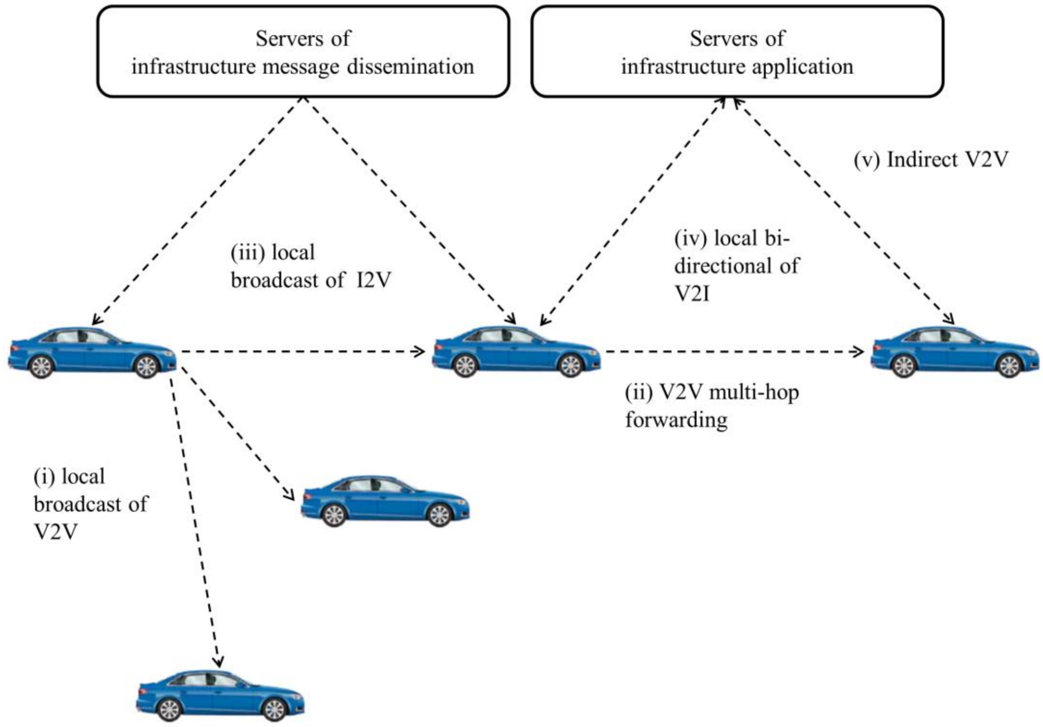

Figure 2.4: Explain the modes of Vehicular Communication.

i) Vehicle to vehicle communications: With the help of vehicle-to-vehicle (V2V) local broadcast, a vehicle can propel information or a message to other vehicles which are in range of their communication system. As the example suggests, V2V local broadcast can inform neighbouring vehicles of speed, heading and current position.

ii) Multi-hop V2V: The multi-hop dissemination of V2V enables the transmission of messages from one vehicle to another as relayed by other vehicles in order to connect outside the communication range of the source vehicle. This type of communication could be used for soft safety purposes, for example of driving and traffic information.

iii) Infrastructure-to-vehicle communications: With the help of infrastructure-to-vehicle (I2V) communications, every vehicle can receive local broadcasts from the infrastructure on the roadside, with examples are given as: (a) a traffic controller signal timing information and phase, (b) information about dangerous conditions of the road, and (c) credentials of security. I2V local broadcast can enact implementation of communication with the help of radio transceivers with short range that are deployed from the roadside. Another way to implement I2V is through digital radio, satellite, or cellular broadcast services, to reach various vehicles present in distinctive geographical areas.

iv) Vehicle-to-infrastructure communications: With the bi-directional communication that is present in vehicle-to-infrastructure (V2I), many conveniences and mobility applications require vehicle-to-infrastructure mode of bidirectional communications including navigation and access to the internet in order to browse, send emails, complete electronic transaction electronically to purchase services or goods, as well as to facilitate media downloads. Communication through V2I can also be utilized to broadcast various messages from vehicle to vehicle via a server of infrastructure applications. This method can be sustained with the use of both short range and long range radios. In vehicle telematics devices, capabilities of cellular networking have also been applied as part of this growing trend.

v) Indirect vehicle-to-vehicle: Indirect vehicle-to-vehicle is used to pursue communication with different vehicles via network infrastructure.

Potential applications for connected vehicles are presented in Figure 2.5.

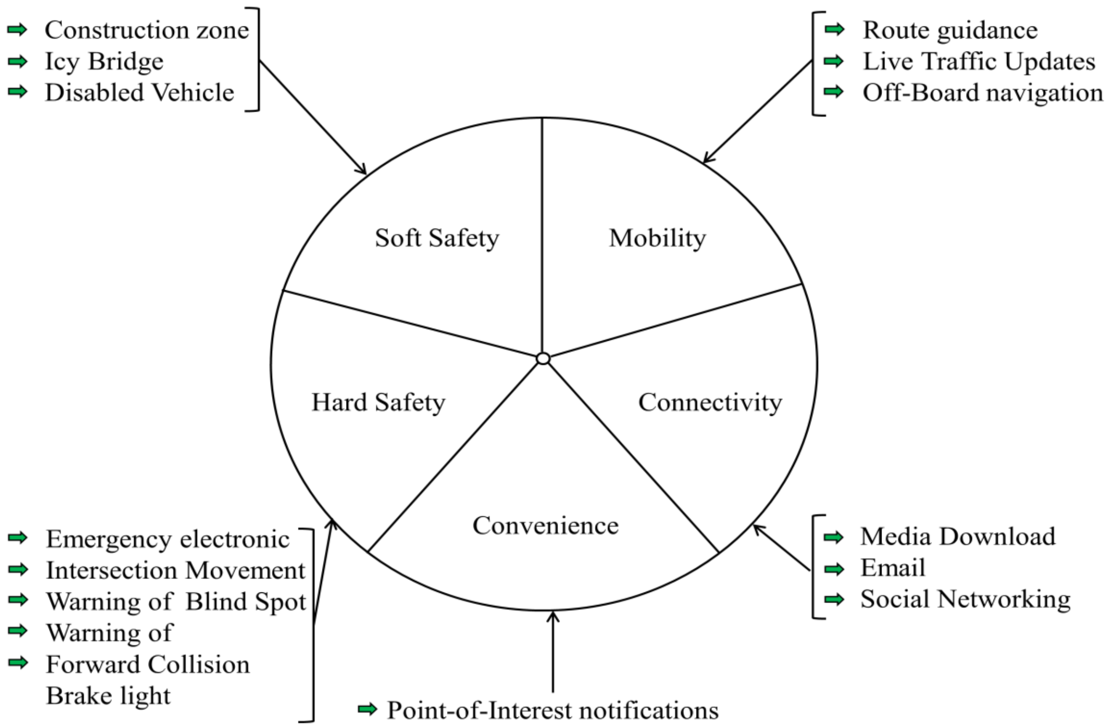

Figure 2.5: Applications in connected vehicular.

