RESOURCE ALLOCATION BASED ON INTERFERENCE COORDINATION FOR MULTICAST-BROADCAST SINGLE FREQUENCY NETWORK (MBSFN)

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FACULTY OF ENGINEERING
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DISSERTATION SUBMITTED IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ENGINEERING SCIENCE

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ORIGINAL LITERARY WORK DECLARATION

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Abstract

The Multimedia Broadcast Multicast Service (MBMS) in Long Term Evolution (LTE) becomes a new technique of delivering the data to the user. It can save the available spectrum since it is shared in one dedicated channel. With enormous development in wireless mobile communication, this service can be easily implemented to achieve high system capacity and system throughput. However, there will be an issue regarding the limited available resources in the heterogeneous system. Therefore, one technique has been adapted from Digital Video Broadcasting-Terrestrial (DVB-T) called Multimedia Broadcast Multicast Service over Single Frequency Networks (MBSFN). In MBSFN, the data content is transmitted synchronously from multiple transmitters in a respective area. The receiver will receive multiple signals and interpret it either it is useful or destructive so that it can differentiate which signal to process. Thus, this approach will improve the spectral efficiency of the signal by only selecting the constructive signal. However, the performance of MBSFN is still restricted in the area that closes to adjacent MBSFN areas due to the impact of external interference from neighbouring MBSFN area. The method to minimize the interference has been studied carefully. The strategy of allocating the resource by static or dynamic allocation can coordinate the interference issue. In static resource allocation, the fixed frequency allocation is to be planned for each MBSFN area by adopting the frequency reuse technique such as traditional frequency reuse and fractional frequency reuse. Likewise, in dynamic resource allocation, the resource is allocated dynamically based on the calculated interference level. Genetic algorithm has been implemented to find the solution of allocating the static of pool of frequency respectively to the MBSFN area and to coordinate its interference (SFA-GA). The impact of interference in each frequency reuse scheme has been evaluated by calculating its SINR. For dynamic resource allocation, we proposed the game theory technique to allocate the

pool of resources (DRA-IC). SFA-GA would give the solution of how to allocate the frequency based on frequency reuse to the respective MBSFN area . Results show higher frequency reuse scheme reduce the impact of interference. However, in DRA-IC scheme give better performance compared to SFA-GA due to the allocated resources are dynamically distributed with better coordinated interference level.

Abstrak

Perkhidmatan Penyiaran Multimedia dan Multicast (MBMS) dalam Long Term Evolution (LTE) merupakan teknik baru bagi menyampaikan data kepada pengguna. Ia boleh menjimatkan spektrum yang ada kerana ia dikongsi di dalam satu saluran yang berdedikasi. Dengan perkembangan yang pesat dalam komunikasi mudah alih tanpa wayar, perkhidmatan ini boleh dilaksanakan dengan mudah untuk mencapai kapasiti sistem dan system pemprosesan yang tinggi. Walau bagaimanapun, isu mengenai sumber yang terhad di dalam sistem heterogen akan berlaku. Oleh itu, satu teknik yang telah disesuaikan daripada Penyiaran Video Digital-Terestrial (DVB-T) yang dikenali sebagaidi Perkhidmatan Penyiaran Multimedia Multicast dalam Rangkaian Frekuensi Tunggal (MBSFN). Bagi MBSFN, kandungan data akan dihantar serentak dari pemancar berganda di kawasan masing-masing. Penerima akan menerima isyarat berbilang dan mentafsirkannya sama ada ia adalah isyarat yang berguna atau merosakkan. Pendekatan ini akan meningkatkan kecekapan spektrum isyarat. Walau bagaimanapun, prestasi MBSFN masih terhad di kawasan yang berdekatan dnegan kawasan MBSFN bersebelahan disebabkan kesan gangguan luar dari kawasan MBSFN yang lain. Kaedah untuk meminimumkan gangguan telah dikaji dengan teliti. Strategi memperuntukkan sumber oleh peruntukan statik atau dinamik mampu menyelaraskan isu gangguan. Dalam peruntukan sumber statik, peruntukan frekuensi tetap perlu dirancang bagi setiap kawasan MBSFN dengan mengamalkan teknik frekuensi semula seperti penggunaan semula frekuensi tradisional dan penggunaan semula frekuensi pecahan. Begitu juga, dalam peruntukan sumber yang dinamik, sumber diperuntukkan secara dinamik berdasarkan tahap gangguan yang telah dikira. Algoritma genetik telah dilaksanakan sebagai satu teknik untuk mencari penyelesaian memperuntukkan frekuensi tetap masing-masing untuk kawansan MBSFN

dan menyelaras gangguan (SFA-GA). Impak gangguan dalam setiap skim penggunaan semula frekuensi telah dinilai dengan mengira SINR. Bagi peruntukan sumber dinamik, kami mencadangkan teknik permainan teori untuk memperuntukkan sumber yang ada (DRA-IC). SFA-GA akan memberi penyelesaian bagaimana untuk memperuntukkan frekuensi berdasarkan frekuensi penggunaan semula untuk kawasan MBSFN masing-masing. Keputusan menunjukkan skim penggunaan semula frekuensi yang lebih tinggi akan mengurangkan kesan gangguan. Walau bagaimanapun, dalam skim SRA-IC akan memberikan prestasi yang lebih baik berbanding dengan SFA-GA kerana sumber yang diperuntukkan secara dinamik diedarkan dengan tahap gangguan yang lebih baik diselaraskan.

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First of all I would like to express the deepest gratitude to my supervisor Dr. Kamarul Ariffin Noordin for his support, encouragement and help throughout my master studies. To Mr. Faizal Bin Ismail who always give me ideas, advice and help to keep me strong finishing this project. I would also like to give sincere appreciation to my master colleague who assisted me and their invaluable advice. Finally, I appreciate the contribution made by University of Malaya as a whole for giving me the opportunity to further my study and providing financial support.

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TABLE 5.1 SYSTEM PARAMETER

List of Abbreviations

3G	-	Third Generation
4G	-	Fourth Generation
3GPP	-	Third Generation Partnership Project
CBS	-	Cell Broadcast Service
CP	-	Cyclic Prefix
CQ	-	Channel Quality Indicator
DRA-IC	-	Dynamic Resource Allocation with Interference Coordination
DVB	-	Digital Video Broadcasting
DVB-T	-	Digital Video Broadcasting-Terrestrial
eNB	-	eNodeB
E-UTRA	-	evolved UMTS Terresterial Radio Access
FM	-	Frequency Modulation
GA	-	Genetic Algorithm
GSM	-	Global System for Mobile Communications
IP	-	Internet Protocol
ISD	-	Inter Site Distance
LTE	-	Long Term Evolution
MB	-	Multimedia Broadcast
MBMS	-	Multimedia Broadcast Multicast Service
MBSFN	-	Multimedia Broadcast Multicast Service over Single Frequency Networks
MCS	-	Modulation and Coding Scheme
NP	-	Nondeterministic Complexity Theory

OFDM	-	Orthogonal Frequency Division Multiplexing
OFDMA	-	Orthogonal Frequency Division Multiple Access
PRB	-	Physical Resource Blocks
QAM	-	Quadrature Amplitude Modulation
P-t-M	-	Point-to-Multipoint
QPSK	-	Quadrature Phase Shift Keying
SINR	-	Signal to Interference Plus Noise Ratio
SFA-GA	-	Static Frequency Allocation using Genetic Algorithm
SFN	-	Single Frequency Network
Sync	-	Synchronize
TTI	-	Travel Time Interval
TUX	-	Typical Urban Channel Model
TV	-	Television
Tx	-	Transmitter
UMTS	-	Universal Mobile Telecommunications System
UTRAN	-	UMTS Terrestrial Radio Access Networ

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Chapter 1: Introduction

1.1 Background

Certainly, tomorrow's mobile market place will be characterized by bandwidth-hungry such as multimedia services which are already implemented in wired networks. Thus, the next generation wireless communication systems such as Long Term Evolution (LTE) has been developed by 3rd Generation Partnership Project (3GPP) to fulfil the demand of multimedia services. The main purpose of 3GPP LTE is to enhance data rate, latency, and optimizing the packet data. LTE supports scalable channel bandwidth of 5, 10, 15 and 20 MHZ which can provide peak data rates target up to 100 Mbps (downlink) and 50 Mbps (uplink) for 20 MHz spectrum allocation. Furthermore, it can support user mobility of 350km/h with a latency of 10 milliseconds with the coverage of 30 km. LTE foresees Orthogonal Frequency Division Multiple Access (OFDMA) as the downlink physical layer.

The 3GPP committee has introduced the Multimedia Broadcast Multicast Service (MBMS) as a means to broadcast and multicast information to 3G and 4G users. MBMS is an efficient method for delivering multimedia content to multiple destinations by allowing resources to be shared in an economical way. This is much more efficient than IP multicast where packets are duplicated for each receiver in a broadcast or multicast group.

Generally, for the transmission modes of wireless communication, they consist of unicast, multicast and broadcast. The Unicast is a one-to-one transmission mode between a transmitter and a receiver for example phone call. Whereas, multicast is a transmission mode between a transmitter and multiple receivers where the receivers must have the authority to access to the data or in a multicast subscription group for instances are streaming multimedia and video conferencing. Broadcast is a transmission from a transmitter to all receivers who willing to receive the data in free condition such as radio FM broadcasting and television broadcasting.

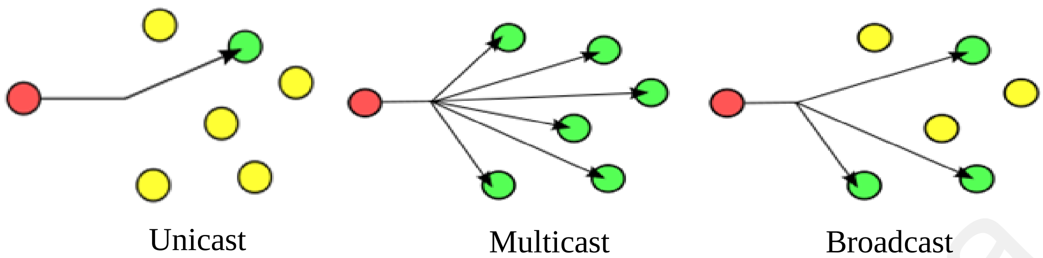


Figure 1.1: Connection methods in wireless communication

In MBMS, the Multimedia Broadcast (MB) is the broadcast mode that uses already existing cell broadcast service (CBS) that was intended for messaging only. Multicast mode allows sending multimedia content for end users that are part of a multicast subscription group. MBMS allows broadcast services with existing GSM and UMTS. Therefore MBMS will be deployed as low cost and less infrastructures as it utilizes existing cellular networks.

1.2 Motivation

Live mobile TV, newscasts, and weather forecasts are the mobile multimedia services that need to be distributed to of multiple users. To support those services in cellular networks, MBMS was introduced by 3GPP in Release 6, which use point-to-multipoint (P-t-M) transmission to efficiently utilize radio resources to supports a large numbers of users at a same time. It improves the scalability of broadcast and multicast in cellular networks by efficiently deliver multimedia content to multiple receivers or users by allowing resources to be shared in a cost effective way, and thus minimizing the usage of network resources. However, there are some issues regarding the implementation of broadcast which use the point-to-multipoint method. Users that are located at the cell edge usually

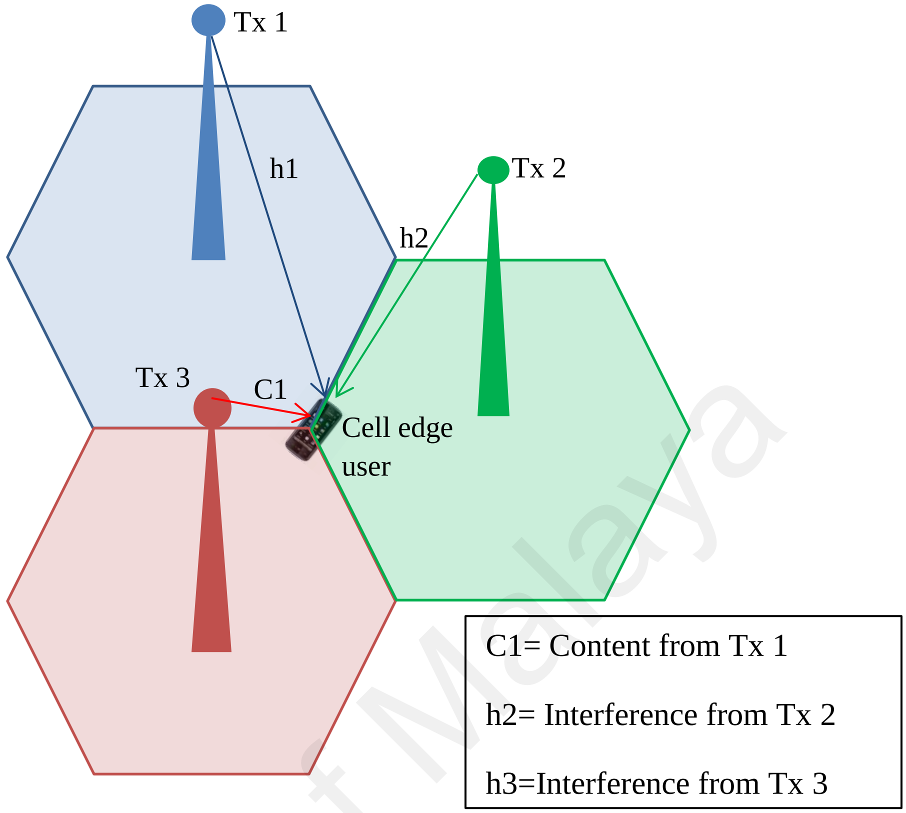


Figure 1.2: Interference from Neighbour Transmitter

experience high interference from the neighbour transmitter as shown in figure 1.2 and thus will degrade the performance of these users.

