LONG TERM EVOLUTION MULTIMEDIA BROADCAST AND MULTICAST SERVICES IN SINGLE FREQUENCY NETWORK

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

FEBRUARY 2015

Specially dedicated to my beloved mother, father, family and friends

ACKNOWLEDGEMENT

"In the Name of ALLAH, the Most Gracious and the Most Merciful"

I would like to express my utmost gratitude to Allah S.W.T and also to my supervisor Dr Norhudah Seman, for spending her valuable time in providing the supports, guidance, motivation and encouragement throughout the period of completing this project.

Secondly, I also would like to thank to my family for their continuous support, motivation and pray. Then special thanks to my co-supervisor Dr Leow Chee Yen and my friends in Wireless Communication Center (WCC) for guidance and continuous help.

My appreciation also goes to Ministry of Education (MOE), University Teknologi Mara (UiTM), Universiti Teknologi Malaysia (UTM) and Hi- CoE WCC for financial support and facilities.

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ABSTRACT

The emerging of broadcasting in wireless telecommunication has brought many interesting features to the users. Besides, the evolution in communication devices such as mobile phones and tablets has introduced many interesting applications that satisfy the user demands. One of them is Multimedia Broadcast and Multicast Service (MBMS) that has been reintroduced in Long Term Evolution (LTE) technology. However, the increment in users' traffic decreases the average data rate performance. This problem becomes more critical when the service is accessed in indoor area and at the cell edge. Indoor users experience signal loss due to wall penetration while users at cell edge face interference from the adjacent cells. To overcome the problem, Single Frequency Network (SFN) is chosen to deliver LTE MBMS as it is able to produce almost consistent data rate and Signal to Interference plus Noise Ratio (SINR) for the user even in cell edge area. It is based on broadcasting technology but using mobile platform to deliver the service. LTE MBMS over SFN employs multi cell transmission where all evolved Node B (eNB) are transmitting the same signal by using the same frequency carrier. The existing eNB infrastructures and frequency resources can be used in its implementation. The performance is evaluated in indoor and outdoor environment by using propagation models such as 3GPP TR 36.814, Okumura-Hata and ITU-R in LTE utilizing digital dividend frequency bands. The investigation aims to tackle the shortcoming in the existing reported research as none of them focusing on different carrier frequency and propagation models. The average data rate for the SFN model is simulated in SEAMCAT simulator with various number of User Equipment (UE). The evaluation in outdoor and indoor environment is continued with SINR evaluation in different UE locations and propagation models. The carrier frequency is varied for both evaluations and all the calculations involved are computed in MATLAB. The results show that the MBSFN performance improves by 9.53% in average data rate and SINR values increases up to 40.28% by using digital dividend frequency compared to other conventional carrier frequency. These findings can be used as a reference for future MBMS implementation.

ABSTRAK

Kemunculan penyiaran di dalam telekomunikasi tanpa wayar telah membawa pelbagai ciri yang menarik kepada pengguna. Selain itu, evolusi alat-alat perhubungan seperti telefon bimbit dan *tablet* telah memperkenalkan banyak aplikasi menarik yang memuaskan permintaan pengguna. Salah satu daripadanya ialah Perkhidmatan Penyiaran Multimedia dan Multisiar (MBMS) yang diperkenalkan semula di dalam teknologi Evolusi Jangka Panjang (LTE). Walau bagaimanapun, kenaikan dalam trafik pengguna mengurangkan prestasi kadar purata data. Masalah ini menjadi lebih kritikal apabila perkhidmatan dicapai di dalam kawasan bangunan dan di pinggir sel. Pengguna di dalam bangunan akan mengalami kehilangan isyarat akibat daripada penembusan dinding manakala pengguna di pinggir sel berdepan dengan gangguan daripada sel-sel bersebelahan. Untuk mengatasi masalah itu, Rangkaian Frekuensi Tunggal (SFN) dipilih untuk menghantar LTE MBMS kerana ia dapat menghasilkan kadar data dan Nisbah Isyarat kepada Gangguan dan Hingar (SINR) yang hampir konsisten untuk pengguna walaupun di kawasan pinggir sel. Ia berasaskan teknologi penyiaran tetapi menggunakan platform telefon bimbit untuk menyampaikan perkhidmatan MBMS LTE di atas SFN menggunakan pelbagai sel penghantaran di mana semua Nod B terevolusi (eNB) menghantar isyarat yang sama dengan menggunakan frekuensi pembawa yang sama. Infrastruktur dan sumber frekuensi yang sedia ada boleh diguna dalam pelaksanaannya. Prestasi yang dinilai dalam persekitaran dalaman dan luaran dengan menggunakan model perambatan 3GPP TR 36.814, Okumura-Hata dan ITU-R dalam LTE dan jalur frekuensi dividen digital. Penyiasatan ini adalah untuk menangani kekurangan yang telah diperhatikan melalui penyelidikan semasa yang dilaporkan kerana tiada satu pun yang menumpukan kepada frekuensi pembawa dan model-model perambatan yang berbeza. Kadar purata data untuk model SFN adalah disimulasi menggunakan SEAMCAT dengan pertambahan bilangan Pengguna Peralatan (UE). Penilaian dalam persekitaran luaran dan dalaman adalah menerusi penilaian SINR di lokasi UE dengan model-model perambatan yang berbeza. Frekuensi pembawa telah dibezakan bagi kedua-dua penilaian dan semua pengiraan yang terlibat adalah dikira menggunakan MATLAB. Keputusan menunjukkan prestasi MBSFN meningkat 9.53% dalam purata nilai data dan peningkatan SINR sehingga 40.28% menggunakan frekuensi dividen digital. Penemuan ini boleh diguna sebagai rujukan untuk pelaksanaan MBMS pada masa hadapan.