The importance of connected vehicle applications are:

i) Applications for hard safety as shown in Fig.2.5: These applications are targeted at damage minimizing and avoiding the imminent crashes.

ii) Applications of soft safety: Applications that contribute to improved drivers' safety, for example, warnings for traffic jams, potholes, reduced visibility, construction zones, icy roads, traffic, road, and weather.

iii) Mobility applications: The mobility application concentrates on improving the flow of traffic as it includes traffic coordination, traffic assistance, traffic information services, road guidance, and navigation.

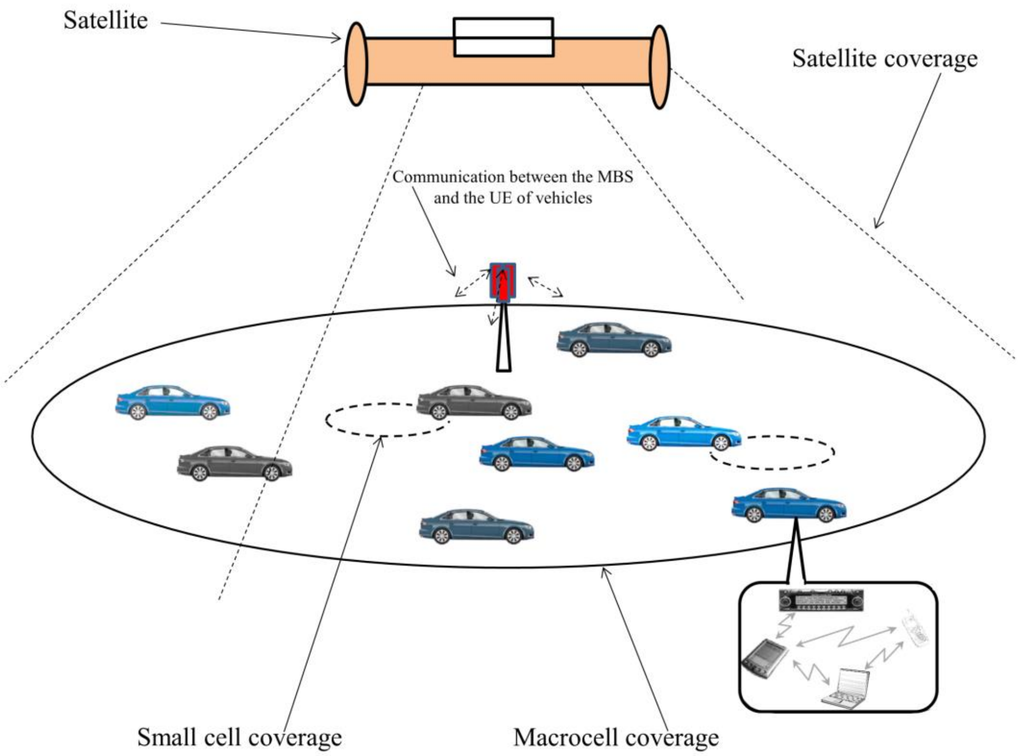

Figure 2.6: Future communication among IT and Vehicular

iv) Convenience and connectivity applications: These applications have a focus to make driving a pleasant experience and to provide more convenience including application updates, media downloads, social networking, email and point of interest notifications. The delivery of this application can be incurred via (a) through smartphones or other consumer electronic devices, (b) devices embedded in a vehicle.

2.1.4 Handover Types and Mechanisms

Mobility is undoubtedly a core feature of wireless communication systems. Seamless mobility across multiple cell coverage regions are achieved through handover mechanism in mobile networks. Handover is the mode to shift the base station or channel (frequency, time slot, spreading code or mixture of these) which is connected to the existing association, while the call is in forward step [31]-[33].

From the point of view of heterogeneous networks, different kinds of handovers may occur which will be described as follows:

(i) Hard handover and Soft handover

Hard Handover (HHO) can be explained as a break before making up of a connection (Figure 2.7a). In this kind of handover, the mobile terminal communicates with only one base station at a time. At the point when a handover takes place, the existing interconnection is discontinued, whilst a new linking is established.

When the on-going link is broken, resources connected with the old base stations are discharged, and the cellular terminal is allocated with new resources that are connected with the newly established base station [34].

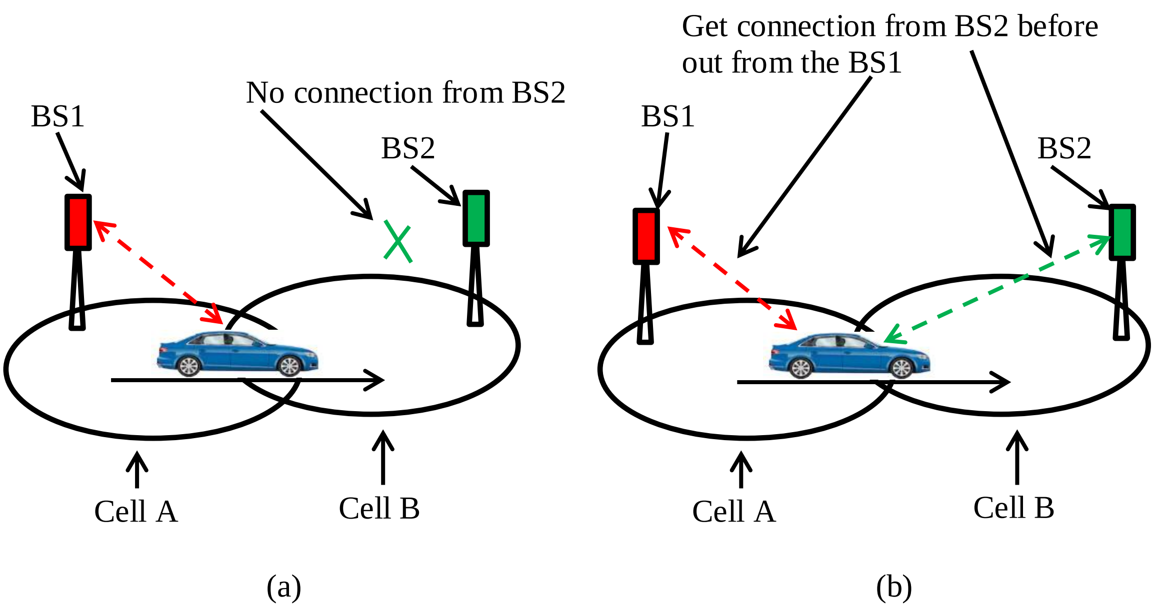

Figure 2.7: (a) Hard handover (HHO) (b) Soft handover (SHO)