To mitigate this issue, LTE has introduced a new key technique to transmit multicast or broadcast data as a multi-cell transmission over the same frequency channel called Multimedia Broadcast Multicast Service over Single Frequency Network (MBSFN), which is adapted from the Digital Video Broadcasting (DVB) technology. In MBSFN operation, MBMS data are transmitted simultaneously to multi users over the air from multiple tightly-time synchronized cells which is called MBSFN area. The transmissions from multiple cells in a MBSFN area are synchronized to enable each datum to arrive and soft-combine at the user within the cyclic prefix (CP) as shown in figure 1.3 .This makes the MBSFN transmission appear as a single large cell transmission to a user. MBSFN greatly enhances the spectral efficiency as compared to the UMTS Release 6 MBMS because when the SINR of the user at the cell edge is improved by translating the inter-cell interference (destructive) in conventional transmissions to constructive interference in MBSFN. Thus, the received signal power increases as the useful signal power being largely contributed from multiple cells.

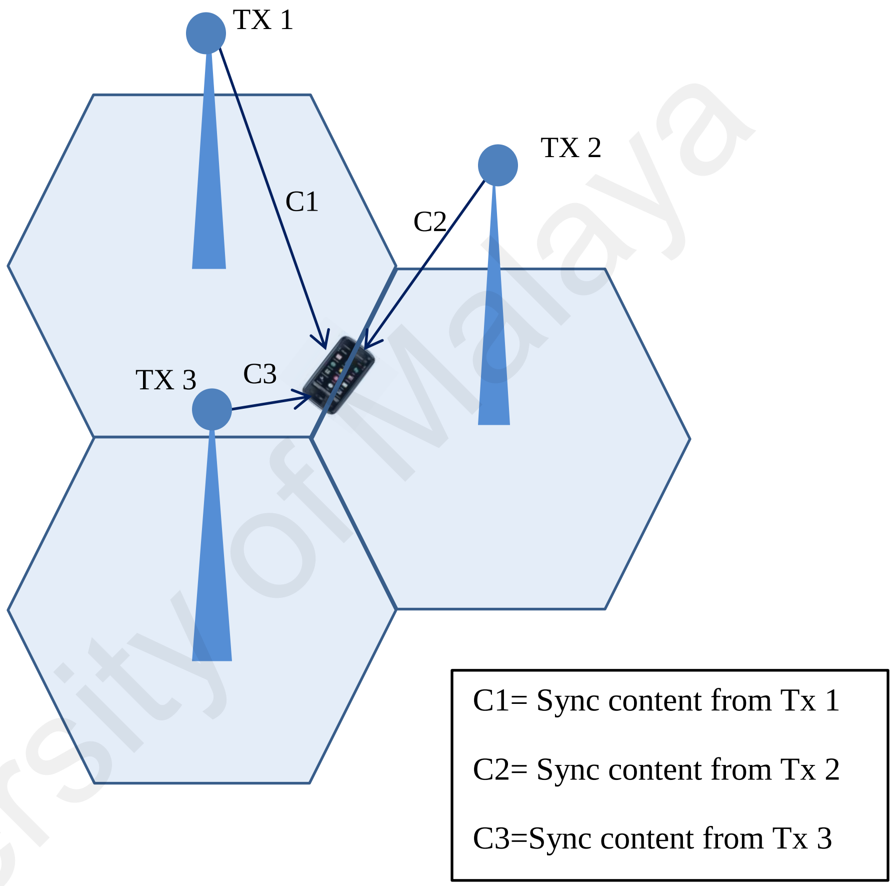


Figure 1.3: The MBSFN transmission scheme

1.3 Problem Statement

MBSFN area can be constructed with more than one continuous cell. Thus, when there are many constructed MBSFN areas, interference exists from other MBSFN areas. Hence, the performance of MBSFN is still restricted in the area that close to adjacent MBSFN areas due to the impact of external interference from neighbouring networks. figure 1.4 shows the interference experienced by the user located near the area edge.

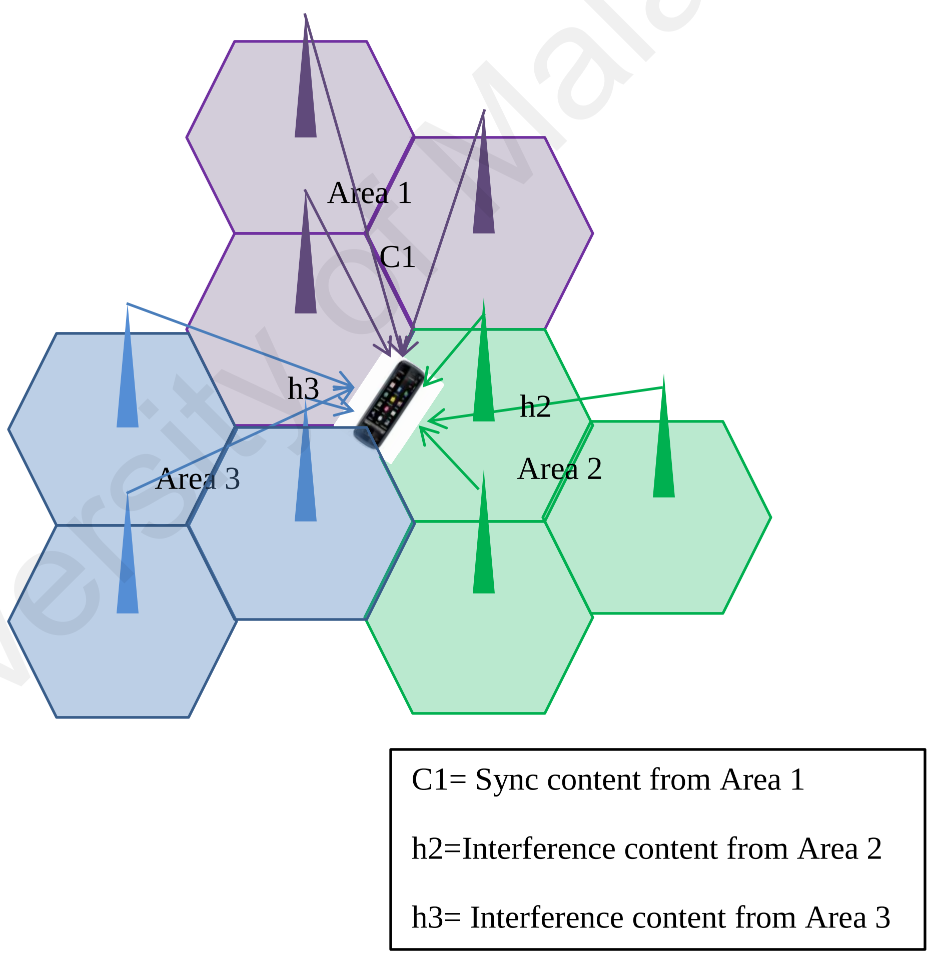


Figure 1.4: Interfered MBSFN area

Figure 1.4 shows an MBSFN network in which one MBSFN area is represented by 3 continuous cells. The network has 3 different MBSFN areas transmitting different contents. The user located at the edge of MBSFN area 1, area 2 and area 3 experiences interfering signal from areas 2 and 3. Throughout this dissertation, we plan to coordinate the interference experienced by the edge area user by allocating the right resource to each MBSFN area.

On the resource management and configuration of cells in MBSFN operation, the provider may target different geographical areas or different user distribution to transmit different MBMS services. Hence, a complication on the radio resource allocation in the adjacent area may be occurring. Throughout this project, we will study the impact of interference and a way to reduce it among MBSFN areas by allocating the right frequency resources.

1.4 Research Objectives

1 To develop an algorithm to allocate frequency resources by fix allocation and dynamic allocation to each of MBSFN areas thus coordinate and minimize the impact of external interference from neighbouring networks.

2 To evaluate the performance of developed resource allocation scheme for each MBSFN area in terms of SINR and throughput.

1.3 Dissertation Overview

The dissertation begins with the introduction in Chapter 1.

In Chapter 2, the literature review of interference coordination and resource allocation is provided.

In Chapter 3, the system model of MBSFN network and deployment is described. The system model will be used by the developed algorithm to evaluate the system performance. The system parameter is also introduced here.

Chapter 4 introduces the proposed method used in this project. The first method is Static Frequency Allocation with Genetic Algorithm approach (SFA-GA). The algorithm is briefly explained while the second method is Dynamic Resource Allocation with Game Theory approach (DRA-IC).

Chapter 5 discusses the performance of each proposed method. The proposed method will be compared to optimal and random allocation schemes.

The conclusion is made in Chapter 6 and some future works are also proposed in this chapter.

Chapter 2: Research Background

We will discuss the MBSFN area configuration and the interference coordination in order to develop the resource allocation for MBSFN network deployment. However, the research regarding the resource allocation for MBSFN network in LTE is still in open discussion. Hence, the literature studies about this research are not much. We have adapted some ideas from the existing research that use in a single cell network and apply it to the MBSFN network in LTE.

2.1 MBSFN area configuration

There are several MBSFN area configuration options. MBSFN areas can either be configured in a static deployment or dynamic deployment [3GPP R2-062155, 2006]. For static deployment, it uses the operation and maintenance (O&M) that self-configured by the network operator. The configuration has a fixed coverage area and the SFN area are not changing. Wide area SFN and local SFN are 2 types of static MBSFN areas as explained by [Malmgren, 1997] . In wide area SFN, all the continuous cells are formed as one big SFN area as shown in figure 2.1 (a). The local SFN has group of a small number of cells to form one SFN area and construct more area in one large network. For example as shown in figure 2.1 (b) , one SFN area is constructed by 7 continuous cells and 7 SFN areas in one network.

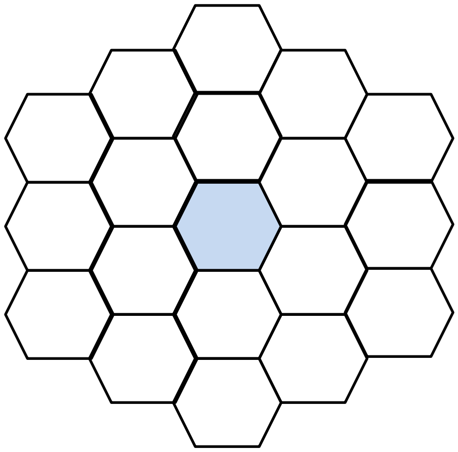


Figure 2.1(a) Wide area SFN static configuration

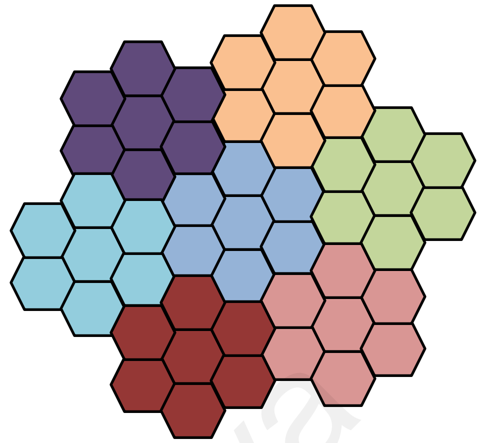


Figure 2.1(b) Local area SFN static configuration

In the dynamic deployment, the location of the cells can be changed where transmitting the MBMS signal based on the requirements depends on the needs of specific requirements such as services and number of subscribers. In [Tuban & Azman, 2011] the deployment of the dynamic MBSFN area using the genetic algorithm approach based on the number of subscribers within the area has been studied.

The constructed SFN area might be overlapping with one another. In [3GPP R2-074671, 2007] , it has stated that an overlapping MBSFN area is not possible to be deployed because, the user face a huge interference from the overlapping area with the neigbour SFN areas. Therefore, we assumed that the SFN area will not be overlapping with one another.

2.2 Noise and Interference

The performance of cellular systems is limited by two factors, called noise and interference. Thermal noise is the most dominant noise that depends on the environment and the hardware components. It is created from background radiation originating from the environment such as rain and terrestrial sources which adds up to the overall noise.

Moreover, it also exists in all parts of the communication system, such as amplifiers, antennas, filters, and etc.

Interference is the major limiting factor and it mostly depends on the cellular layout and the applied radio technology. It can be divided into two major classes. First, the interference sources within the same cell sector is called co-channel interference or intra-cell interference. Second, the interference from neighboring cells which contributes to an undesired signal known as adjacent interference or inter-cell interference. For OFDMA as in LTE, there will be no intra-cell interference, since all users are using a unique subset of the available sub-carriers. However, the inter-cell interference (ICI) still contribute in degrading the capacity of the signal after being interfered by the neighbor cell.

There has been extensive research to compensate the ICI in the OFDMA network such as in LTE. The ICI is the important element to reduce in a network to obtained the better system throughputs for cellular mobile networks. Three main techniques to mitigate the inter-cell interference is interference cancellation, interference randomization and interference coordination [3GPP TR 25.814, 2005].

