Faculty of Engineering

ENERGY-EFFICIENT MOBILITY MANAGEMENT FOR 5G HETEROGENEOUS NETWORKS

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Bachelor of Engineering (Hons) in Electronics (Telecommunications)

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ENERGY-EFFICIENT MOBILITY MANAGEMENT FOR 5G HETEROGENEOUS NETWORKS

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A dissertation submitted in partial fulfillment of

the requirements for the degree of

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Dedicated to all who have motivate, aid, challenge and inspire us in this journey of knowledge and wisdoms.

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ABSTRACT

The number of mobile device users has been growing rapidly, particularly on the use of smartphones for business, education, navigation and everyday communications. This has enable the development of the Fifth Generation (5G) mobile architecture to be brought forward as an advancement of mobile communication systems in order to satisfy the demands of the users. Thus, 5G network is predicted to be able to sustain an enormous amount of mobile data rate and a vast number of wireless connection. In addition, 5G is able to reduce cost and power consumption, as well as, produce better quality of service (QoS) with regard of communication delay, reliability, and security. This project is focused on supporting ubiquitous communications with high user mobility rate (pedestrian speed) at a lower energy consumption via the 5G Heterogeneous Networks (HetNets). An analytical model is created based on researched approaches such as user-centric and user behaviour characteristics in 5G HetNets, were also shown in this project. This model provides solutions to power consumption and mobility management issues whenever the user is at a mobile environment such as walking or running. The related variables were measured and the simulation results were evaluated accordingly as a defined conclusion to the project.

ABSTRAK

Penggunaan peranti mudah alih seperti telefon pintar telah meningkat secara mendadak, kerap digunakan untuk perniagaan, pelajaran, panduan arah dan komunikasi harian. Penggunaan ini menyebabkan perkembangan seni bina peranti mudah alih generasi ke lima (5G) demi kemajuan dalam komunikasi peranti mudah alih bagi memenuhi permintaan pengguna. Oleh itu, rangkaian 5G diramalkan mampu menampung kadar data peranti mudah alih yang tinggi dan juga menyokong rangkaian tanpa wayar yang banyak. Dengan ini, 5G mampu untuk kurangkan kos dan pengunaan kuasa elektrik. Malah, 5G juga mampu untuk menyediakan perkhidmatan yang memuaskan dengan mengambil kira kelawatan, kebolehpercayaan dan keselamatan. Projek ini memberi keutamaan di mana rangkaian yang mempunyai kadar pergerakan tinggi (kelajuan pejalan kaki) dan mempunyai pengunaan kuasa yang rendah melalui 5G rangkaian dua hala (HetNets). Analisa model telah dibuat berdasarkan pendekatan kajian seperti pertengahan pengguna dan kelakuan pengguna dalam 5G HetNets, juga akan ditunjukkan di dalam projek ini. Model ini menyeduakan analisa mengenai pengurusan pergerakan dan juga berkait dengan penggunaan kuasa apabila pengguna bergerak seperti berjalan atau berlari. Pemboleh ubah yang berkaitan telah di ambil kira dan keputusan simulasi telah dikaji dan rumusan juga telah dibuat untuk projek ini.

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List of Abbreviations

4G	-	Fourth Generation wireless communication
5G	-	Fifth Generation wireless communication
BSs	-	Base Stations
BSC	-	Base Station Controller
CAGR	-	Compound Annual Growth Rate
D2D	-	Device-to-Device communications
EE	-	Energy Efficiency
FENG	-	Faculty of Engineering
HetNets	-	Heterogeneous Networks
HOFs	-	Handover Failures
IP	-	Internet Protocol
LTE	-	Long Term Evolution
SimuLTE	-	Long Term Evolution User Plane Simulator
mMIMO	-	Massive Multiple Input and Multiple-output
M2M	-	Machine-to-Machine Communications
MOOC	-	Massive Open Online Course
MAC)	-	Media Access Control
MIMO	-	Multiple Input Multiple Output
RAT	-	Multi-radio Access Technology Architectures
NFV	-	Network Function Virtualization
OMNET++	-	Objective Modular Network Testbed in C++
PGW	-	Packet Data Network Gateway
QoE	-	Quality of Experience
QoS	-	Quality of Service