Soft handover (SHO) is also called a "make-before-break connection", which involves the process of making a new connection before breaking the previous one (Figure 2.7b). Thus, a user has two connections with two different base stations at a time [34].

(ii) Horizontal and Vertical handover:

When an interconnection is handed over to the same wireless network's base station, it is called "horizontal handover" (Figure 2.8a), and this handover process is also known as "intra-system handover" [34], [35].

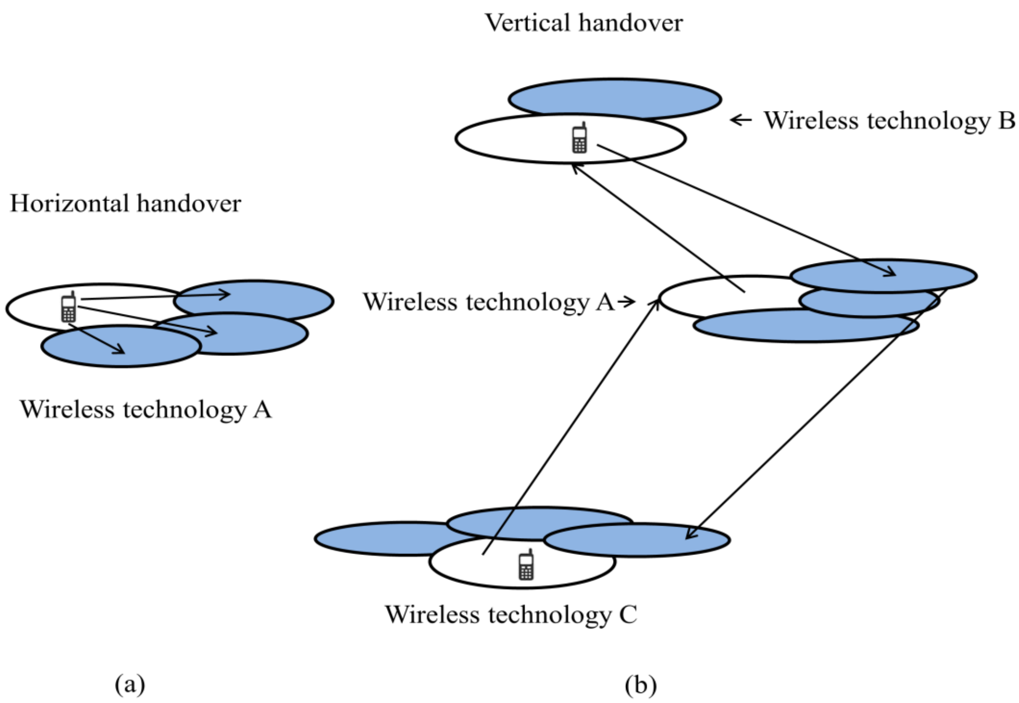

Figure 2.8: (a) Horizontal handover (b) Vertical handover

Similarly when communication link is handed over to the base station of a dissimilar mobile network, it is called, "a vertical handover" (Fig.2.8b), and this handover process is also known as "inter-system handover" [34].

Fig. 2.9 represents the arrangement of two cells having a distance d in between, and frequency fr_1 for being co-channel. The value of 'Q' affirms the value of distance d and radius r of the cells. It is desired to facilitate the whole area with a communication system, which demands the inclusion of other frequency channel within the existing arrangement of the co-channel cells, while the frequency channels to be added are fr_2, fr_3, and fr_4.

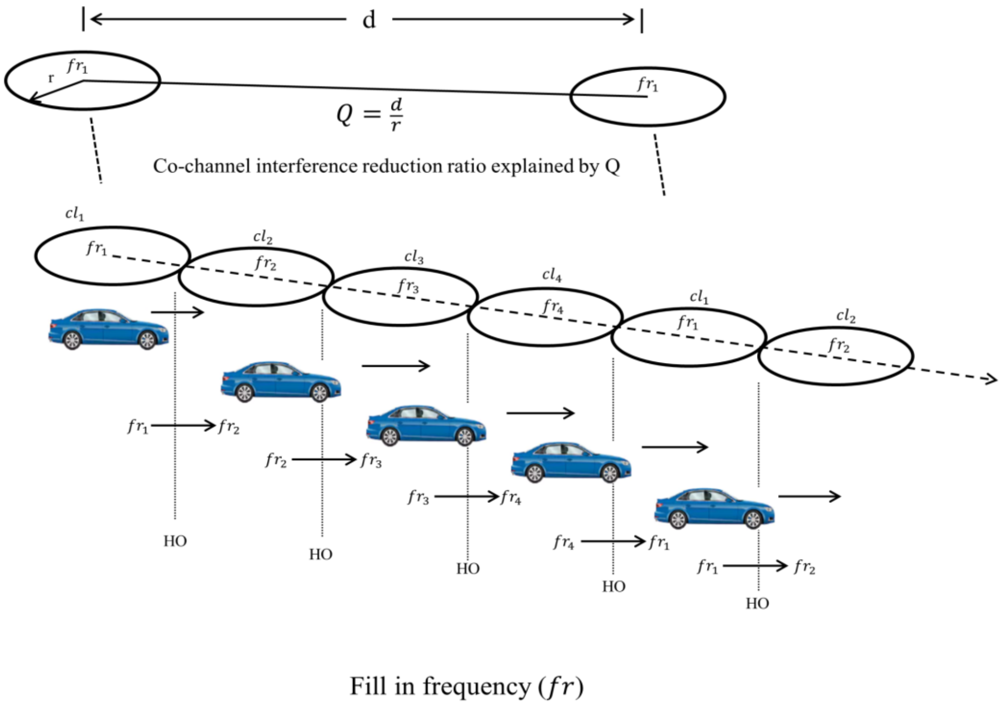

Figure 2.9: Handover mechanism

As illustrated in Figure 2.9, cells cl_2, cl_3, and cl_4 have acquired the new add-in frequency of fr_2, fr_3, and $fr_{4,}$ respectively. However, the handover must ensure that the values of distance d and radius r are assigned in accordance with the value of 'Q'. In case a Mobile Nodes (MN) moves into the cell cl_2 from cl_1 while making the call, it resulting in dropping the call, and it being quality re-initiated there would be a frequency change from fr_1 to fr_2 channel. Although this process may seem to aggravate the mobile users, the frequency changing process can be automated without requiring the involvement of the user. This handover process is executed for the FDMA, and TDMA systems [36].