2.2.1 Interference cancellation

The purpose of interference cancellation is to remove interference from the received signal. One technique that can be applied to cancel the interference is when the mobile terminals are equipped with multiple receive antennas. The mobile terminal with two receive antennas could treat the signal of interest and the interfering signal as a 2 X 2 Multiple Input Multiple Output (MIMO) system which is known as space domain interference cancellation . Hence, in ideal case it can cancel one interfering source of the signal received. Even though this can only be done in the space domain, it can be transferred to the frequency domain if only one transmit antenna is used. The 3GPP LTE standardization has proposed in [3GPP R1-050829, 2005] and [3GPP R1 051085,2005] to coordinate the symbol repetition where the neighboring base stations should transmit a data stream twice on two different frequencies. Thus, this allows interference cancelation by applying the same signal processing algorithms as in the MIMO case with different frequencies.

As stated in [Hoeher et.al., 2005] there are two classes of co-channel interference consoles. First, the Filter-based approaches where co-channel interference is mitigated by the means of linear filters and the interference models. In the other class, the Multi-User Detection (MUD) directly compressed the interfering signals in the decoding process. This is done by decoding and subtracting the unwanted or interfering signals from the total received signal. The interference cancellation is an attractive technique because it does not require any changes of the system standard. It has been applied to both TDMA systems as in [Hoeher et.al., 2005] and CDMA systems as in [Ping, 2007].

2.2.2 Interference Randomization

In contrast of interference cancellation which eliminates the interference at the received signal, interference randomization, which is also known as interference whitening, tries to convert the interference part to appear like background noise. Interference randomization can be done by averaging the interference across the data symbols of a data block or the whole frequency band. This technique is widely applied in the CDMA systems, where neighboring cells are separated by pseudo noise sequences. Furthermore, this technique also can be applied in FDMA/TDMA systems like GSM where frequency hopping in combination with interleaving would achieve a whitening effect. In OFDMA-based systems interference randomization can be achieved in several ways. First, different spreading patterns can be used in adjacent cells if a frequency-domain resource allocation is used. Second, the combinations of CDMA systems and IDMA systems with OFDM have been proposed as in [Ping, 2007]. IDMA-based schemes have also been proposed within the 3GPP LTE standardization [3GPP R1-050608, 2005].

2.2.3 Interference Coordination / Avoidance

As stated in [Xiangning et al., 2007] interference randomization does not reduce the interference and interference cancellation showed that it only deals with the dominating interference. Thus, the interference coordination or avoidance is the best technique to reduce the inter-cell interference

Recently, the studies about the Interference Coordination (IFCO), also known as Inter-Cell Interference Coordination (ICIC), has gained attention to mitigate interference in cellular networks thus improves the overall network throughput. IFCO coordinates and manage the radio resource usage such that inter-cell interference is kept under control [3GPP TS 36.300,2009]. ICIC technique could reduce the probability of frequency resource conflict of each user from different cell through the effective resource allocation. Hence, it would decrease the interference level, improves the signal to interference plus noise ratio (SINR) as well as maximizes system throughput and spectral efficiency for each user [Zhaoming, 2011]. For example, in an OFDMA system, IFCO can prevent two cell edge terminals in the neighboring cell to be served at the same time and frequency resource.

In cellular systems, the frequency should be assigned to a desired cell or area. However, the allocated frequency is very limited and it is not sufficient to allocate each frequency to each area. Hence, the frequency reuse concept is to reuse or reassign the same frequency to a desired cell by a certain amount of distance to keep the interference levels within the tolerable limits [Kim, 2007]. There are some techniques for interference coordination as found in the literature which can be categorized as follows.

i) Interference coordination using resource partitioning

- Traditional frequency reuse
- Fractional Frequency reuse
  a) Soft frequency reuse (SFR)
  b) Partial frequency reuse (PFR)

ii) Interference coordination by Fast Cell Selection approach

iii) Dynamic inter-cell interference coordination

2.2.3.1 Interference coordination using resource partitioning

A reuse factor of 1 or more, also termed as a universal reuse factor (UFR) can be achieved by reusing the same frequency in each and every cell without any restriction to frequency resource usage. Thus, this will result in the worst inter-cell interference situation.

Hence, the available frequency spectrum could be divided into the N factor of sub-bands and each cell is given an orthogonal sub-band among neighboring cells. Then a reuse of the N sub-band can be achieved from the available frequency spectrum [MacDonald, 1979]. This technique obviously could improve the inter-cell interference. However, it will result in an inefficient resource distribution due to the frequency partitioning.

Traditional Frequency Reuse: In traditional frequency reuse, it will divide the whole bandwidth to a number of n factor of frequency known as reuse factor. Reuse factor can be varied from 2 up to 7. LTE aims at high quality multimedia service in mobile communication, hence the smart use of frequency resource has attracted a lot of attention as promising technique that eventually increase the total system capacity in the mobile cellular environment. According to frequency reuse principle,neighboring cells cannot use the same frequency for communication because it may create interference for users located near the cell boundaries. In fact, a set of C different frequencies $\{f_1, ..., f_C\}$ is used for each cells of *C* adjacent cells. The cell patterns and the corresponding frequencies are re-used in a regular pattern over the entire service area. Figure 2.2 shows the frequency reuse plan for C=3. Each color represents a sub-band, hence there are no two similar colors assigned adjacent to each other.

Reusing frequencies by dividing the allocated band by a specific integer number of cells and assigning each cell one division and then repeating the assignment over and over produces a tradeoff between network capacity and reception quality as follows:

1. The higher the number of divisions of the spectrum over cells (higher cell-reuse factor), the lower the capacity of the network but the further away cells with similar frequency allocations is located resulting in lower interference.

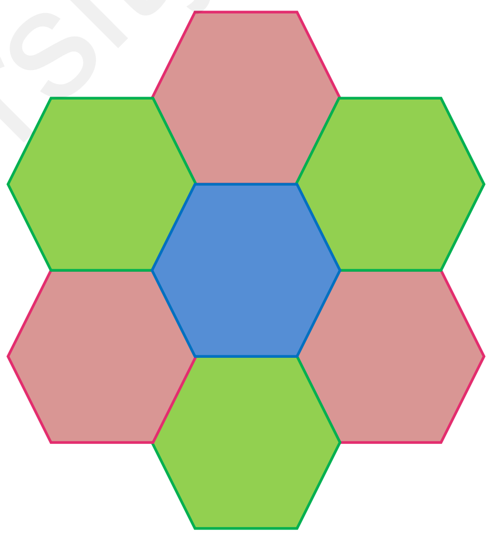


Figure 2.2 Frequency reuse plan for C=3

2. The lower the number of divisions of the spectrum over cells (lower cell-reuse factor), the higher the capacity of the network but the closer cells with similar frequency allocations is located resulting in higher interference.

In [3GPP TR 36.913,2008], the traditional frequency reuse system has been proposed. The system assigns the whole frequency resource to all cells, and then it defines a cell-specific resource allocation rule for each cell, to control the mutual interferences among the neighboring cells.

Fractional Frequency Reuse: The Fractional Frequency Reuse (FFR) scheme is achieved by using an effective reuse of factor 1 and 3. Two types of FFR scheme are Soft Frequency Reuse (SFR) and Partial Frequency Reuse (PFR).

FFR scheme was introduced to the Global System for Mobile communication (GSM) systems in [Begain et al., 2002] and has attach interest among researcher. WiMAX forum and 3GPP LTE have adopted this scheme to its network. The FFR scheme could achieve a robust interference for the users in central area due to the fact that they are likely having weak interference and strong desired signals from the base station. Hence they can utilize the reuse of 1 compared to the users at the cell border with high interference as well as high distance dependent attenuations from the base station. Therefore it is more effective if we use mixed resource factors with higher frequency reuse factor in the cell-edge compared to the cell-centre areas which can support reuse of 1. An example of an FFR for a network with one BSs located in the centre of the cell is a combination of reuse factor of 1 and 3 in the cell-centre and cell-edge areas, respectively as shown in figure 2.3.

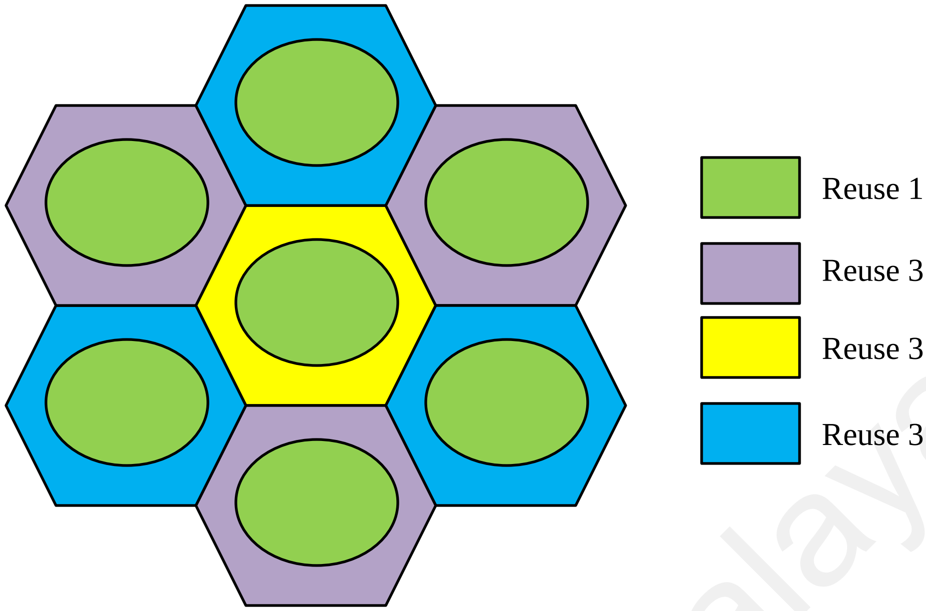


Figure 2.3: Fractional Frequence Reuse Scheme with reuse factor of 3 in outer region

Based on the location from the base station, users are classified into cell edge and cell center groups. Furthermore, the resource is partitioned into an inner band which is allocated to the inner users and an outer band which is allocated the outer users. The partitioning of resources into the cell edge and cell center bands will determine the effectiveness of the reuse factor. Generally, the allocated resources which are used for the cell-edge UEs will be using higher power. Some literature such as [Shariat et al., 2008], has studied the the effect of power coordination in FFR scheme. The study applies the predefined power and frequency planning to show that the coordinated power of FFR scheme outperforms the uncoordinated power which is using the same power through all the base station schemes. The Soft frequency reuse (SFR) [3GPP R1-050507, 2005] and Partial frequency reuse (PFR) [3GPP R1-060291, 2006] are two schemes which is modified from the FFR scheme.

Soft Frequency Reuse: Soft frequency reuse (SFR) scheme is a modification of FFR scheme. The reuse factor of 1 and a factor equal to or greater than 1 are applied in the cell centre and cell edge areas, respectively.

It was proposed in [3GPP R1-050507, 2005] and [3GPP R1-050841, 2005] under 3GPP LTE framework to provide a higher data rate to UEs with weaker signal which is generally located near the cell edge. Figure 2.3 shows an example of an SFR scheme. The cell-edge band is usually 1/3 of the available spectrum and it is orthogonal to those in the neighboring cells.

Usually, the major sub-carrier band is allocated for the cell edge user while the cell-center frequency users is allocated to the minor sub-carrier band. The total transmit power is set to be fixed. Each group is assigned with the transmission power depending on the effective reuse factor to be used. Generally, it is determined by the ratio of the assigned power of the cell - centre (minor) to the assigned power of cell-edge groups (major).

Higher transmission power is used on the major band as shown in the figure 2.4. Consider that the power per Physical Resource Block (PRB) i.e., time-frequency resource reuse of 1 is power of unit 1 per PRB, and for the cell-edge (major) band is α for the SFR scheme. Then power per PRB in the minor band would be (3-α) /2 giving a power ratio of

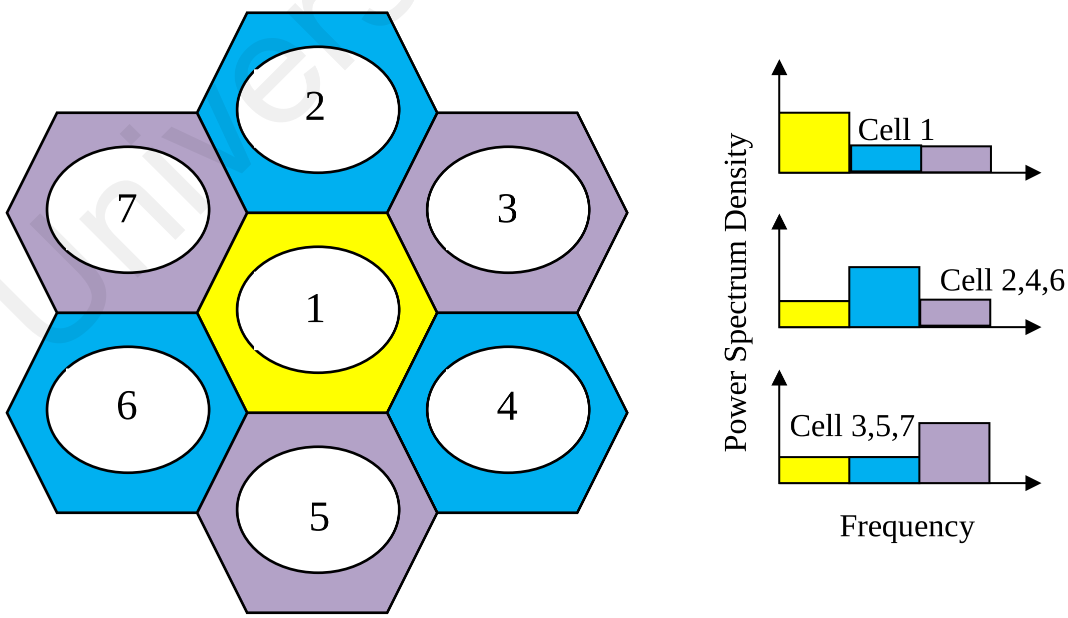


Figure 2.4: Soft Frequency Reuse and Power Transmission

(3-α) /2α for the minor to major band. Minor band is available for cell-centre UEs only while the major band is flexible to be used for cell edge and cell centre UEs. By adjusting the power ratio from 0 to 1, we could successfully utilize the reuse factor of 3 to 1.