RF	-	Radio Frequency
RSRP	-	Reference Signal Received Power
SIC	-	Self Interference Cancellation
SBSs	-	Small Cell Base Stations
SCs	-	Small Cells
3GPP	-	Third Generation Partnership Project
UNIMAS	-	Universiti Malaysia Sarawak
EMM	-	User-Centric Energy-Aware Mobility Management
VNI	-	Visual Networking Index

CHAPTER 1

INTRODUCTION

1.1 Introduction

In this era of modernization, cellular traffic has escalated rapidly due to the popular and booming trends in mobile devices. As the number of users rise, higher data communication capacity and speed are required to enable a smooth run of applications [1]. To facilitate this, 5G networks introduce small cell networks as part of their important features in order to extend their capacity and coverage. A 5G mobile network will have the capabilities of supporting multimedia applications with various specification such as lower latency, better peak and data transmission rates, energy efficiency and many more [2].

One of its effective tactics to increase the data communication speed is by shrinking the coverage radius of cell, which consequently will decrease communication distances between users and base stations (BSs) [3] . This could be done through the deployment of heterogeneous networks (HetNets) which is constituted of small cells (SCs). A HetNet is an integration of several radio access technologies that enable the mobile user to be served by any base station using numerous of techniques. These small cells are used to offload user traffic locally, supply high data rate transmission and extend the service area coverage [4].

Nonetheless, the remarkable growth of network infrastructure will result in a very large energy consumption, particularly in wireless networks, which may affect environment. Thus, green networking has been identified as a prominent way to lower such energy, and to meet environmental-friendly targets. Researchers found that energy consumption is directly proportional to the number of isolated radio access nodes in HetNet [2]. Thus, the number of isolated radio access nodes need to be reduced in order to reduce carbon dioxide emission and hence, reduce the energy consumption [2].

Additionally, societal development has created tremendous changes of how mobile and wireless communication systems are used. Critical services such as e-banking, e-health e-commerce, and e-learning, will continue to escalate and enhance their mobility services. On-demand news and entertainment updates, such as in the form of augmented reality will continuously to be delivered over mobile and wireless communication system [5]. These development will gradually lead to a major surge of mobile and wireless traffic volume, which is estimated to reach more than 63 percent of total IP traffic by 2021 based on Cisco Forecast [6]. Thus, mobility in modern day wireless networks is plays a vital part in our everyday life. With a proper mobility management scheme, mobile user can maintain their connectivity and at the same time the Quality of Experience (QoE) is guaranteed [7]. Poor mobility management increase handover failures (HOFs), unnecessary handovers, radio link failures and unbalanced loading among cells, in which cause resource wastage and poor user experience [8] [9]. To solve such dilemma, a dynamic mobility management is used to optimize the best mobility option based on the cell traffic loads, coverage areas of the respective cell as well as the speed of the user equipment [8].

In conclusion, to effectively keep up with the rising number of users' needs for data traffic, coverage and speed, small cells is deployed through the heterogeneous network. This enable better QoE, improved connectivity and a reduced in energy consumption.

1.2 Motivation

Societal development have transformed how mobile and wireless communication systems are used, particularly in the use for crucial services such as e-banking, e-learning, and e-health. In addition, real-time applications for navigation, social networking, information and entertainments are progressively growing larger as people adopt them into their everyday lives. [5]. Gradually, this will lead to an avalanche of mobile and wireless traffic volume that is projected to increase sevenfold between 2016 and 2021, at a compound annual growth rate (CAGR) of 47 percent based on Cisco Global Mobile Data Traffic Forecast Update [6]. Besides this, energy consumption is becoming an increasing concern due to the heavy usage of network on mobile devices. This has directly impact the environment as global carbon emissions is getting increasingly high and sea levels are rising, while weather condition and air pollutions in many cities across the world is getting more severe, in addition to the rising [10]. Hence, it is essential that future mobile and wireless communications meet the needs of consumer while being a key player in saving the environments.