2.2 Literature Review

2.2.1 Handover

In heterogeneous networks, data rates can be improved at hotspots by deploying small cells that overlap with the macro cell. As a result of small-macro combinations and the smaller coverage of small cells, more handovers are required in these heterogeneous networks [16]. Zhang *et al.* [37], have conducted research to reduce the handover related overheads in macro-femto HetNets. The authors in [38] suggested to reduce the overall delay of the packets and to avoid excessive vertical handovers that are present in the two-tier architecture for downlink cellular networks. In [39] and [40], the authors used the Mamdani fuzzy logic method for analysing the handoff factor. The researchers studied the scenarios of two different handoffs, i.e., handoff from WLAN to UMTS and handoff from UMTS to WLAN. However, defining the fuzzy sets for such networks is a challenging task. The authors in [41] conducted a study to jointly tune the time to trigger and handover margin. In this study, a self-optimizing algorithm was deployed in a fuzzy logic controller. Nonetheless, the parameters update policy was dependent on the information acquired from the ratios of call drop and HOs.

Authors in [42] and [43] suggest a practical and proactive mechanism with the aim of developing further the performance of handovers when it comes to WLANs pertaining to handover impediment, professed throughput and jitters. A handover resolution algorithm has been proposed in [44] by Liming Chen, from WLAN to 4G networking systems, after comparing the contemporary levels of RSS and dynamic and versatile RSS threshold assessment in the case where a WLAN AP connects to an MN. The later RSS threshold helps to reduce the amount of avoidable handovers while keeping the percentage of failures from the handover under some specified perimeter. Some authors believe that the likelihood of failure relating to handovers is more significant in situations with either rising velocity or handover, which is a sign when a predetermined value of RSS threshold has been used up.

Becvar *et. al.* [45] recommends a handover method of maximizing the efficiency from the handover prophecy as well as efficiency by means of the stricture of RSSI with hysteresis as in [46]. To use it in the best possible way, they have suggested two thresholds for this parameter. This idea involves the extent of mean value of the specified thresholds, for handover commencement. Accordingly, adequate sample sizes of RSSI are calculated to assist in the estimation of the approximate number of handovers that have a likelihood of happening between the target base station and the actual. This process assists in the evaluation of probabilities and possibilities in handover among the BSs that are participating.

The authors in [47], [48], and [49] place a lot of emphasis on how by scanning of the real-time data actively, information such as direction of mobile node, the speed and the time involved can be smartly retrieved and resources needed can be reserved in advance. Similarly, a useful resolution with end-to-end effectiveness and efficiency can be gained by some smart reconfiguration systems such as configuration which is self-channelled and managed as well as alteration being incorporated in network entities. This approach may aid in the selection of the most suitable network configuration for operation of a handover that not only fulfils the requirements of the users but also the QoS requirements.

Authors in [50] present a SINR based approach by considering the data-rate available as well as the backhaul bandwidth for coming up with and settling on the decision time required for the handover while maximizing the allocation of all the available resources in networks. To improve the usual throughput of the vertical handovers, Hu et al. [51], [52] advised the co-operation of the fast cell assortment as well as softer handover grounded assessment algorithms in the 3GPP networks. Taking help from SINR to be the performance indicator for VHO, they suggested a new boundary, the ratio of interference to that of other Interferences plus Noise, while illustrating its practicability in the overall path of the handover. The authors also suggest that the IINR be used only if those cell nodes selected for handover have cooperation expenditure or outflow is less than their cooperation inflow or gains. Once this is confirmed, the total average throughput of the entire handover process can and may be improvised. However, this approach is only applicable in environments supporting a cooperative network.

Table 2.1: A comparative survey of representative handover techniques

Scheme categorization of Handover Decision	Scheme for deciding the Author Handover	Method Description	Method benefits	Method Restrictions
RSS Threshold based Schemes	[42], [43], [44], [45], [46]	In this regard, the calculated values of "Dynamic RSS threshold" and current threshold are compared for determining the period of handover of cellular and data networks.	i) Minimized initiation of false handover. ii) Minimized failure of handover.	i) Maximized failure of handover between data and cellular networks. ii) Over consumption of network resources.

Channel Scanning based Schemes	[47], [48], [49]	The time of handover is decided by the combination of RSS with the estimated scanning period.	i) Adjustment to the user mobility and application. ii) Improved throughput.	i) Higher delays in handover. ii) Need of additional lookup table.
SINR based Schemes	[50], [51], [52]	During a handover, the distribution and reservation of the resource is considered for the optimization.	i) Maximized throughput. ii) Optimized allocation of resource.	i) Increased latency in handover. ii) Inappropriate for high speeds. iii) Effect of Ping-Pong.
Network Score Function based Schemes	[53], [54], [55], [56], [57]	The networks are ranked using the scoring function based on MADM in accordance with the needs of the users for selecting appropriate network.	i) Low blocking rate of handover. ii) Minimized effect of Ping-Pong. iii) Selection of network on ranking basis.	i) Degraded QoS. ii) Increased Latency.
ANN based Schemes	[58], [59], [60]	The complex problems are dealt by the application of ANN in which the behaviour of handover in dynamic situations is carried out automatically.	i) Efficient handovers. ii) Lower delay of handover processing. iii) Better selection of network.	i) Increased Latency. ii) Slow process of learning and training. iii) Consumption of supplementary resource.
Intelligent Protocol based Schemes	[61], [62], [63]	The handover mechanisms are aligned with proper networking for seamlessly providing different mobility protocols.	i) Minimized packet loss. ii) Resource conservation at terminal. iii) Efficient handovers. iv) Ensured security.	i) Relatively high latency. ii) High overhead of signalling. iii) Centralized control.
Mobile Agent Based Schemes	[64], [65], [66], [67]	The handover is carried out by the mobile agents that are employed in terms of partially distributed solution. In his regard, these agents gather and distribute the required contextual information.	i) Intelligent collection of context. ii) Flexibility to different networks. iii) Proper storage of context. iv) Optimized rate of handover blocking.	i) Increased overhead in communication. ii) Increased number of agents. iii) High latency of handover. iv) Real-world issue of deployment.
Mobility Prediction Based Schemes	[68], [69], [70], [71], [72], [73]	The decision of handover is made by collecting the patterns of users' mobility and the historical data.	i) Minimized Ping-Pong in the case of low speeds. ii) Appropriate in vague network environments.	i) Volatility for different speeds. ii) Longer duration of handover delay. iii) Higher losses in packet data.
			i) Proficient decision making.	i) High cost of signalling.