Usually, the power ratio of minor and major band can be adjusted depending on the traffic behavior in the network. When the traffic load is high near the cell edge users, a relatively high power is transmitted for the cell edge UEs , hence the small power ratio is obtained. In contrast, when the traffic is largely focused on the central part of the cell, a relatively high power ratio is suggested by adjusting the high transmission power for the major band. In that sense, the SFR can be adapted in a static, or dynamic resource allocation.

The cell layout without sectorization simulations are performed in for different power ratios in [3GPP R1-050841, 2005] with a static deployment. The results show that with the decrease value in the power ratio, a higher throughput in the cell-edge is achieved with the decreasing in the throughput for the cell-center UEs and the cell in general. The maximum soft reuse factor for the static SFR is 1/3 with the sub-band is allocated to the cell-edge users can be up to 1/3 of the total frequency band. However, in semi-static SFR, the percentage of frequency resources allocated to cell edge users is considered to be equal to the percentage of cell-edge terminals relative to the total number of users which may become larger than 1/3 as stated in [3GPP R1-050841, 2005]. A single antenna transmitter and dual antenna receiver have been assumed for simulations. The result showed that the semi-static SFR outperforms the static SFR by providing up to 50% higher cell-edge

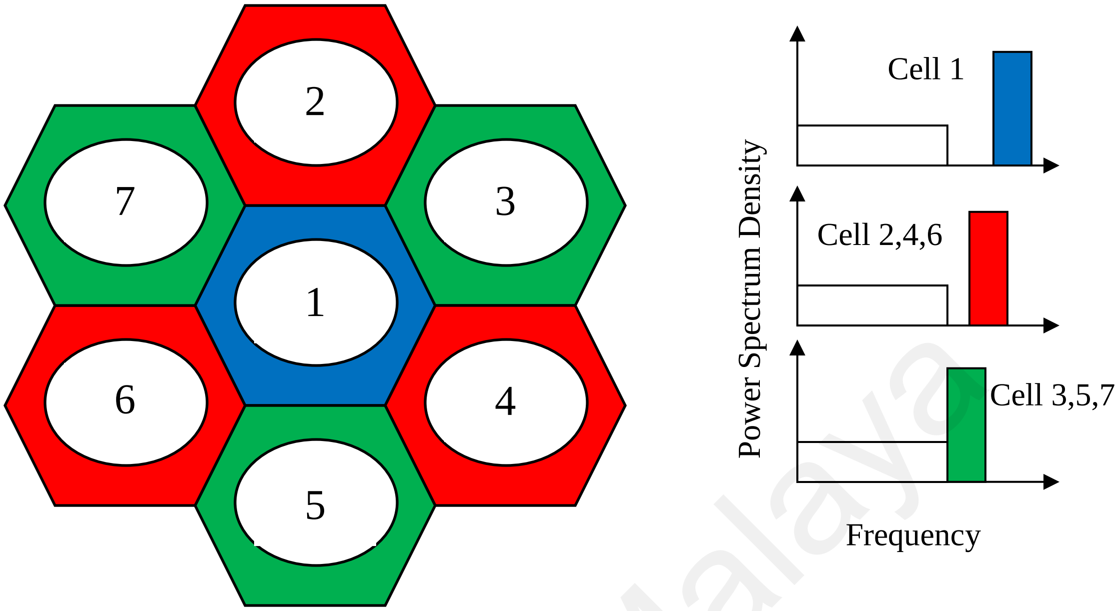


Figure 2.5: Partial Frequency Reuse (PFR) and Power Transmission

throughput while keeping the cell-center throughput slightly better. Also, different user speed scenarios have been considered in the simulations. The UEs are categorized into cell-edge and cell-centre based on user geometry determined by the received signal power (averaged over multi-path fading) taking into account the large-scale path-loss, shadowing, and antenna gains.

Partial Frequency Reuse: The concept of the PFR scheme presented in [Sternad et al., 2003] is to limit some of the resources so that some frequencies cannot be used in the certain cells at all. The effective reuse factor of the scheme is determined considering on the fraction of the unused frequency spectrum. The PFR are studied in the 3GPP projects as in [3GPP R1-060291, 2006] .An example of PFR for 3 cells is shown in figure 2.5. First, let β be the available system bandwidth and is divided into the inner and outer zones with β_i and β_o, respectively. Usually, β_i is used with a reuse factor of 1 and allocated to the inner zone. The βo uses the reuse faction of 3 for the outer zone. Hence, in this partition the effective frequency reuse factor is specified by $\beta/(\beta i+(\beta o/3))$. Therefore, we can conclude that the effective reuse of PFR scheme is always greater than 1. The power used on the sub-band for the outer zone is always amplified as shown in figure 2.5. Several scheduling approaches also have been considered to prioritize the allocation to the cell-edge users in different ways besides the interference avoidance through SFR and PFR. First, the cell-edge UEs are scheduled first then it can obtain the sub-channels from the cell-center band.Then, the cell-edge UEs can only use the sub band from the cell-edge. If the cell-edge UEs are scheduled for the cell edge band and it need more resource, they will obtain it from the cell-center band.

2.2.3.2 Interference Coordination by Fast Cell Selection

Fast cell selection approach has been studied in [Keon et al., 2006] as another method to coordinate the interference. This method is to detect each users which is located at the cell-edge. The detected user will monitor its interferers as the possible candidates for a future handover. The user will switch to another corresponding BS when it receives the strongest interference from another base station. Hence, the user would avoid the strong interference and also to ensure a strong link for future connection. In order to switch to another corresponding base station, the user will arrange a set of an active base station by calculating the desired criteria such as instantaneous SINR or achievable rate.

The user then requests for admission to each of the cells in the set of the active cell. The cell will become a non-primary cell if the cell cannot afford to approve the request from the interested UE. Furthermore, the cell which approved the request from the user is termed as the primary cell to which a handover takes place. The resource is partitioned into common sub-channels where all the cells can use. The sub-channels with restrictions will be determined during the arrangement of the set of the active cells. Hence, the sub-channels with no restrictions can be restricted at the non-primary cells. The conventional handover are compared with and without interference avoidance method and the results show that the spectral efficiency is better with the interference avoidance. The study has been investigated in [Son et al., 2007], where the optimal inter- and intra-cell association is discussed considering the network load and inter-cell interference. The PFR has been used as a default partitioning for each cell. The association of UE to a cell either for inner-cell or for outer-cell resources are determined through a network-wide utility maximization problem.

2.2.3.3 Dynamic Inter-cell Coordination

Most available research on fractional frequency schemes are based on static coordination among the base stations. As in [WINNER, 2007] , the FFR schemes that use the interference coordination in a static configuration do not result in higher overall gain as cell-edge throughput can only be improved with a significant penalty to the system throughput .This is because of the static resource partitioning and power allocation on a larger time scale is unable to exploit channel dynamism. Any static reuse partitioning scheme would be a highly sub-optimal solution because an optimal partitioning depends on the, arrived the traffic of each user, the distribution of the users, arrived traffic, and the channel dynamism. The dynamic resource partitioning based on users' traffic load and the mutual interference between users situation may provide balanced overall improvements for both the cell edge and cell-center users' performance. Thus, this example of the approach of dynamic reuse adaptation requires the dynamic inter-cell coordination. Furthermore, the schemes that require the static frequency planning could not be applied to the Femto-cellular networks [Chandrasekhar et al., 2008]. This is due to the fact that the

Femto-cells will be placed at the end user locations in an ad hoc system resulting in a difficulty of any prioritization of static frequency planning.

On the other hand, dynamic coordination schemes do not require prior frequency planning and operate based on dynamic interference information from neighboring transmitters. Therefore, the dynamic coordinates schemes are not only effective to avoid the interference in macrocell deployment, but they are also capable of handling interference from macrocells if applied to femtocell or picocell base station. Some studies in the literature that address interference avoidance between the macro and femtocell deployments and [Lee et al., 2010] and [Bharucha et al., 2010]. Dynamic inter-cell coordination based dynamic coordination schemes can be applied by exploiting the channel dynamism to achieve maximum interference avoidance gain. [Rahman & Yanikomeroglu, 2007] , [3GPP R1-072762, 2007] and [Madan et al., 2010].

In [3GPP R1-072762, 2007], a dynamic inter-cell coordination scheme is studied in a simple scenario and a few assumptions. The scheme chooses a reuse pattern of four defined patterns with varying degrees of partitioning such as reuse of 1 to reuse of 3. In [Ali S.H & Leung V.C.M,2009], the dynamic frequency reuse factor scheme is studied. The scheme partitions the resources dynamically into a primary group which are allocated to cells and secondary group which are allocated to sectors. The scheme was proven to obtain higher system throughput, but the cell-edge users' performance degrades as compared to a static frequency reuse factor scheme. The 2-level algorithm has been developed to formulate the interference coordination problem in [Rahman & Yanikomeroglu, 2008] and [Rahman, 2010]. The first level is the sector level algorithm in which each sector will find a list of resource units to be restricted as the form of requests in the surrounding region with the higher interference. Meanwhile, a central optimal algorithm is the second level algorithm which maximizes the utility for restrictions at the central controller. The central controller is used to process all requests from all the sectors involved.

In the context of LTE technology, the distributed dynamic interference coordination scheme system is studied in [Rahman & Yanikomeroglu, 2009]. The interference has been categorized into intra eNB and inter eNB interference. There are different approaches to mitigate the interference for intra eNB and inter eNB inter-cell interference. As the LTE system does not encourage the central processing due to the network architecture, the inter-cell coordination for inter-eNB interference is performed over the X2 interface (eNB to eNB) [3GPP TR 36.913,2008] through the negotiations. In [Stoylar & Viswanathan, 2008] , a self organizing dynamic FFR scheme is studied. The algorithm is tested in a simple scenario with each sector applying the selfish optimization to reach the Nash Equilibrium. The concept of the algorithm is that each sector greedily tries to minimize its total power usage. This will result in the process of allocating the good sub-bands to the cell-edge users with higher power. Thus, these allocated sub-bands are not good enough to be allocated to the neighboring sectors. As a consequence, the neighboring sectors will not allocate these sub-bands to their cell-edge users. The allocation of these sub-bands to their cell-center users with the lower power will make these sub-bands better for the former sector deployment. The algorithm will work iteratively and will obtain an equilibrium value. The transmits powers of respective sector also can be minimized. Furthermore, the interference coordination is also studied by using the interference graph approach as in [Necker, 2009] and [Chang, 2009]. In [Necker, 2009] , the interference graph is created based on a predefined SINR. The interfering signals for each node are removed from the highest interference until the SINR is above the defined threshold value. Then, the interfering nodes that are removed are said to be connected to the node of interest in the interference graph with lower interference value. Hence, the resources are allocated in such a way that connected nodes are given to value of interference.

In [Chang, 2009] the graph theoretic approach used ICIC as well as Base-Station Cooperation (BSC) have been studied. The algorithm adopted the Tabu Search algorithm in the graph coloring approach to allocate resources. For BSC algorithm, it is defined as a system architecture, where the same data are transmitted from multiple base stations to a particular user on a same time-frequency resource unit. Interference coordination using power control has been studied in [Madan, 2010], where the power adapter is performed in an iterative manner by exchanging information among the neighbor base stations.

Chapter 3 System Model

3.1 MBSFN Network Configuration

We model a local area MBSFN network as proposed by [Malmgren, 1997]. The network is configured as a set of MBSFN area that are not overlapping. One MBSFN area may consist of N hexagons varied from 1, 3, 7, and 19 each with a transmitter located in the centre. Each MBSFN area uses one frequency block to broadcast its contents. We assume to vary the value of $\check{S}$ where $\check{S}$ is a frequency reuse factor and also the total of available frequency blocks. It is important to have a low value of $\check{S}$ since the radio spectrum is a limited resource. Generally, most services use a large bandwidth in MBSFN systems, for example Television broadcast services.