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LIST OF ABBREVIATION

2G	-	Second Generation
3G	-	Third Generation
3GPP	-	Third Generation Partnership Project
4G	-	Fourth Generation
16QAM	-	16 Quadrature Amplitude Modulation
64QAM	-	64 Quadrature Amplitude Modulation
bps	-	Bits per second
BS	-	Base Station
CEPT	-	European Conference of Postal and Telecommunication
DAB	-	Digital Audio Broadcasting
DVB	-	Digital Video Broadcasting
eMBMS	-	Evolved Multimedia Broadcast and Multicast Service
E-UTRA	-	Evolved Universal Terrestrial Radio Access
E-UTRAN	-	Evolved Universal Terrestrial Radio Access Network
eNB	-	Evolved Node B
EU	-	European Union
FDD	-	Frequency Division Duplex
GE06	-	Geneva 2006 Agreement
GSM	-	Global System for Mobile Communication
GPRS	-	General Packet Radio System
GHz	-	Giga Hertz
Hz	-	Hertz
HSDPA	-	High-Speed Downlink Packet Access
HSDPA+	-	Evolved High- Speed Packet Access
HSUPA	-	High-Speed Uplink Packet Access
HeNB	-	Home evolved Node B
ICI	-	Intercarrier Interference

ICIC	-	Intercell Interference Coordination
ISI	-	Intersymbol Interference
ITU-R	-	International Telecommunication Union, Radio Communication Sector
IMT	-	International Mobile Telecommunication
IPTV	-	Internet Protocol Television
IMT	-	International Mobile Telecommunication
kHz	-	Kilo Hertz
km	-	Kilometer
LTE	-	Long Term Evolution
LTE-A	-	Long Term Evolution Advanced
MBMS	-	Multimedia Broadcast and Multicast Services
Mbps	-	Mega bits per second
MBSFN	-	MBMS in Single Frequency Network
MCS	-	Modulation Coding Scheme
MHz	-	Mega Hertz
MIMO	-	Multiple Input Multiple Output
MME	-	Mobility Management
OFDM	-	Orthogonal Frequency Division Multiplex
Ptm	-	Point to multipoint
Ptp	-	Point to point
QPSK	-	Quadrature Phase Shift Keying
RF	-	Radio Frequency
SFN	-	Single Frequency Network
SINR	-	Signal to Interference plus Noise Ration
SEAMCAT	-	Spectrum Engineering Advanced Monte Carlo Tool
TDD	-	Time Division Duplex
TV	-	Television
UE	-	User Equipment
UHF	-	Ultra High Frequency
UL	-	Uplink
UMTS	-	Universal Mobile Telecommunication Systems
VHF	-	Very High Frequency
WiFi	-	Wireless Fidelity