Cooperation Based Schemes	[74], [75], [76], [77]	The decisions of handover are made on the basis of collaboration of multiple entities in the network.	ii) Enhanced QoS. iii) Appropriate for real-time streams. iv) Completely distributed. v) Improved utilization of system.	ii) Higher loss of packet data. iii) Security provision.

The authors in [53] and [54] present a selection of network as well as a handover decision method inspired by the system for preference of order by way of similarity to perfect solution for grading networks in a wireless superimpose environment. It is vital to consider the history parameter of handover as a major aspect for establishment of a handover decision as well as a suitable network selection. Other important aspects include sanctuary, the expenditure, jitter, bandwidth, postponement and package loss.

The aim here is to ensure that the persistence of an MN is in the presently linked access network for the longest possible time. The bonds are committed to memory by the method inspired by the system for preference of order by way of similarity to perfect solution decision engine, whose job is to manipulate them in a suitable grade way that it is according to user’s wishes. Authors recommend decreasing the figure of handovers. However, it appears that MN is strained to continue to staying in a network even when the network’s QoS drops beneath the user threshold hence shows the unsuitability and inaptness of such answers in the varied environments of radio access, also depicted by [55], [56], and [57].

In their work, Nasser *et al* [58] presented a vertical Handover Manager. The approach based on neural was used in identifying signal putrefy as well as formulation of the handover decision. Some researchers also aspire to propose an intellectual system of network selection, which will be able to opt for the greatest wireless networks that are available. This would have the benefit of user predilections, device potential (like power utilization), and wireless network components such as the expenditure and security network parameters to make sure that there is an enhanced handover decision and network assortment. Nasser *et al* declared that when the rate of knowledge and tolerable inaccuracy rate of price are correctly harmonized, it follows that the projected design becomes skilled enough to pronounce the finest available network at optimum level [58].

According to Horrich *et. al.* [59], fuzzy logic based procedures as well as propositioned neural networks can be used for the handover decision. The researchers also suggest using Fuzzy Logic Controller techniques for handover decision-making. Fuzzy Logic Controller pertain the specifically defined regulations to the existing system environment. A neural system uses the results from the handover features matrix to learn the FLC's limitations. From this study the authors projected to exploit the velocity and network fills in the RSS, as the handover decision restrictions. An introductory choice of networks targeted by the handover is executed earlier than commencing the vertical handover method. Target network load and networks with indication level above the ones that are already defined threshold limits are filtered. The targeted network with the paramount signal eminence gets selected. Such a prior selection diminishes the FLC complexity while saving the processing time. Moreover, this proposal suffers from the similar constrictions as the one previously presented in [59], [60].

Vidal *et al.* [61] recommend a structure for positive and practical backgrounds transmit for P2P IPTV service contained in IMS networks. The authors measured handover between networks and its circumstances to reduce the packet loss and improving the experience of the users. The authors in [62] concentrated on the matter of joint confirmation in networks that lacked any relationship, in the context of Mobile-Controlled Handovers. In the first stage, a confirmation label is generated which follows speedy verification of the newly incoming mobile nodes within that particular network. The authors took advantage of the benefit of the Authentication, Authorization as well as Accounting method and definite AAA proxy [63] that viaducts the trust relationship with the help of a shared key across diverse networks. The communal key usually propels to the candidate networks in proceed. The AAA proxy is used to directly authenticate the mobile node as it assigns to a new network and does not entail the home network in as far as this purpose is concerned. It is expected that the process will help in minimizing and controlling the packet loss. Additionally, the complete control of keying data for speedy substantiation is given to a MN which determinations the matters of secrecy and safety such as masquerading attacks and DoS to certain extent as well.

Programs characteristically written in a form of a script that may be transferred from a user computer as well as related to a remotely located server computer to aid in implementation [64], are called Mobile Agents. Wei *et al*. suggested a decision mechanism framework that was based on handover in [65], describing a decision-making system that is based on mobile agent from which useful data can be downloaded at one point and also invoked later at the point of handover. Furthermore, the projected structural design comprises of three most important parts: (i) a framework for context management, (ii) a platform that is programmable and (iii) a service exploitation plan to supply the operations required in the case of context-aware handover. In [66], the authors put forward a multimedia middleware available everywhere that was based on the mobile agent with the intention of blatantly keeping away from service disturbance during vertical and horizontal handovers in the assorted environment. Zafeiris and Giakoumakis [67] anticipated another insightful input to the context based handovers by suggesting using a design based on mobile agent for handover administration by cantering on the handover instigation as well as decision stages.

Incidentally, the work presented in [68] offers a resolution based on the Dynamic Bayesian Network to tackle the concern of handover while utilizing context changing variables and Semi-Markova models. Nevertheless, it is impossible to compute all the information that is based on various contexts which may impact the future availability of network. The work demonstrated in [69] presents a device that predicts mobility on by way of approximating the behaviour of the user. The authors consider what the what time of the day it is, the amount of time used up in a precise network, the history of handover, group as well as position as handover decision constraints. Authors in [70], [71] and [72] present a solution on a mobility design based mobile supported handover. These authors also suggested to accumulate the historical data of the movement of users in a database and also each time a roaming client uses the same trail using an invariable velocity; Mobile network handovers to the formerly recognized networks. According to Wang *et. al.* in [73], it is crucial that handover decision making codes in the radio systems should be used to resolve the issue concerning handover indecision as well as where the requirement of handover is owing to corrosion of signal. The initial method is based on the theory of conformist decision where diverse levels of signals are observed, as the succeeding tactic is supported by the Markov model in which mobility forecast performs an essential role. They take into consideration complex factor of environmental impact on the behaviour and performance of radio signals, device configurations, user inclination and network conditions.