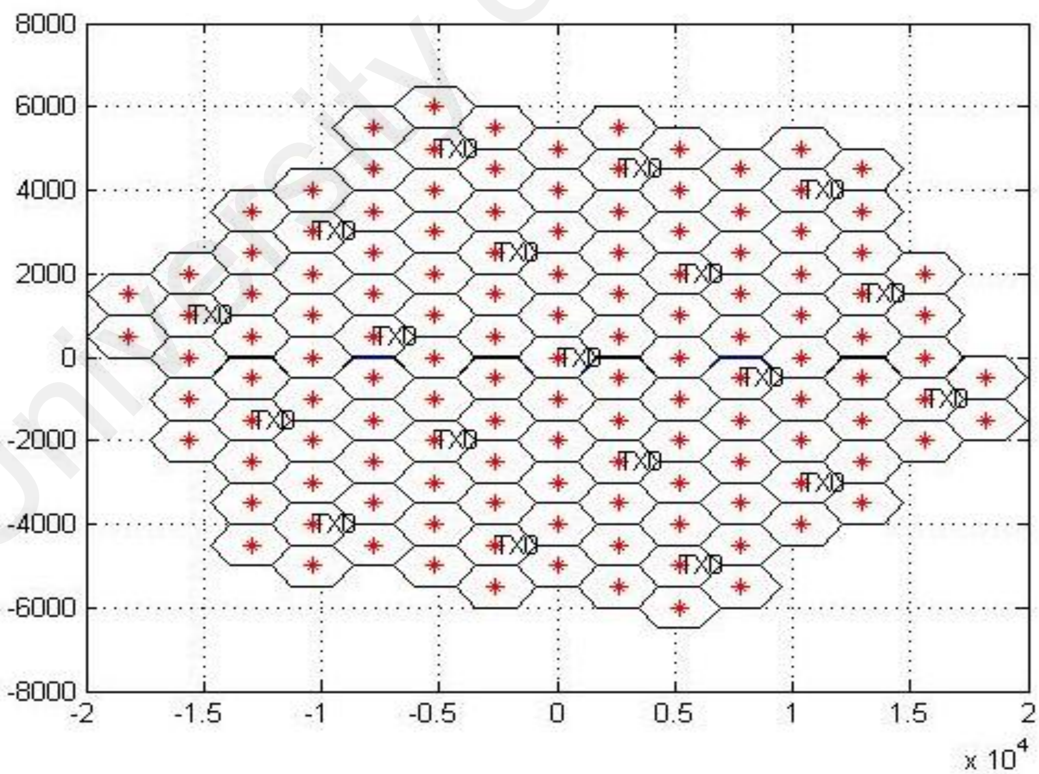


Figure 3.1: A model for MBSFN with N=7

Figure 3.1 depicted one MBSFN network with 19 MBSFN areas adjacent to one another. One area represents a set of 7 small hexagons.

3.2 MBSFN Channel Model

We use typical urban channel model from 3GPP standard [3GPP TR 25.943,2011] for urban area. This channel model has 20 taps power profile and Rayleigh fading model as shown in the Table 3.1.

TABLE 3.1: CHANNEL FOR URBAN AREA [3GPP TR 25.943,2011]

Tap Number	Relative time(μs)	Average Relative Power(dB)	Fading Model
1	0	-5.7	Rayleigh
2	0.217	-7.6	Rayleigh
3	0.512	-10.1	Rayleigh
4	0.514	-10.2	Rayleigh
5	0.517	-10.2	Rayleigh
6	0.674	-11.5	Rayleigh
7	0.882	-13.4	Rayleigh
8	1.230	-16.3	Rayleigh
9	1.287	-16.9	Rayleigh
10	1.311	-17.1	Rayleigh
11	1.349	-17.4	Rayleigh
12	1.533	-19.0	Rayleigh
13	1.535	-19.0	Rayleigh
14	1.622	-19.8	Rayleigh
15	1.818	-21.5	Rayleigh
16	1.836	-21.6	Rayleigh
17	1.884	-22.1	Rayleigh
18	1.943	-22.6	Rayleigh
19	2.048	-23.5	Rayleigh
20	2.140	-24.3	Rayleigh

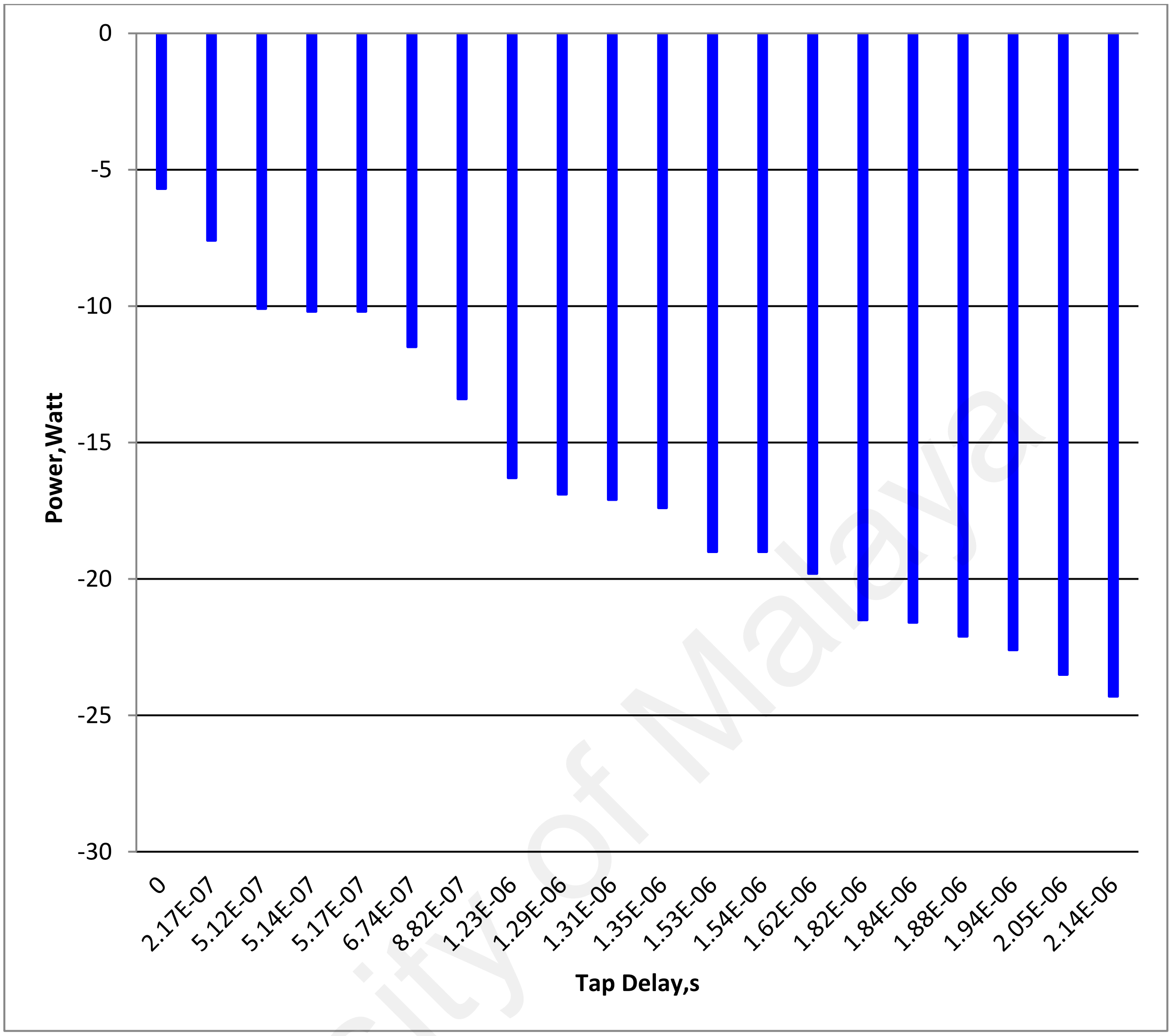


Figure 3.2: Typical urban channel model (Tux) Channel Impulse Response

3.2.1 Propagation Model

Two main factors to model the wireless channel on the large scale are path loss and shadowing.

3.2.1.1 Path Loss Models:

The path loss model estimates the reduction in the power density of transmitting signal over the propagation path associated with the position of receiver with distance d.

The free space propagation model is used as the simplest example to evaluate the received signal strength when the transmitter and receiver have a clear line of sight path between them. The path loss L can be written as [Theodore S. R,2002]:

$$L = \frac{Prx}{Ptx} = \frac{GrxGtx\lambda^2}{(4\pi d)^2} \quad (3.1)$$

Where:

Prx= Received power

Ptx=Transmitted power

Grx=Receiver antenna gain

Gtx=Transmitter antenna gain

λ= Wavelength

The path loss in Equation (3.1) can be expressed in dB as [Theodore S. R,2002]:

$$Pl(d) = Lo - 20\ \log_{10} d \quad (3.2)$$

where Lo depends on the frequency and the antenna height of respective receiver and transmitter. In wireless communication, the free space is not used as the actual propagation model. Several studies have offered an actual path loss model in urban and suburban areas. The most widely used is Okumura-Hata model.

Furthermore the path loss in Equation (3.2) depends on the propagation environment. The path loss value will be changed by multiplying the value of path loss exponent α. It can differ from 2 to 6 dB as stated in [Theodore S. R, 2002]:.

$$Pl(d) = Lo - 10\alpha \log_{10} d \quad (3.3)$$

The path loss model used in this project is referring to the 3GPP standars as provided in [3GPP TR25.943, 2011].

$$Pl(d) = 128.1 - 36.7 \log_{10} d \qquad (3.4)$$

3.2.1.2 Shadow fading

The propagation loss is extended to

$$Pl(d) = 128.1 - 36.7 \log_{10} d + \xi s \qquad (3.5)$$

Where ξ_s is a random variable and has a Gaussian distribution with zero mean and standard deviation σ_s

$$p(\xi s) = \frac{1}{\sigma s\sqrt{2\pi}} \exp\left(\frac{-\xi s^2}{2\sigma s^2}\right) \qquad (3.6)$$

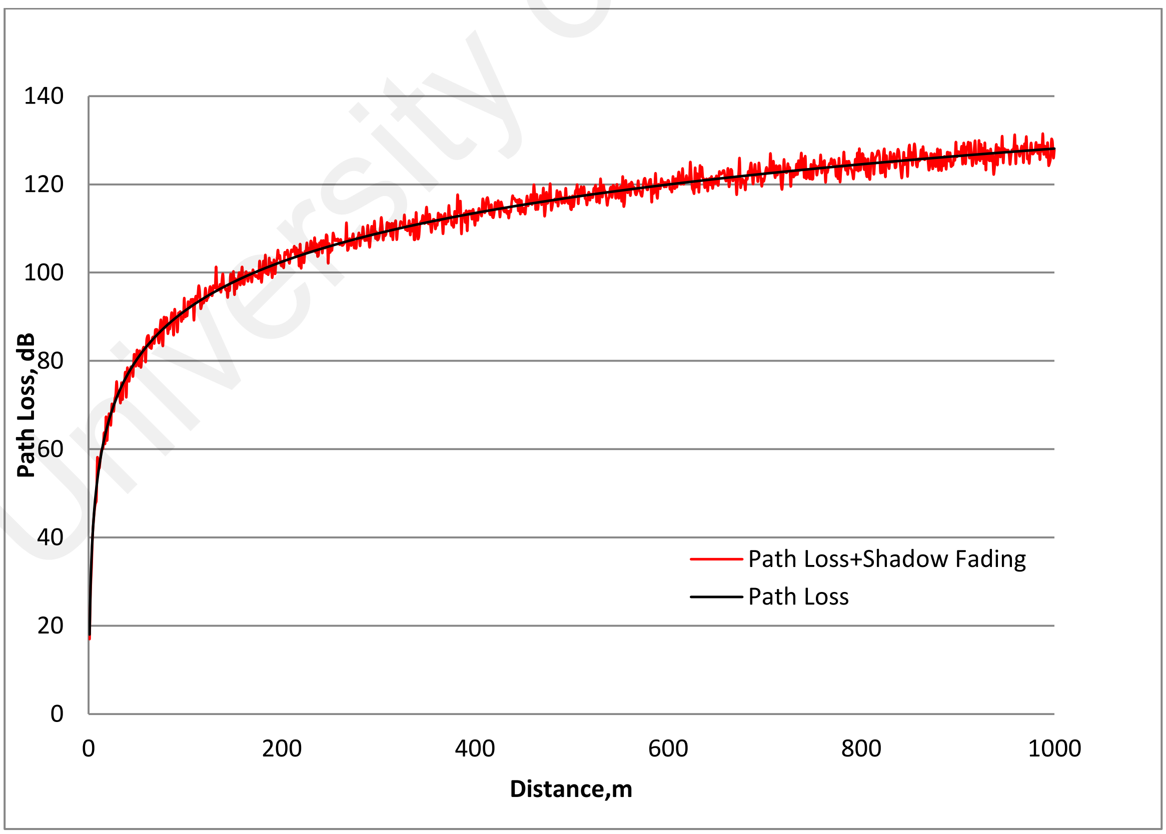


Figure 3.3: Propagation model. Path loss with and without Shadow Fading

3.3 SINR Mapping

In the LTE resource allocation, each user will be assigned to a chunk of sub-carriers called physical resource blocks (PRBs). Each user will experience a different quality of SINR due to different channel condition. After obtaining the value of their own SINR, each user should report its value to eNodeB via upload control channel.

Since the feedback overhead is large between the user and eNodeB, the user can report to eNodeB with the channel quality indicator (CQI) to reduce the overhead. There are 2 methods to map the SINR for each user. There are the aperiodic feedback and the periodic feedback [Donthi, 2010].