1.3 Problem Statement

Wireless connectivity influences almost every aspect of our everyday life. For example in a working environments, where tele-conference and video-conference are now considered as a norm. Besides, in education sector, most universities and schools offer massive open online course (MOOC), which is a Web-based distance learning model that is created for the involvement of a considerable numbers of geographically-scattered students. For both entertainment and social purposes, most people enjoy their free time browsing the web for news updates and staying connected with their family and friends, along with their post via social media. In addition, all navigation applications require internet connectivity to pinpoint their current location and desired destination. All this require us to stay connected, thus leading to a dense deployment of Fifth Generation (5G) networks and the deployment of small cells in the HetNets. On the contrary, this dense architecture increases the probability of interference and energy consumption of the network. In addition, there are mobility related issues, which include signaling overhead, increased handover delay, failures, and rates. These occur especially when there is a dense number of users or when the user is moving at a high speed from one location to another. Therefore, 5G heterogeneous network is required to have a more energy efficient and a better mobility management scheme to be implemented.

1.4 Project Objectives

The objectives obtained for this project are:

1. To design an energy efficient mobility management for user moving at pedestrian speed.
2. To determine critical concerns in the mobility performance of different HetNets scenarios.
3. To evaluate the QoS of mobility management in different HetNets scenarios.

1.5 Project Scope

The scope of this project is to support ubiquitous communications with high user mobility rate at lower energy consumption. Different mobility scenarios will be considered, for example, user mobility at lower (pedestrian) and moderate speed (cyclist). The project will be simulated in 5G heterogeneous environments, by using OMNET++.

1.6 Significance

The thesis provides information regarding the issue on 5G heterogeneous networks deployment, specifically in the energy efficiency associated context and mobility management of the networks. Furthermore, the research from this thesis would be advantageous to the network operators and service providers as this research emphasizes on developing an energy efficient mobility management scheme for a 5G networks. Additionally, the research in this thesis will be very beneficial to both network operators and mobile users as it define a method on how to optimize the energy consumption and improve the mobility support on the user. This would ensure a reduced amount in energy usage, as well as, its impact to the environment. Moreover, users would benefit from a seamless connection, and uninterrupted service delivery as a solution would be identified to certain handover management issues during mobility. For example, mobility related signaling load, ping-pong handovers, and handover failures that may lead to a handover delay. For future researcher, this thesis will provide a detailed information on green technologies for the deployment of a 5G heterogeneous networks.

1.7 Report Structures

The report features a proposed work, theoretical simulations and scenarios as well as relation to an energy associated issues in 5G Mobility Management For a Heterogeneous Networks. This report is partitioned into five chapters, which begins with an introduction, literature review, methodology, then research analysis and followed by conclusion. The report is outlined for each chapter as follows:

- Chapter 1 introduces the main components of this project comprised of the research background, motivation and a clarification on the research problem. The objectives of this project is provided in this chapter. The problem statement is defined sufficiently and from this, the objective and methodology are determined. In addition, the project scope presents the context and limitation of the project while the project significance shows importance of this study to other researchers, academicians, network operators and service providers.

- Chapter 2 presents a literature review on different factors, focusing on mobility management and energy related issues in a 5G heterogonous network. Different perspective from various authors are presented. Additionally, a technical background regarding 5G architecture and HetNets is also provided.

- Chapter 3 provides an explanation on the methodology used in this project through the research process. Parameters of the approach are declared and clarified together with their variable. A user-centric and behavior approach on user is defined, which will be used to measure and interpret the scenario. Moreover, the reliability and validity of the research will be assessed.
- Chapter 4 presents the design implementation and result analysis for each scenario is explained here. In addition, elaboration on the parameter metric is done here.
- Chapter 5 concluding the thesis, while recommending directions for future works.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Based on Cisco VNI Forecast, smart devices are portray globally as 46 percent of the total mobile devices and connections, while being accounted for 89 percent of the mobile data traffic in 2016 [6]. On an average, a smart device is able to produce 13 times more traffic, compared to non-smart devices [6]. With this rapid development of wireless data services, mobile Internet and smart devices has prompted the investigation of the 5G cellular network. It is estimated by 2020, the deployment 5G mobile networks will be released the capabilities to support multimedia applications with various of requirements, including larger peak and user data rates, lower latency, enhanced indoor coverage, improved energy efficiency, and many more [11].

This chapter overviews of Fifth Generation (5G) cellular networks in Section 2.2. Then, in Section 2.3, a discussion on HetNet, which include the conceptual idea, issues and its solutions, is provided. Meanwhile, Section 2.4 reviews about mobility management, this include the functions and operations which may be related to location and handover management. In addition, Section 2.5 discusses the energy related issues in HetNets and its potential existing and implementation in cellular networks.