Another novel handover system is recommended in [74] that merges the MIH framework for analysis as the case study for movement management in different wireless networks and the spectrum awareness. Liu *et. al.* had suggested to use a game theory that is basis of loose-coupling interworking amid WiMAX and WLAN, specifically for the vertical handovers [75]. The origin of the handover decision is a game procedure that is conducted using a bidding model that considers the delays, bandwidth, loss of packet, charges offered by a wireless network and jitters. Wang *et. al.* [76] came up with a design that supports mobility in omnipresent environments. The authors also offer a management design-based on a decentralized situation that is premeditated to please the requirements of the user like in [77]. The design involves a path-planning module as well as a handover module, which are a mass on the U-gate also known as ubiquitous gate. The U-gate is a key mechanism of the projected design while working as a gateway amidst networks and devices such as sensors or even equipment that is more intelligent. This structural design works with a communication model that plays the role of an intermediary between both, the ubiquitous environment and U-gate and all the contextual information is gathered and modelled in it.

In [78], a network controlled handover optimization and soft-metric mechanism was introduced to more easily cope with the variable user speeds. The speed of user equipment is an essential factor in managing mobility and handover rates. Some other research articles [8] and [15] focus on the high-speed users considering the movement in vehicles and railways whereas some other works [79], [80] focused on the mobility management for users with limited paths. It is worth mentioning here that as the user speed increases, the handover rate also increases because an UE is more probable to cross the coverage boundary of the associated BS.

An available research suggests that BS density for small cells and macro cells is an essential variable for measuring 5G network capacity as the number of UE increases rapidly. Some studies carry out their analysis and simulations on low density cells (2 MBS/Km^2) [14]. In contrast, another study [81] used high density for small cells up to 400BS/km^2. Some other researchers [82], [83], and [84] also considered the density of UE to study the impact on coverage probability and the average throughput, which is also affected by the UE's velocity along the moving trajectory.

In [85], the authors proposed to avoid frequent handover for high speed mobile nodes by serving them by the MBS even though some smaller cells with better SINR were present. However, the work in [85] assumes that enough resources are always available for mobile nodes. Power consideration in heterogeneous networks requires that the number of active small cells be kept low, meaning more power efficiency can be achieved when users can be served by the MBS instead of small cells [86], [87]. As a result, an energy-efficiency network attempts to utilize the MBS spectrum first, leaving not enough resources for new mobile nodes unless some other mechanisms are deployed. In this proposed study, the authors propose one such mechanism to reduce both the handover and the power consumption.

2.2.2 Handover and Transmission Latency

The primary concept of heterogeneous networks is that numerous smaller cells (e.g., microcell, picocell, femtocell) operate under the umbrella of macrocells to increase the coverage or enhance the ability to support high traffic rates for all areas [6], [22]. In the heterogeneous network repeated handovers with macro-small cell occur owing to its very narrow coverage and the fact that numerous small cells are overlaid [88]. As a consequence of handover, interference between source and target eNBs occurs [89]. This leads to throughput performance degradation. Therefore, many studies have been conducted on reducing handovers in heterogeneous systems.

In a heterogeneous network (during the handover), Lee *et al.* [90] proposed a mechanism for call admission control; however, in the same network, they do not work on the different traffic load environment, which leads to call dropping. According to the research on internetworking between WLAN and WiMAX networks, regarding tightly coupled internetworking architecture [91] the available bandwidth and packet delay are parameters that are taken into consideration (related to the evaluation algorithms). However, even in the case of achieving high throughput, high handover delay is predominant with the mobile nodes' arrival, which causes increasing the number of call dropping. In [92] and [93] the performance analysis was carried out over HO rates. The analysis was primarily conducted for the irregularly shaped topologies of the network. It is due to the fact that no remedial actions have been proposed for the frequent issues, associated with HO.

The study of Emmelmann *et al.* [94] proposed the design along with developing the prototype for high-speed vehicles based on seamless and unified handover mechanism. In this regard, dynamic dwell timer was used as a significant element regarding the delay issues. The designed scheme was for the networks of IEEE 802.11 that aimed at minimizing the delay of handover mechanism of telemetry services' provisioning. The projected prototype had two coverage areas of macro and micro cells operating on same frequencies. Likewise, an innovative handover technique was also proposed by the authors in [95] for the minimization of the probability of handover failure along with the eradication of the unnecessary handovers. For the successful attainment of these functions, three dissimilar techniques were fused together. These techniques included, (a) signal trend detection: It served as the indicator of vertical handover in upward or downward directions. For instance, the adjacent WLAN access-point was triggered for the handover as RSS increased due to the entry of mobile node into the coverage area of WLAN, (b) adaptive threshold fixing: It served as a trigger for adjusting the changes in the channel parameters and the velocity of MN. It also facilitated the estimation of possible delays in the handover, (c) dwell timer: It was used for the reduction of waiting time and making the handovers fast as the handover of MN must execute immediately due to the high velocities of terminals' movement. In the same manner, an algorithm of low complexity was developed by the authors in [96] that took a small dwell time prior to handing the user of macrocell off to the nearest femtocell. In this regard, adequate decision making prevented the unnecessary handovers during the simulation. The proposed design of Bazzi [97] defined softer VHO in a different manner than [98], entailing a discussion supporting algorithm for heterogeneous wireless systems. In this regard, the network conditions of available bandwidth, user mobility, and application type were considered. It focused on serving the UMTS networks in terms of variant mobility scenarios.

Besides the study [99] asserted that the MBS-zone planning based on LMA delivered effective services of broadcast and multicast than the WiMAX Mobile Systems. The results of Sumathi [100] reflected improvement in the entire throughput using the handover algorithm of pre-determined bandwidth requirement. In the same manner, the consideration of bandwidth was found to be effective with respect to the simulation outcomes of reduced packet loss and handover latency in the studies [101]-[103].