"In aperiodic feedback, the user sends CQI only when it asked to by the eNodeB.On the other hand,in periodic feedback, the user sends CQI periodically to the eNodeB; the period between 2 consecutive CQI reports is communicated by the eNodeB to the user at the start of the CQI reporting process" [Donthi2010]. Each user owns a frequency channel response due to different locations within the MBSFN area. Furthermore, the PRBs assigned to each user in different parts of the frequency band.

In Table 3.2 , we used a simple method of table mapping for 15 modulation and coding scheme (MCS) as provided in [3GPP TR25.943,2011] . In Figure 3.4, the graph shows the SINR and CQI index mapping

TABLE 3.2: SINR TO CQI MAPPING TABLE [3GPP TR25.943,2011]

CQI index	Modulation	Efficiency (information bit/symbol)	SINR dB
0	No Transmission	NIL	< 9.8
1	QPSK	0.1523	-5.6
2	QPSK	0.2344	-3.85
3	QPSK	0.377	-2.1
4	QPSK	0.6016	-0.35
5	QPSK	0.877	1.4
6	QPSK	1.1758	3.15
7	16QAM	1.4766	4.9
8	16QAM	1.9141	6.65
9	16QAM	2.4063	8.4
10	64QAM	2.7305	10.15
11	64QAM	3.3223	11.9
12	64QAM	3.9023	13.65
13	64QAM	4.5234	15.4
14	64QAM	5.1152	17.15
15	64QAM	5.5547	18.9

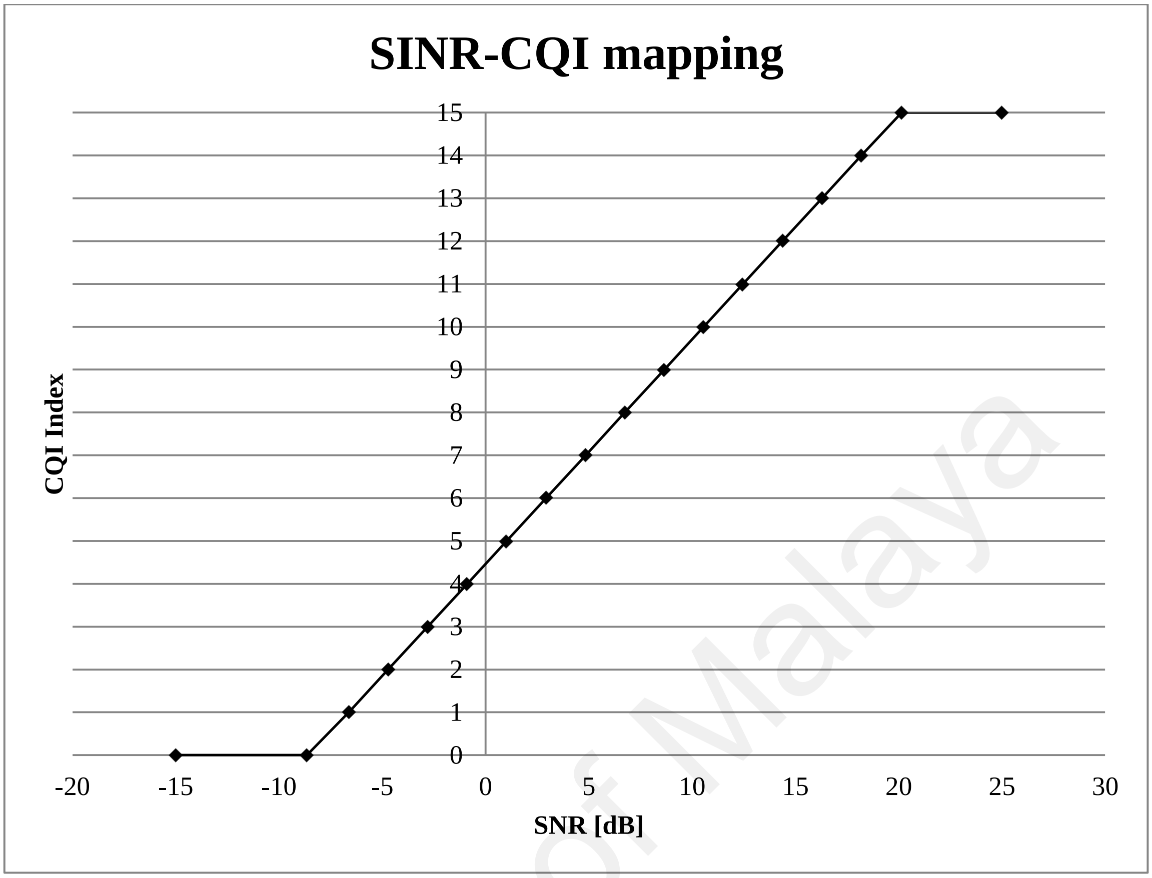


Figure 3.4: SINR and CQI index mapping

3.4 Signals to Noise Interference Ratio (SINR) Calculations

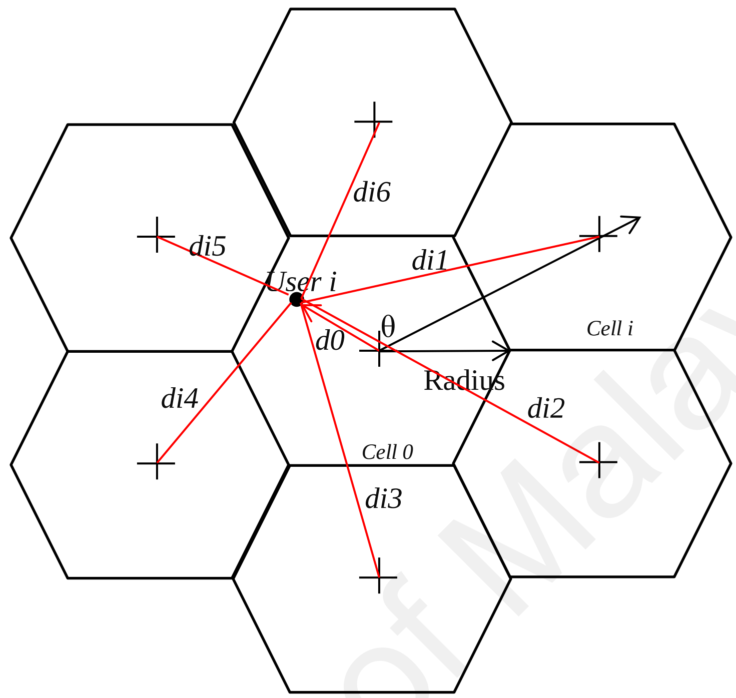


Figure 3.5: SINR calculation at a given point of the cell

Figure 3.5 shows some parameters needed to calculate user *i*'s SINR at a given point. A user is in a target cell 0. d_0 is the user's distance from base station 0, and θ is an angle with a reference axis that is connected to other base stations in another cell. *dij* is the user's distances from the neighbour base station in cell *i*. Before calculating the SINR, we are interested in investigating the impact of SFN signals from other cells ($i \neq 0$).

In MBSFN OFDMA, due to different multipath channel delays, the signal that arrives from other base stations at the receiver is viewed as constructive interference (i.e. gain) if the delay is within the cyclic prefix and the remaining is destructive portion. One impact of the signals from a base station is the propagation delay, $\tau\ (i)$ in Equation (3.7), where c is the speed of light.

$$t(ij) = \frac{dij-do}{c} \tag{3.7}$$

For a given delay that is calculated using Equation (3.7), the weight function of the constructive portion of a received SFN signal is [Rong, 2008]:

$$w(\tau) = \begin{cases} 0, \tau < -Tu \\ \frac{Tu+\tau}{Tu},\ -Tu \leq \tau < 0 \\ 1,\ 0 \leq \tau < Tcp \\ \frac{Tu-(\tau-Tcp)}{Tu}, Tcp \leq \tau < Tcp + Tu \\ 0, otherwise \end{cases} \tag{3.8}$$

where:

Tu, Useful signal frame = 66.67μs

Tcp,Cyclic prefix length=16.67 μs

For simplificity, the above weighting function can be rearranged in such a way that they contain distances (d) instead of delays (t) by multiplying by the speed of light, *c*. [Malmgren, 1997].

$$w(d) = \begin{cases} 0, \tau < -du \\ \frac{Tu+\tau}{Tu},\ -du \leq \tau < 0 \\ 1,\ 0 \leq \tau < dcp \\ \frac{du-(d-dcp)}{du}, dcp \leq \tau < dcp + du \\ 0, otherwise \end{cases} \tag{3.9}$$

where:

d(ij)=dij-do, *du*=20km, *dcp*=5km

During SINR calculation, one important thing to be taken into account is locating the FFT window to start sampling the received signal. In [Malmgren, 1997], a simple FFT window positioning strategy is utilized such that the first signal received from the cell 0 (central cell) is used as the reference signal in which all signals received after (i.e., signals from neighbouring cells) will align to it. Therefore, the propagation delay will never be less than a useful signal length.

Multipath propagation delay can also affect the received signal whether it is constructive or destructive. Therefore, the weight function should consider the total delay of each fast fading tap, as well as the propagation model.

The user's distance from the reference cell (cell 0) base station, *d0*, and from others base station, *dij* can be calculated using simple geometry distance with given *(x, y)* point. For example, if the user is located at *(xr,yr)* , reference base station *(xcell0,ycell0)*, and other cell base station *(xcell ij,ycell ij);*

$$d0=\sqrt{(xr-xcell0)^2+(yr-ycell0)^2} \tag{3.10}$$

$$dij=\sqrt{(xr-xcell\ ij)^2+(yr-ycell\ ij)^2} \tag{3.11}$$

Signal-to-Interference Noise Ratio is a reasonable measure of the signal quality for one receiver. It is defined as

$$SINR=\frac{Puse}{Pself+Pext+No} \tag{3.12}$$

where *Puse* is the portion of the total signal power that falls within the FFT window and *Pself* is the portion of the power due to the signal delay overlaps into the preceding symbols or self-interference. *Pext* is the interfering power from nearby transmitters broadcasting other contents and *No* denotes the thermal noise power in the receiver.

With an MBSFN area that consists of N cells and propagation channel model with M tap filter, the received SINR by each user can be formulated as:

$$SINR = \frac{\frac{\sum_{i=1}^{N}\sum_{j=1}^{M} Pj*[w(di+\delta j)]}{Li}}{\frac{\sum_{i=1}^{N}\sum_{j=1}^{M} Pj*[1-w(di+\delta j)]}{Li}+Piext+No} \quad (3.13)$$

where di is the propagation delay for base station i and δj is the additional delay caused by path j.

Pj is average power associated with the j-th path and can be modelled as

$$Pj = 10^{(Ptx(dB)-Pl,tap\ j)/10} \quad (3.14)$$

Ptx is effective transmitted power of each transmitter. .

Li represents path loss associated with distance d from UE to cell i. As Li can be modelled as:

$$Li = 10^{(128.1-36.7log10d+\xi i)/10} \quad (3.15)$$

ξi is the component of the local shadow fading with Gaussian random variable of zero mean and 8db variance.

3.5 User Distribution

In the simulation system, users are distributed randomly on each area. The number of users in is set up from 5 to 200 users per area to vary the traffic load. The users are divided into two groups the inner users and outer users. Inner user is defined as the user that located in the region that less than the value of inter site distance (ISD) where the outer users are the user that located more than ISD value. According to 3GPP, the minimum distance between users and eNodeB should be at least than 50m.

3.6 System Parameter

The system level simulation of MBSFN in LTE will run based on the following parameters as shown in Table 3.3 . The simulation runs in MATLAB.

TABLE 3.3: SYSTEM PARAMETER

Parameters	Value
Carrier Frequency	2GHz
Bandwidth	10MHz
Number of Subcarriers	600
Number of Subcarriers per Resource Block	12
Sub-carrier Spacing	7.5kHz
Number of Physical Resource Block	50
Cell Radius	1000m
User Distribution	Random Distribution
Slot Duration	0.5ms
Scheduling Time	1ms per TTI
Number of OFDM symbols per Slot	6
Simulation time	10s
MBSFN area	19 Continuous areas with 7 hexagonal cells
Number of users of each area	5- 200 users

Chapter 4 Proposed Method

We developed 2 methods for resource allocation in MBSFN area. The first method is to allocate the frequency by using the genetic algorithm approach. This method is the static resource allocation. Next, the game theory approach is adopted for dynamic resource allocation.