2.2 Fifth Generation Cellular Networks

Mobile devices have grown at an exponential rate over the past 10 years, beginning from a tiny screen of a monochrome device and a small processing power to incredibly high-resolution palm-sized screen and a powerful processor. With this, combined with the broadening cache of bandwidth ravenous applications have prompt the demands for higher data rates [9]. According to Cisco VNI Mobile 2017, global mobile data traffic will rise up to sevenfold between 2016 and 2021. Mobile data traffic will increase at a compound annual growth rate (CAGR) of 47 percent from 2016 to 2021, touching 49.0 exabytes per month by 2021 [6] .

Mobile service providers faced several issues and challenges, whenever it comes to new wireless applications with the ever-increasing number of user on connected devices. Even with the Fourth Generation wireless communication (4G) systems that is able to support data rates of up to 1Gbps for low mobility and 100Mbps for high mobility, there are still a number of challenges that failed to be accommodated by 4G [12][13]. For instances, mobile communications have stated that physical scarcity of radio frequency (RF) spectra is crucial. By using ultra-high-frequency bands for mobile frequencies, the frequency spectra have been employed heavily, resulting limited range for operators. Moreover, high-energy consumption is another cost to consider while deploying advanced wireless systems, which resulted in the increase of carbon dioxide emission as the requirement for the 4G wireless system was not an energy-efficient communication. However, it was an issue that appeared in a later stage. To address these issues, 5G mobile architecture is implemented [13].

It is envisioned that 5G mobile architecture features seamless connectivity, low latency, high data transfer and network capacity, low power consumption, better security and privacy, improved interference and handover management and better quality of service (QoS). With such revolutionary scope and advantages of the envisioned 5G, it requires a new form of architecture, methodologies and technologies. This is illustrated by energy-efficient heterogeneous frameworks, cloud-based communication, network function virtualization (NFV), self-interference cancellation (SIC), device-to-device (D2D) communications, and machine-to-machine (M2M) communications. The 5G now also allow dense-deployment, backhaul connections, massive multiple-input and multiple-output (mMIMO), multi-radio access technology (RAT) architectures. Notably, 5G is more than an improved 4G network, but it is a system architecture conceptualization, visualization, and redesigning at each form communication layer [14].

2.3 Heterogeneous Networks

In recent years, there has been a massive increase in the number cellular devices, which has led to a surge in the need for data rate. This has cause mobile operators to seek new ways and approaches in facilitating larger network capacity, providing better coverage and decreasing the network congestion [15]. The existing cellular architectures created solely to cover large areas failed to provide a good throughput for a seamless connection in the uplink, especially when the user move further away from the base station as this led to increase to transmission power, which in turn reduce battery life. In addition, poor indoor penetration and presence of dead spot by macrocell often lead to a reduced indoor coverage [16]. According to experts, HetNet is the key solution to address this issue [15]. HetNet refers to the use of multiple types of access nodes consisting of macrocells and small cells such picocells and femtocell. A HetNet offer cellular coverage in various environment ranging from an outdoor environment to corporate building, homes and underground areas [17]. The macro-tier ensure the coverage, while the overlay network is a means to offload the data traffic from the macrocell network and fulfill the local capacity demand. Small cells in this two-tier architecture can be micro-cells, picocells or femto-cells, where the variation of small cells type depends on the cell size and its ability to auto-configure and auto-optimize. Small cells help by increasing the network coverage and the smaller cell-sized give an increased spatial frequency reuse and better network capacity, thus achieving increased data rates while maintaining a seamless connectivity and mobility in cellular networks [18].

Nevertheless, there are limits to how far the idea of HetNet can be taken. The authors pointed out with a HetNet, the capacity demand can be solved. Even so, one of the main obstacles in deploying HetNet is to manage interference among cells [19]. HetNet has three overall channel allocation schemes among tiers, specifically orthogonal deployment, co-channel deployment, and partially shared deployment. With small cell tier, base stations (BSs) are usually utilized in a random manner, resulting an extravagant co-channel interference in heterogeneous networks than in conventional single-tier. Thus, experts view interference management as something critical due to the severity of the co-channel interference under both intra-tier and inter-tier. In order to implement interference management, but also to increase spectral efficiency and energy efficiency, a new cell cluster scheme is needed to be introduced. It is then found out that interference-minimized user association help decrease the downlink interference in multi-tier in HetNet while the limitation on the QoS of users is satisfied [20].