Table 2.2: A comparative study of illustrative handover method for decreasing the handover delay

Scheme categorization of Handover Decision	Scheme for deciding the Candidate Handover	Scheme Description	Scheme Benefits	Scheme Limitation
Dwell Timer based Schemes	[94], [95], [96]	For the scenarios of high mobility, "Dynamic Dwell Timer" is used.	i) Minimized failure of handover. ii) Minimized effect of Ping-Pong. iii) Minimized delay of handover.	i) Maximized loss of packet data. ii) Maximized signaling. iii)Inappropriate for the applications of real time.
Available Bandwidth based Schemes	[97], [98], [99], [100], [101], [102], [103]	Higher throughput is achieved by considering the available bandwidth in the case of vertical handover.	i) Low latency of handover. ii) Enhanced throughput. iii)Proper selection of network.	i) High loss of packet data. ii) Inefficient calculation of bandwidth.
Fuzzy Logic based schemes	[104], [105], [106], [107], [108], [109], [110], [111], [112], [113]	QoS dynamics are prioritized for performing the handover decisions that are assisted by network in accordance with the preferences of user.	i) Minimized delay in handover. ii) Minimized packet loss. iii) Intelligent selection of network. iv) User satisfaction in terms of QoS.	i) Enhanced complexity. ii) Higher delays in decision processing.
AHP based schemes	[114], [115], [116], [117]	It entails the handover decisions based on predefined objective. Moreover, merit functions and scoring mechanisms are used for the selection of network.	i) Optimized latency in handover. ii) Minimized packet loss. iii) Increased throughput. iv)Optimal selection of network.	i) Consumption of resource. ii) QoS could be compromised with low cost of the network.
MIH Based schemes	[118], [119], [120], [121], [122], [123], [124], [125], [126]	Predefined triggers are used for the decision of distributed handover, considering the context of user application.	i) Minimized packet loss. ii) Optimal selection of network. iii) Embedment of security. iv) Minimized latency. v) Optimization of the throughput.	i) Additional signalling. ii) Higher consumption of resource. iii) Context distribution.

The proposed scheme of Attaullah *et. al.* [104] incorporated the decision model for vertical handover based on fuzzy logic for the improvement of QoS of the wireless networks in a heterogeneous environment. In order to sustain the established connection during the handover, the handover strategy of “make-before-break” was applied as compared to the decision-making strategies of [105]-[107]. In this regard, more parameters of QoS, service type, user preference, and battery level were used for the designing of the “autonomic-oriented approach”. Similarly, Ceken *et. al.* [108] proposed another scheme based on the fuzzy logic that considered the input as RSSI, data transmission rate as well as the terminal speed for making the decision of handover along with the selection of a network. In the same manner, the study [109] proposed the algorithm based on fuzzy rule aware of the QoS requirements in association with the consideration of the bandwidth, bit error rate and jitter as well. Additionally, another model was also proposed based on the Markov chain having the correspondence of the available networks. As a result, an improvement was attained in the prospects of availability and delay concerns. The study [110] proposed an adaptive algorithm of decision making for the vertical handover that entailed the optimization of the fuzzy functions through the genetic algorithm. This researcher intended to attain the optimum state regarding the handover performance. Likewise, Takaaki [111] presented the scheme of “Fuzzy-Based Multi-Interface System” (FBMIS) in which two separate interfaces of the mobile communication network also “Mobile Ad hoc Network” (MANET) were used. The designed scheme was capable of switching in between the Ad-Hoc mode and the cellular network. In this regard, the parameters of nodes distance, nodes angle and node mobility were used. Furthermore, the approach was then implemented in [112] with the addition of another element of URS “User Request Security”. The study [113] presented a fuzzy algorithm based on dynamic Q-Learning approach of managing the mobility in the networks of small cell. Based on the system learning, initially no fuzzy rules were there, but the algorithm generated new rules of balancing the handover related signalling cost along with the improvement in the user experience. Moreover, the simulator based on LTE system was used to measure the performances along with the speed of UE.

The study of Ahmed *et. al.* [114] presented the architecture of handover decision based on context awareness. This is transferring sessions among the different modes of the mobile devices. In this regard, AHP [115] was used for selecting the most suitable alternative among the available handovers. The study of Sogra *et. al.* [116] proposed the mechanism of making the decisions based on multi-attributes using TOPSIS and AHP mechanisms. In [117], the handover decision was based on the cost function that was affected by the factors of security, cost, signal strength, and signal delay and power consumption. In order to make the weight values adjusted, the adaptive mechanism was utilized. The simulation was carried out in terms of the construction of the network model of UMTS and WLAN in a heterogeneous environment. By using an additional adaptive method, the authors had compared the previous algorithm with the proposed one. As a result, the handover times, and handover delay were decreased along with enhanced user experience.

Besides, the study [118] proposed the scheme grounded on MIH whose full abbreviation is Media Independent Handover. However, that used the information from both the client side and the network for making the decision of cooperative handover. In [119], EIS Architecture-“Enhanced Information Server” was presented for the prospect of increasing the speed of the vertical handovers of the MIH networks. The significance of EIS was in its information gathering related to the RSS level, timing and location from the mobile nodes for exploiting it in a cooperative manner. Thus, the prospects of skipping the scanning of the channels were attained that reduced the latency of handover. Consequently, an approach grounded on context was suggested by Pedro *et. al*. [120] for the same task. In this regard, the developed scheme was based on the same approach of [119] to use the information server CIS "Context-aware Information Server". Accordingly, the collection, management and the distribution of the real-time information were collected by the server. The study [121] proposed GVLL "Generic Virtual Link Layer" scheme by combining it with MH platform for the achievement of QoS during the handover between WiMAX and WLAN. GVLL was intended for selecting the most suitable network along with the inter-operability of MAC layer. This is carried out by the measurement and comparison of the QoS of the networks available. In the same manner, Corujo *et. al.* [122] addressed the aspects of diversity and complexity of services and technologies in the ubiquitous environments. Therefore, MIH was used to deal with these issues in the proposed platform that was capable of communicating with both the network devices and services in the ubiquitous environment.

In addition to this, the study [123] performed a wide-ranging examination for evaluating the impacts of QoS during the intended process of vertical handover. In this regard, the objective of evaluating the mobile speed was intended. Moreover, the study [124] presented the decision-making approach based on the signalling of MIH among the networks. In this approach, the criteria of SINR "Signal to Interference and Noise Ratio" were preferred rather than the RSS "Received Signal Strength". Additionally, the VHD scheme provided the information of the approachable networks' bandwidth through SINR. This reflects that the attainment of efficient and seamless handovers turned out to be challenging with respect to the satisfaction of the Security and QoS constraints. Thus, standards for facilitating the handovers issue were required. In this regard, the MIH based on IEEE 802.21 protocol was used that was evaluated on the basis of two diverse protocols of SIP “Session Initiation Protocol” and MIP “Media Independent Handover” protocol [125]. Similarly, the study [126] proposed a smart framework for simplifying the process of network selection along with reducing the frequency and latency of the handover. This author carried out by the integration of the SDN “Software-Defined Network” and MIH technologies that established the handover among the most potential networks.