4.1 Genetic Algorithm to solve Static frequency allocation through the MBSFN area (SFA-GA)

Frequency allocation can be solved by using graph colouring method. The graph colouring method is an NP complete problem. This method can be easily implemented by using genetic algorithm. A genetic algorithm is a powerful evolutionary approach as a search and optimization tool. It imitates the natural concept of evolution, where natural genetics will evolve, to produce the best sample. Table 4.1 shows some of the basic workflow of genetic algorithm

TABLE 4.1: BASIC WORK FLOW OF GENETIC ALGORITHM

Process	Explanation
1. Initialization of population	Generate the *Np* number of chromosomes which is mostly random
2. Evaluation of each chromosome	Each chromosome will be evaluated and the fitness will be determined
3. Parent selection	Select the best chromosome based on the higher fitness.
4. Crossover/Recombination	The parent chromosomes will be crossover with another parent to vary the genes
5. Mutation	The parent will mutate it gene to vary its string
6. Termination criteria	The GA will find the best chromosomes until the required criteria satisfies

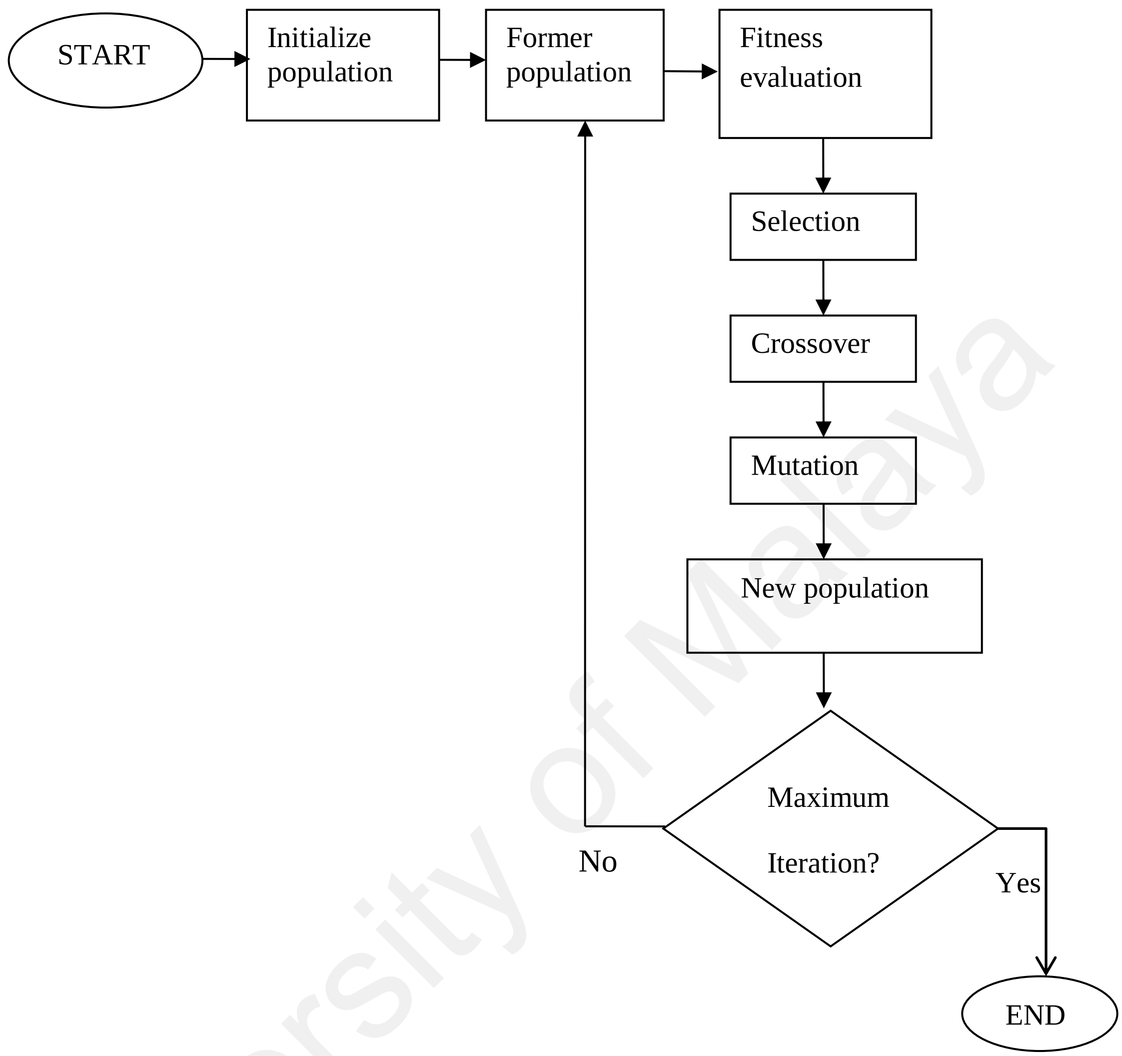


Figure 4.1: Genetic Algorithm flow

The frequency allocation problem for MBSFN area can be solved with the help of an undirected graph. Each vertex of the graph represents MBSFN area and the edge of the graph represents as the connectivity between vertexes. The adjacency matrix of $M\ X\ M$ area can be derived as:

$$aij = \begin{cases} 1, & i\ and\ j\ is\ adjacent \\ 0, & otherwise \end{cases} \qquad (4.1)$$

We have 19 areas in one MBSFN network. An adjacency matrix of *19 x 19* will be generated as follows.

Vertex	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
2	1	0	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
3	1	1	0	1	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0
4	1	0	1	0	1	0	0	0	0	0	0	1	1	1	0	0	0	0	0
5	1	0	0	1	0	1	0	0	0	0	0	0	0	1	1	1	0	0	0
6	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	1	1	0
7	1	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	1
8	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1
9	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
10	0	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
11	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
12	0	0	1	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
13	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
14	0	0	0	1	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0
15	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0
16	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	1	0	0
17	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0
18	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	1
19	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0

Hence, we can list out the vertexes representing the MBSFN areas as listed in Table 4.2.

TABLE 4.2

MBSFN AREA WITH ADJACENT AREA

MBSFN Area	Adjacent MBSFN Area
1	2,3,4,5,6,7
2	1,3,7,8,9,10
3	1,2,4,10,11,12
4	1,3,5,12,13,14
5	1,4,6,15,16
6	1,5,7,16,17,18
7	1,2,6,8,18,19
8	2,7,9,19
9	2,8,10
10	2,3,9,11
11	3,10,12
12	3,4,11,13
13	4,12,14
14	4,5,13,15
15	5,14,16
16	5,6,15,17
17	6,16,18
18	6,7,17,19
19	7,8,18

4.1.1 Genetic algorithm approach:

1. Initialization of *Np* chromosomes.

   Np chromosomes will be generated randomly. The chromosomes are constructed with *M* genes, which represent number of areas. The value of the gene is randomly generated from the range of [1, *Š*]. *Š* represents the number of frequency blocks or the frequency reuse factor.

   The value of *Š* is varied in the range of [1, 7] as 1 represents the lowest value and 7 is the maximum value of frequency reuse factor.

   If we take one example of *Š*=3, the chromosomes will be constructed as follows:

Chrm 1	1	2	3	2	3	3	3	2	3	3	1	1	1	2	3	3	2	1	2

2. Evaluation

   Each chromosome that is generated will be evaluated by a fitness function. Fitness function, *fp* is very vital in the process to identify which chromosome is the best. Table 4.1 is the main reference to calculate the fitness function, *fp*. The step to calculate the *fp* is shown as follows. We take chromosome 1 as an example.

   Figure 4.2 depicts the flow chart of evaluating the chromosome to determine the *fp*. As a conclusion, *fp* can be calculated as:

$$subfitness(gi, j) = \begin{cases} 1, \; if \; Mi \; \neq M \forall j, \; \forall j \; is \; adjacent \; with \; i \\ 0, \; otherwise \end{cases} \quad (4.2)$$

$$fp = \sum_{i=1}^{M} subfitness(gi, j) \quad (4.3)$$

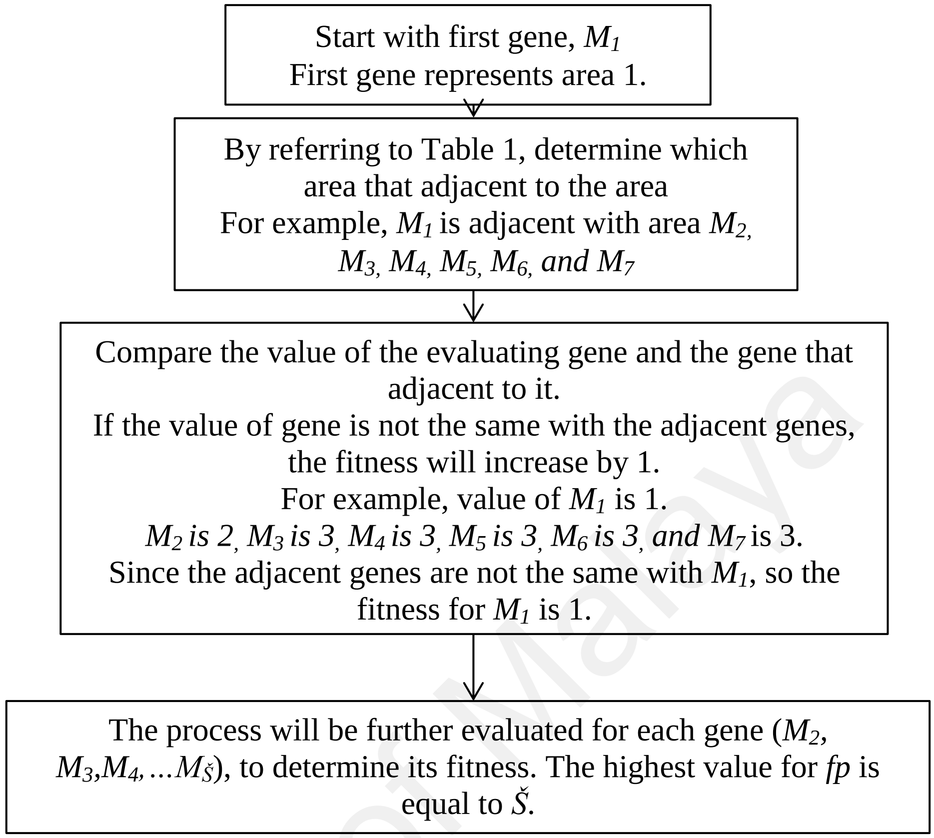


Figure 4.2: Flow chart to calculate *fp*

3. Parent selection

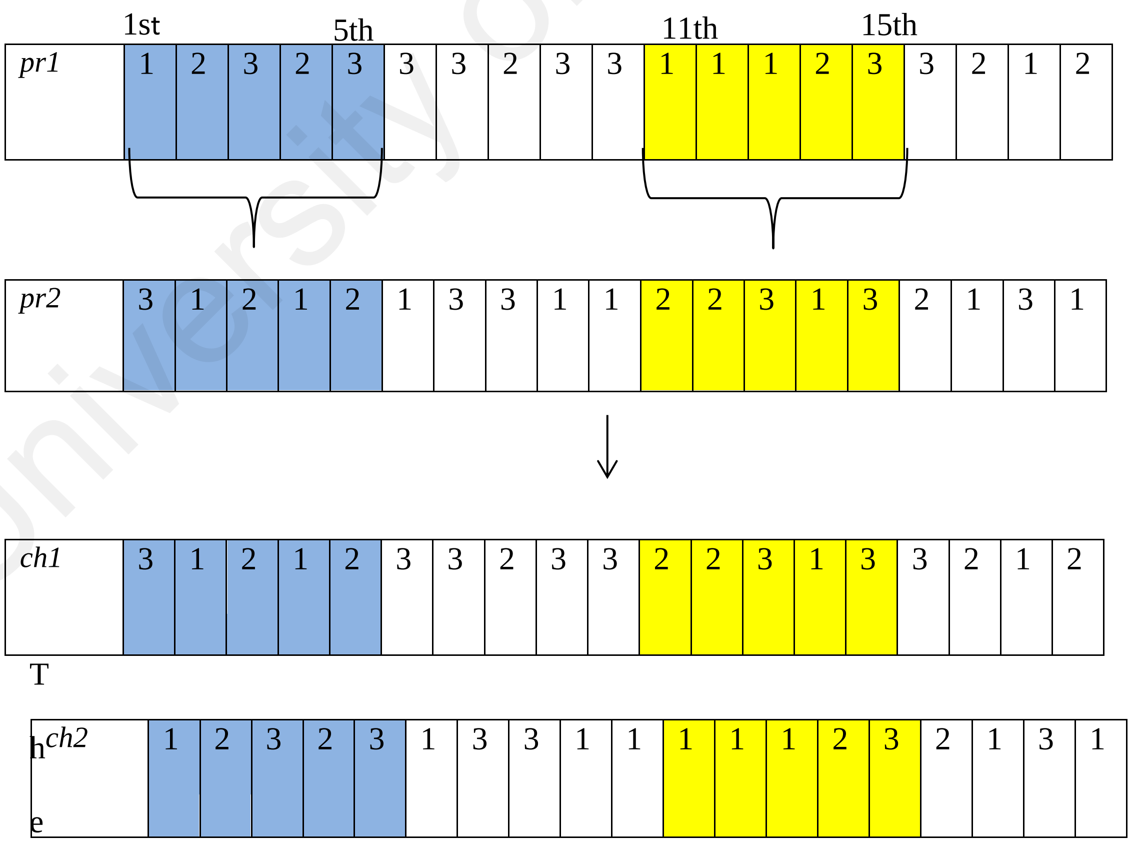
After determining the value of *fp* for each chromosome, four chromosomes with higher *fp* (*pr1, pr2, pr3, and pr4*) will be selected as the parent. The chromosomes with less fitness will be discarded as it is not fit enough to evolve. *Np* chromosomes will be replaced with the chosen four parents. The parent will be evolved to obtain another *Np*-4*pr* new chromosome to replace the old *Np* chromosomes.