LIST OF SYMBOLS

τ	-	Propagation Time Delay
δ_j	-	Additional Time Delay
θ	-	Angle
δ_k	-	Nominal Distance
λ	-	Wavelength
A_h	-	Surrounding losses equation
C	-	Speed of light
f	-	Frequency
f_c	-	Carrier Frequency
h_a	-	Clutter height
h_b	-	Height of base station
h_t	-	Height of transmitter
h_r	-	Height of receiver
k_{wi}	-	Number of penetrated wall
L_c	-	Constant loss
L_{fs}	-	Free space loss between transmitter and receiver
L_{iw}	-	Penetration loss of indoor wall
L_{ow}	-	Penetration loss of outdoor wall
N_o	-	Spectral Noise Density
P_i	-	Power
PL_{free}	-	Free Space path loss
q_i	-	Propagation path loss
r_i	-	Distance between UE to adjacent eNB
r_o	-	Distance between UE to reference eNB

T_{CP}	-	Cyclic prefix time
T_u	-	Useful Time frame
w	-	Weight function

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CHAPTER 1

INTRODUCTION

1.1 Background

Recently, most of the communication technology has move towards the digital technology to satisfy users demand. With the evolution of communication technology, the digital communication then has been introduced with many advantages and attractive features to the various wired and wireless services. Wireless communication is one of the rapidly progressing technologies with the introduction of wireless broadband and also the improvement from the previous technology to fulfil the increasing user demand. The growth in the number of smart phones [1] and tablet computer devices in the market contributes to the high traffic demand [2-3].

With the evolved wireless technology and increasing demand for multimedia services, mobile phones or handheld devices have potential to be used in broadcasting beside of other established services such as terrestrial television (TV) and internet protocol television (IPTV). Therefore, this leads to the prediction of more than 70% data rate traffic generated from mobile phones indoor in future as reported in [4] and in 2015 mobile video will generate two third of world's mobile data traffic [5].

The major problem in wireless communication is signal fading or loss due to the propagation of the signal through the wireless channel [6]. The degradation of the signals is affecting the signal coverage and data throughput performance. In addition, the increment of users leads to a higher traffic demands. Therefore, any newly introduced technologies need to overcome these problems, which can promise better signal coverage, higher data rates and higher data throughput. This is to ensure that the requirements specified by International Mobile Telecommunications (IMT) are fulfilled.

Beside that, spectrum efficiency also needs to be concerned to make sure that the future radio technology can be implemented. Spectrum efficiency is one of the important factors because of various digital radio technologies such as digital audio broadcasting (DAB), digital video broadcasting (DVB), Global System for Mobile Communications (GSM), General Packet Radio System (GPRS) and Universal Mobile Telecommunications Systems (UMTS) require large frequency spectrum. Since the radio spectrum is very limited, it needs to well planned and utilized so that other services can be introduced and implemented in the future. So, the Multimedia Broadcast and Multicast Service (MBMS) is one of the best alternatives in broadcasting technologies because of the efficient method in delivering multimedia content which at the same time, allows sharing of frequency resources between adjacent cells. This can be realized through Single Frequency Network (SFN) technique in indoor and outdoor area.

This research aims to investigate the use of Multimedia Broadcast and Multicast Service (MBMS) in Long Term Evolution Technology (LTE) in multimedia broadcasting. This service is based on the cellular technology as it originates from the evolution of cellular mobile services as depicted in Figure 1.1.

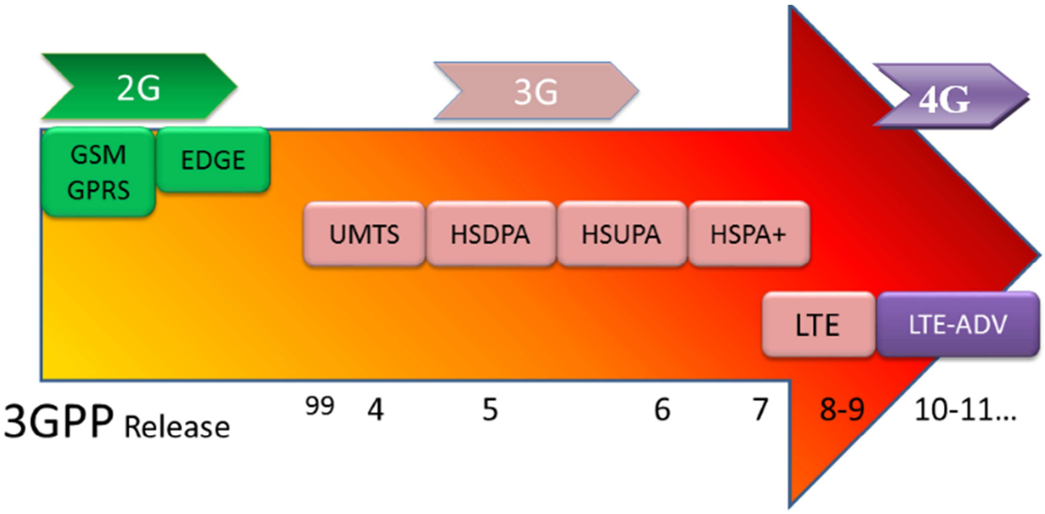

Figure 1.1 The evolution of Mobile Technology [7]