To avoid unnecessary handover to the WLAN network by predicting the travelling distance, a mathematical model [127] is developed. In a circular region’s access point, this scheme measures the available RSS for the mobile node; however, it has various limitations. Although the approach aims to reduce and avoid unnecessary handover, it is not useful when the mobile node moves away from WLAN network’s boundary. A method to avoid unnecessary HOs by minimising the number of scanned SCs is put forward by the authors in [128]. SC (small cell) list is formulated on the basis of the ToS (Time of stay) criteria and downlink received power. This helps in avoiding the SCs while assuring the minimum time of stay. The HO (handover) is performed to the SC by the UE with the strongest downlink received power from the list. However, cell load and interference scenario are not considered in this work, which may cause radio link failures and throughput unaware HO strategy. Another handover decision method is developed by Tariq *et al.* [129] consider user velocity, which is based on the RSSI samples’ moving average, connecting the WLAN medium and mobile terminal using the VH (vertical handover) algorithm. Although the probability of handover process decision is likely to be simple, the scheme does not take into account the target network condition. These schemes, in short, consider RSS as an appropriate criterion to start the decision scheme of vertical handover. However this handovers (e.g., based on RSS) under unfavourable conditions and signal interference, initiates unnecessary vertical handovers, and influencing the overall network performance. In addition, due to the fading effect, the signal fluctuations result in undesirable Ping-Pong effect, increasing the call drops and failures' probability during the handoff process.

Moreover, A HO technique of management which is based on maps (self-organizing) is proposed in the two-tier heterogeneous networks, in order to reduce unneeded HOs [130]. Multiple other techniques for the reduction of unwanted HOs is discussed in [131] (downlink). Moreover, for single tier networks, HO delays are characterized in [132]. Regardless, none of the above mentioned studies discusses the HO costs and user interplay overall as a BS intensity function.

2.3 Research Question

As discussed in Section 2.2, in the literature researchers have reported numerous techniques for addressing the challenge of handover and latency. However, most of these studies were not conducted in the context of heterogeneous networks. In particular, none of the studies investigates handover, power consumption and latency at the same time in a 5G heterogeneous networks.

Therefore, the following research questions will be addressed in this project:

[1] How to reduce the number of handover and power consumption in a 5G heterogeneous network?

[2] How to reduce the handover and transmission latency for emergency vehicular communications?

Chapter-3

A New Handover Management Scheme for 5G Heterogeneous Networks

This chapter is not included in this version of the thesis.

Chapter 4

Reducing Delay for Delay Sensitive Application Vehicular Communications

This chapter is not included in this version of the thesis.

Chapter 5

Conclusion and Future Work

5.1 Conclusion

In this thesis, a new mobility management technique was introduced to reduce handover rate, power consumption and latency in 5G heterogeneous networks.

Cell densification in future generation networks offers some key advantages including frequent frequency reuse and higher data rates. Small cell densification however, causes frequent handovers for mobile nodes due to the smaller coverage areas of small cells. Frequent handover is detrimental for mobile nodes moving at high speeds since high handover cost results in higher overheads and lower average throughput. This thesis addresses high handover and latency challenge. The thesis first reviews all studies relevant to handover and latency management, where Research gaps were subsequently identified and the aims of this research were correspondingly presented.

In the first contribution chapter, a new handover technique was presented. The target was to minimise handover cost and power consumption. This research introduced a new term in the form of association preference factor, which was considered as one of the two objectives in the optimisation model. The other objective is to keep the power consumption low, leading to the small carbon footprint and reduced energy bill for the network provider. The research problem was modelled as a constrained multi-objective optimisation problem. This study implemented the proposed solution in a simulation scenario and generated results in terms of handover cost, power consumption and throughput. Simulation results suggest that the proposed solution significantly outperforms existing solutions. In a bid to find a robust solution, we also introduced a heuristic solution, which performed reasonably well compared to the optimum solution.

In the second contribution chapter, a new technique was presented to address high latency problems in vehicular communications. The target applications included delay-critical applications used in emergency vehicles, for example, ambulances, police cars, fire and emergency services. The challenge of reducing latency in 5G heterogeneous network was first modelled as a constrained optimisation problem. Considering the time complexity of the optimum solution, a heuristic solution was introduced. The proposed solution was implemented in a simulation environment and benchmarked against the solution presented in Chapter 3 and other existing solutions.

5.2 Future Work

In the coming years, 5G will undergo a massive evolution process which will likely provide facilities that include: upgrading mobile devices in terms of incorporating sensors driven by sustainable sources, numerous active connections, and limitless data transmission. UAVs (Unmanned Aerial Vehicles), or multi-tier drones, will likely dominate cellular transmission in multiple situations. 5G heterogeneous networks combined with UAVs, provide various cases such as information distribution and data assortment for IoTs (Internet of Things), instant service recovery after natural adversities, responding to an emergency, search and rescue, and machine communication [145]. Integrating UAV with 5G heterogeneous networks poses certain challenges with respect to 5G design and UAV communication systems. This is due to the high elevation, mobility, severe restrictions related to size or weight, power limitation of UAV particularly ground links, exclusive channel attributes of UAV, asymmetric QoS (Quality of Service) as well as requirements for uplink and downlink data broadcast. Moreover, other challenges linked to UAV related to 5G networks include: trajectory development planning and controlling of UAVs, energy usage by UAVs, backhauling mobile communications, spectrum management and several access arrangements for cellular-coupled UAVs, MIMO (massive) and MIMO (millimetre) wave technologies for UAV systems, and spectrum division and synchronisation amongst both airborne and ground base stations etc. New research is required to address the above mentioned challenges to accommodate UAVs in 5G networks.

The difficulty and cost in front hauling and backhauling a large number of small cell base stations (SBSs), in 5G heterogeneous networks' has emerged as a key challenge. Novel radio access network architecture is needed to understand a dense small cell deployment. In this deployment small base stations (SBSs) can be associated to core networks through a vertical front haul/backhaul. A Key technology for this kind of novel network framework is networked flying platforms like UAVs.

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