As a method to control inter-cell interference, time or frequency resources are allocated in an intelligent manner across multiple cells, by identifying which BSs should transmit on which channels, and at which time instance. However, researchers identified that resource allocation will pose an issue in HetNet which is increasingly coupled with user association policy. In macro-only cellular network, a user is associated to the BS with the greatest downlink signal strength as the user association can be decoupled from the resource allocation. But in

HetNet, the association policy causes macrocells resource to be limited, while the small cells is severely underutilized, on account of large discrepancy in the transmit power. In addition, when balancing the load, a user may remain connected to a small cell, despite the received power from a macro BS is higher. This consequently cause severe interference and large cell-splitting gain, if the radio resources are not carefully partitioned among cells. Thus, experts has suggested joint user association and interference management in HetNet [20].

In addition, other literature have indicated that HetNets face several issue regarding seamless handover. In a cellular network, the handover management is the process in which the mobile device maintain its active connection as the user moves from one location to another due to the small coverage area provided by a single BS transceiver [21]. At the same time, HetNet can maintain uninterrupted connection, as well as, improve the performance of the entire network and the user's QoS by shifting an active user session in one BS to another. While the coverage area, propagation of signal and transmission power vary, the handover in HetNet is much more complicated and more intelligent. However, with small cell deployed overlaid each other, it often causes excessive handover and inter-cell interferences. To solve the excessive handover, the coverage range of small is increased via decreasing the handover threshold. It is noted when increasing the coverage range the signal-to-interference-plus-noise ratio (SINR) of small cell UEs will decrease and corresponding the throughput as such careful trade-off should be made [22].

2.4 Mobility Management

With the rapid pace of technology, more users demand for higher data rate and better coverage as cellular devices are becoming easily available and inexpensive [23]. Moreover, there are numerous wireless technologies and networks that have been developed to meet different demand and necessity of cellular users. To add, the deployment of these network allows user to stay connected to the best available access network as the different wireless network are interdependent to each other. In addition to their ability and compatibly for distinct application. Through the implementation of HetNet, however, heterogeneities will occur in access technologies and network protocols. In order to fulfil user necessity under the heterogeneous environment, a joint framework is tasked to connect multiple access networks whenever required. An adaptive protocol stack is still needed to balance the various characteristics and properties of the networks, even though, IP protocol is identified as the default protocol for future integrated network in an operation between several of communication protocols. With adaptive and intelligent terminal devices and BSs of multiple air interfaces, users are able to connect in a seamless manner between different access technologies. To obtain an efficient delivery of services, wireless network need a proper mobility management schemes where the location of each user is determined before the service is send [24].

As such, BSs area coverage usually are integrated into a single zone. A location notification is aimed to permit cellular device to acknowledge or notify a network whenever it moves from one location to another. When a user moves from one area to another, the cellular device will detect a new area code from previous update and execute a location update by sending a location request to the Specific Temporary Mobile Subscriber Identity, and previous location and network. Essentially, mobile terminal provide data regarding on updated network location like reselection of cell location area. The location area is mainly a cluster of BSs that function to optimize signal, these BSs are combined together to make a single network area under the umbrella of a base station controller (BSC). BSC's role is to manage the assignment of radio channels by obtaining the signal strength measurements from cellular devices, as well as, to control handoffs from base stations to another base stations. In addition, one of the key features of mobility management is roaming. Roaming ensures the user a smooth connection service while being mobile beyond a geographical area of a specific network. The user's life pattern is influence by the growth of development of communication sector of various stage, the fixed interconnection stage, the fixed and wireless interconnection as well as the mobile interconnection stage [25].

Besides this, mobility management handles the location of user for data delivery, maintenance for the user connection during the conversion of one base station to another. The mobility management is also related to location and handoff managements. Mobility management allows communication network to pinpoint the roaming terminal location, as a way to send data packet like function for static scenario, as well as to maintain connection with terminal that is moving into new areas such as function for dynamic scenario [21].

In the literature, location management is termed as a process, which allow the system to find out the cellular device's current location, for example, the current network attachment point where the cellular device can receive data from the system [24]. This includes crucial tasks like location update and call delivery. From a location update, a cellular device regularly