Figure 1.1 shows the evolution in mobile technology, where it started with Global System for Mobile Communication (GSM), General Packet Radio Service (GPRS) and Enhanced Data for Global Evolution (EDGE), commonly known as the second generation 2G. After that, it is evolved to third generation (3G) that starts with Universal Mobile Telecommunication System (UMTS) to High-Speed Downlink Packet Access (HSDPA), High-Speed Uplink Packet Access (HSUPA), Evolved High Speed Packet Access (HSPA+) and the early version of LTE. However, the increasing in user demand always exists and the evolution to the fourth generation (4G) is to overcome this problem, where the LTE-Advanced (LTE-A) is introduced.

The MBMS is a technology offered by Third Generation Partnership Project (3GPP) for distribution of multimedia content. MBMS has been introduced earlier in Universal Mobile Telecommunications System (UMTS) [8] and later re-introduced in LTE Release 8. Although the evolution is originally to improve the shortcomings of previous technologies but the problem with signal degradation still remains. To overcome this, the MBMS implementation in Single Frequency Network is proposed. Challenges in implementation of this service will be discussed in this thesis and related solution will be recommended to solve the problems.

1.2 Problem Statement

Multimedia Broadcast and Multicast Service (MBMS) is one of the promising alternatives in delivering multimedia contents to mobile users. Existing mobile broadcasting technology relies on frequency reuse technique, which is not efficient in spectrum and frequency usage. This can be due to each cell is assigned with different frequency. With the high number of the user equipment (UE), the system performance can be severely degraded, by traffic congestions [9],[10]. This problem is detrimental especially when the UEs are located at the cell edge indoor area. This is due to the signal degradation contributed by interference from adjacent cells and propagation loss from the building walls.

In the case of broadcasting, most of the user access to the multimedia services indoor where it signal loss is a major problem. The service connection become worse when a lot of users are accessing to the service simultaneously, especially during peak hours. This problem becomes critical when the broadcast service is delivered to the portable devices such as handheld devices, where the signals need high power to propagate through. For example, in the urban area that has a lot of high buildings and high population, the signal is easily attenuated by the obstruction of buildings and congestion occurred from the higher traffic demand, respectively.

Therefore, the Single Frequency Network (SFN) is proposed in this thesis to improve the performance of the MBMS service. It is expected that the implementation of SFN will provide almost consistent data throughput even though the number of users are increasing. In addition, it is also capable to reduce the traffic congestion from Base Station (BS).

Existing research in MBMS only focuses on the 2 GHz carrier frequency such as reported in [11],[12],[13],[14]. Lack of interest shown in the other carrier frequency such as 2600 MHz, 1800 MHz, 900 MHz, 800 MHz and 700 MHz because most of the carrier frequencies are used for other services. Besides that, in Malaysia the analogue broadcasting is expected to be switched off in 2015, where fully digital broadcasting takes over. When the transition is started, there will be empty spaces especially in ultrahigh frequency (UHF) band. This empty space is called digital dividend band [15],[16]. The available spectrum in digital dividend band can be fully utilized by current and future wireless technologies including MBMS [17],[18]. As the expected available spectrum is from 470 MHz to 862 MHz, this lower carrier frequency than LTE 1.8 GHz and 2.6 GHz is expected to offer a larger coverage. Therefore, it is essential to investigate the operating frequency lower and/or higher than 2 GHz in the implementation of MBMS. In this thesis the other carrier frequencies chosen are 700 MHz, 800 MHz, 900 MHz, 1800 MHz and 2600 MHz. The 700 MHz and 800 MHz are used to utilize the digital dividend band, while 900 MHz, 1800 MHz and 2600MHz are in GSM and LTE frequency bands.

The successful of data delivery of the MBMS service is determined by the data throughput, coverage of the signal, bandwidth allocation and multi-user usage. Therefore, good signal coverage is important to guarantee accessible services to the users. Without good signal coverage, the communication data cannot be delivered to users. Other than that, the good signal coverage will contribute to high data throughput as it is one of the major concerns in digital communication. It is known that, the carrier frequency as well can influence the data rate and data throughput of the system as the carrier frequency itself determine the signal coverage. The lower frequency carrier has better penetration and lower path losses. So, this proposed study can provide a solution in improving the signals coverage, especially when the user is located at the cell edge and also inside a building.

1.3 Research Objectives

This research is conducted to solve the defined problems with the following objectives:

1. To investigate the performance of the Multimedia Broadcast and Multicast Services (MBMS) in Single Frequency Network (SFN)

deployment for frequencies in digital dividend band of 700 MHz and 800 MHz, and cellular band 900 MHZ, 1800 MHz and 2600 MHz with increment number of UE.

2. To study the UE’s Signal to Interference plus Noise Ratio (SINR) in indoor and outdoor environment with different propagation models and carrier frequencies in Multimedia Broadcast and Multicast Service for Single Frequency Network (MBSFN).

1.4 Scope of the research

This research considers the LTE MBMS in Single Frequency Network for downlink (DL) since only the data transmission to the user is concerned in broadcast communication. This is due to it has simplex system where the base station only transmitting the signal without involving uplink (UL) for user’s feedback signal. The Single Frequency scenario needs to be developed first and then the performance of the system will be evaluated with different carrier frequency, which in this case the frequency are 700 MHZ, 800 MHz, 900 MHz , 1800 MHz and 2600 MHz. All data and analysis are from the simulation results and mathematical calculation.

1.5 Significance of the research

MBMS is one of the alternatives in the delivery of multimedia contents. This service is good in spectrum usage where it can be implemented in any frequency band especially the digital dividend band. The usage of the service is not limited to outdoor but in indoor area as well. With the introduction of SFN for outdoor, it improves the UE performance at the cell edge, while for home or small building, it improves the indoor signal coverage without being interfered by base station or known as evolved Node B (eNB).

Other than that, compared to the previous works which focusing only on 2 GHz as the carrier frequency in SFN, the proposed research looks into other possible carrier frequencies too. The other carrier frequency is explored with the used of different path loss equation. Then, the new derived path loss equations are presented for femtocell area so that they can be used for other carrier frequencies. Therefore, in this study the challenge is to create a suitable actual SFN scenario that can be used in the investigation. The performances of the MBSFN with different carrier frequencies are evaluated. This study is expected to be useful as a reference in the MBSFN implementation.

1.6 Research Contribution

This research is to investigate the performance of MBMS in SFN in indoor and outdoor area. The investigation considered the carrier frequency of 700 MHz, 800 MHz, 900 MHz, 1800 MHz and 2600 MHz for the UE in indoor and outdoor area. Different propagation path loss models are used and derived. Other than that, this research also introduced the digital dividend frequency 700 MHz and 800 MHz as the alternative carrier frequency for the implementation of new mobile technology and features.

1.7 Thesis Outline

This thesis consists of five chapters. Chapter 1 consists of the introduction of the research. It includes the background, problem statement, objectives, scope and significance of the research. Then from the problem statement, literature review on the related works is discussed in Chapter 2. The review is started with the previous broadcast technology and evolution towards MBMS technology. This evolution of broadcasting has created the digital dividend with the migration to the digital services and broadcast via handheld devices such as MBMS service in LTE. In addition, previous reported research on MBMS is reviewed in Chapter 2. Most of the researches concentrate only on 2 GHz carrier frequency and 3GPP model.

Next, Chapter 3 describes the proposed research methodology in conducting the study. All the required equations, procedures and parameters are explained thoroughly while the research stages are summarized in the flow chart. Simulation tools that used in this research also discussed in this chapter including the simulation and the calculation procedures

Then, Chapter 4 presents the results obtained from two different scenarios of the MBSFN in outdoor and indoor area. The evaluation of the performance in the outdoor area is in terms of the data rate of the system with the increment number of user usage. It concerns the simulation of the traffic congestion in the actual scenario. After that, the evaluation continues to UE’s SINR in outdoor especially in urban environment. The UE’s SINR evaluation in indoor area is performed with different carrier frequencies and propagation path loss models. Finally in Chapter 5, conclusion of the presented research and findings in this thesis is drawn. The future works to enhance the research on MBMS are suggested at the end of the chapter.

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