4. Crossover and recombination

Crossover process mainly represents a reproduction of new chromosome that replacing the poor parent while at the same time preserving the elitism. For diversity purpose, crossover point will be randomly generated. The point should be along the chromosome length. When the crossover point has been chosen, the chromosome will change the information on the stated gene position. After that, the algorithm will check whether there are duplicate genes created. If duplication exists, the algorithm proceeds to find what the missing genes along the chromosome string are. Eventually the generated child will be assured free from similar genes production and can be successfully proceed to the next step (mutation).

The selected four parents (*pr1*, *pr2*, *pr3 and pr4*) will evolve to obtain children by making the process of crossover. *pr1* will be crossed over with *pr2* and *pr3* with *pr4*.

We choose *pr1* and *pr2* to demonstrate the crossover process. The point of crossover will be chosen randomly. For this crossover, we have chosen point 1 to point 5 and point 11 to point 15 to be crossed over.



ch1 and *ch2* is generated. *pr2* and *pr2* will do the same process until *ch3* and *ch4* is generated. Now, another four new chromosomes (*ch1, ch2, ch3*, and *ch4*) can be replaced. There are *Np-8* remaining chromosomes to be replaced by now.

5. Mutation

Mutation applied to prevent identical chromosomes. It helps in producing variety of diverging solutions. Children generated from crossover will go through different type of the mutation process. Two identical chromosomes forms by a crossover process usually occur when the iteration is increased. Thus, two different types of mutation will help the solution to converge again so that it will not easily stuck.

New child produced for the mutation part are inserted into the new pool of chromosomes. Therefore the size of the population eventually remains the same. The new children will go through the same process as their parents did. This process repeated until the desired goal is reached.

Types of mutation operator used are:

i) Swap mutation.

Swap meaning that gene from position 1 and 2, 5 and 6, 9 and 10, 13 and 14, and 15 and 16 will be changed in place. Thus offspring become:

ch1	3	1	2	1	2	3	3	2	3	3	2	2	3	1	3	3	2	1	2
ch5	2	1	3	1	3	2	2	3	2	2	3	3	3	3	3	1	1	2	2

Since the chromosome is quite long, the point of mutation can be chosen up to 10 points.

ii) Flip mutation.

With same point of mutation, the string at n position 1 and 19 will be changed in reverse order. The offspring become:

ch2	1	2	3	2	3	1	3	3	1	1	1	1	1	2	3	2	1	3	1

ch6	1	3	1	2	3	2	1	1	1	1	1	3	3	1	3	2	3	3	1

Reverse order

ch2, *ch3*, and *ch4* will be mutate until *Np-8* chromosomes are obtained to replace the new pool of chromosomes

6. Termination criteria

The process will be repeated with the new population that generated from the process of selection, crossover and mutation.

There will be *Lp* iteration to search for the solution. If there has more than a Vp solution with fp=Š, the process will be stopped.

4.2 Game Theory to solve Dynamic Resource Allocation based on Interference Coordination (DRA-IC).

We have modelled the interference coordination between the MBSFN area in downlink LTE as a non-cooperative game (DRA-IC) . The developed DRA-IC algorithm is a part of a hierarchical resource allocation process based on interference coordination. The DRA-IC proved to coordinate and reduce the interference by allocating the certain of resources to the respective area and restrict the resource in neighbouring areas. Hence, a set of resources will be allocated to the certain area and the respective user will be scheduled by performing the fast scheduling based on the instantaneous channel conditions or SINR.

The configuration of MBSFN deployment as shown in Chapter 3 will be used to develop the DRA-IC algorithm. In Figure 4.3, there are 3 MBSFN areas with each area has 16 resources. Area 1 shows eight marked resources are allocated.

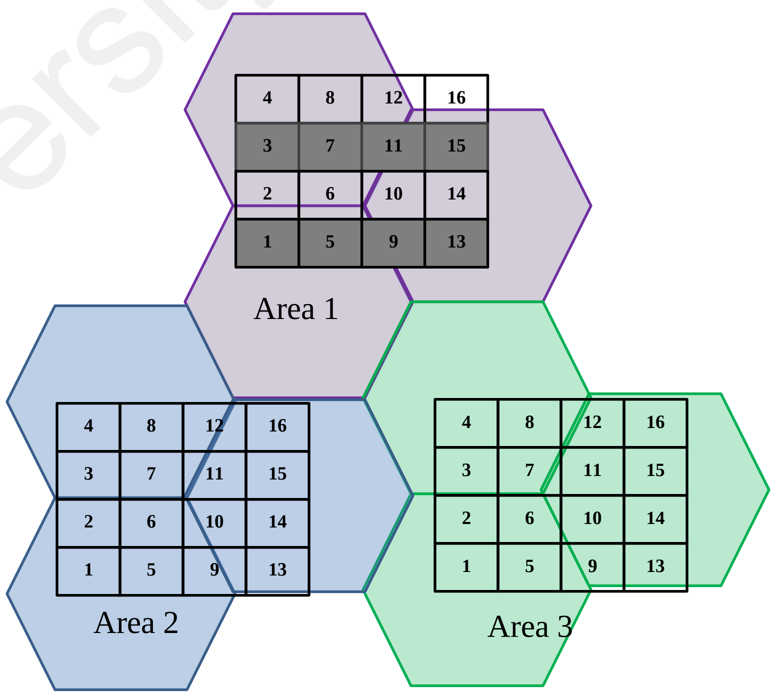


Figure 4.3: Scenario with 3 MBSFN areas and 16 resources.

Each area in MBSFN network will have the same set of 1… $\acute{R}$ orthogonal resources as in the frequency domain in OFDMA chunks. Thus, the resource allocation of each area would consist of a subset of resources to be used in that area. We represent the resource used in area i as the $\acute{R}$ dimensional binary vector $r_i \in B^{\acute{R}}$ with $r_{i,k}$ =1 indicating that the resource k is used in area i. Figure 4.3 shows an example scenario which consists of 3 MBSFN areas each having a total of 16 resources. Area 1 shown the resource allocation r_i = [1 0 1 0 1 0 1 0 1 0 1 0 1 0 1 0] $\in B^{16.}$

We assumed that the usage of resource in area i will cause the interference in other area which use the same resource. The impact of the interference of resource k in area i which also be used by area j will be defined as $h_{i,j}$. The resource allocation of other area is defined as $r_{-i} = [r_1 , r_2 , \dots , r_{i-1}, r_{i+1} , \dots, r_n]$. Thus, by using this notation, we can develop the total interference $I_{i,k}$ of area i receives on resource k as :

$$Ii,k = \sum_{j \in P\{i\}} h\, i,j\, rj,k \tag{4.4}$$

Where $h_{i,j}$ is the channel condition from area i to area j and $r_{j,k}$ =1 if resource k is used by area j. The channel condition is not symmetric i.e. $h_{i,j} \neq hj_{,I}$ since the distance of each transmitter in the respective MBSFN area is different.

4.2.1 Non Cooperative Game Model

A game theory is a game that models a decision of a situation where more than one decision maker or players have to face a situation of strategic interdependence and decide their best action to take. Every action taken by the players will face the consequence and each player have their target to achieve.

In DRA-IC algorithm, we have modeled the game theory to solve the resource allocation issue. The MBSFN area will represent the decision makers or players of the game, *P*. The allocation vector, $r_i \in B^{\acute{R}}$ is the action taken by the player, *Ri* which to maximize their utility function, *U*. In general, a finite formed game is denoted by a tuple, $\Gamma = ((P,(Ri)_{i \in P}, (Ui)_{i \in P})$ where P is the finite set of players and (Ri)i∈P and (Ui) i∈P denote as a possible set of finite action taken and utility functions respectively. We have assumed that each area will demand a number of resources that it needs, *Di*. Therefore, the action taken by a set of vector *Ri* has the specific value for each area because the total allocation of vectors, r_i of each area is equal to *Di* as shown as :

$$\sum_{k=1}^{\acute{R}} ri,k = Di \tag{4.5}$$

Each player will play a pure strategy game or a deterministic action as only probabilities of 0 or 1 to assign the action taken.

Each player's action will map its own utility function $U(r_i, r_{-i})$ as well as the actions of r_{-i} from other than area *i*. The area is interested to obtain the least interfered link by choosing the right action, r_i. Hence, the area utility function of the game is to minimize the interference and it can be defined as the negative sum of the total interference received on its own selected action. The utility function $U(r_i, r_{-i})$ is shown in Equation (4.6):

$U(ri\,,r-i) = -\sum_{k=1}^{\acute{R}} ri,k\; Ii,k$ (4.6)

$U(ri\,,r-i) = -\sum_{k=1}^{\acute{R}} ri,k \sum_{j\in P\{i\}} h\; i,j\; rj,k$ (4.7)

subject to :

$\sum_{k=1}^{\acute{R}} ri,k = Di$ (4.8)

The utility function of equation (4.7) is defined as the complete formal definition of the normal form game. The game is an anti coordination game due to the fact the players will try to coordinate their own resource allocations with all players will use different resources. They are two types of classical game theory, i.e. static and extensive games. The player will only play in a single time for static games, while in extensive games, the player will play repeatedly to learn and obtain the solution. The players will know that they will repeat the same game over and over again to choose their action in a way to maximize their utility function. We proposed that the game developed above is played multiple times and it is done mainly to obtain a good solution. The phenomena like revenge, cooperation, and threats can occur to change the behavior of the game. In contrast to other classic games such as 'The Prisoners' Dilemma', the players are unable to obtain a solution from the knowledge of the players' action and utility function only. This is also cannot be happening to the developed DRA-IC algorithm due to the fact, apart from the interference level , all resources are equal thus there will be generally a big number of good solutions and only differ in the resource numbering vector. The most important issue to obtain the best solution in the game theory is the existence of the Nash equilibrium.

4.2.2 Convergence of Dynamic Interference Coordination

In a traditional cellular systems, the resource allocator will automatically decide the base station to allocate the resource. One issue is whether the distribution of the resource allocation process will stabilize and reach a steady state when obtaining the best solution. When the neighboring areas constantly changing between two resources of R_1 and R_2, the lockstep which results from the previous decisions might occur if they decide at the same time with the knowledge of the interference level. The existence of Nash equilibrium in game theory will show that the distribution of the resource allocation process will reach the steady state.

A steady state can be achieved by introducing the Nash equilibrium action profile for the DRA-IC algorithm game. The Nash equilibrium action profile, (r_i* ,r_{-i}*) describe the state which no player can gain higher utility value by deviating their chosen action of r_i* as long as other player do not change its action r_{-i}*. Generally, at a Nash equilibrium $U(r_i^* ,r_{-i}^*) \geq U(r_i ,r_{-i}^*)$ for all players $i \in P$ and for all $ri \in Ri$. The area i would only want to change its resource allocation from ri to ri' if the total interference is reduced i.e U(ri',r-i) > U(ri,r-i). We will prove that DRA-IC algorithm game belongs to the class of potential games which are guaranteed to have Nash equilibrium that will be obtained after a finite number of game rounds.

4.2.3 Potential games

The individual change of the player's action will result in a change of the utility. The consequence of the changing in the utility is called the potential games which form a special class of normal form games. The potential function is described as the change in the utility function and denoted as Φ (*ri, r-i*). The potential is called an exact potential if the change in player is utility exactly equal to the change in the global potential function as:

$$U(ri',r\text{-}i) - U(ri,r\text{-}i) = \Phi(ri', r\text{-}i) - \Phi(ri, r\text{-}i). \qquad (4.9)$$

We have formulated the exact potential function is equal to the total interference summed over all interfering links as:

$$\Phi(\text{ri, r-i}) = -\sum_{i=1}^{P}\sum_{j=1}^{i}\sum_{k=1}^{R} hi, j\ ri, k\ rj, k \tag{4.10}$$

To prove the exact potential function in Equation (4.10), consider an area *i* that individually switch one of its previously allocated resources from resource *k* to resource *l* due to the fact of the $Ii_{,\ l} < Ii_{,\ k}$. The total interference of $I_{i,k}(r_{-i}) = \sum_{j\in\text{P}\{\text{i}\}} h\ i, j\ rj, k,$ that is received from all other areas by not using resource *k* anymore, will exactly equal to the sum of the improvements in the interference of all areas. This is because the area *i* will abstain from using resource *k* in the future.

To prove the existence of a Nash equilibrium, the potential games will have the finite improvement path [Monderer, 1996] which help to indicate how a Nash equilibrium might be reached by a set of players. We assume that each player is capable to know the outcome in the form of calculating interference or utility function which resulted from the other players' resource allocation actions. All players will consecutively choose their action one at a time. Therefore, if the player *i* has a better response of the changing resource to r_i' which would obtain the better utility by *U(ri',r-i) - U(ri,r-i).* Thus it is exactly equal to the corresponding increase in the game's potential. All other players' action is assumed to remain constant while the player i playing. If some other player j performs a better response to its utility, that player will further increase the global potential function Φ. The consecutive improvement process would reach a state with no player is able to change its action, thus improving its utility as the number of players and the actions set taken are finite. This is the description of the Nash equilibrium. The potential function is monotonically increasing in each iteration due to the selfish behavior of the player that never makes them to obtain the lower utility from the action taken. This will prevents the repeat distributed allocation process which the algorithm does not reach the steady state. Figure 4.4 shows the implementation of the DRA-IC algorithm where each MBSFN area represents the players of the resource allocation game.

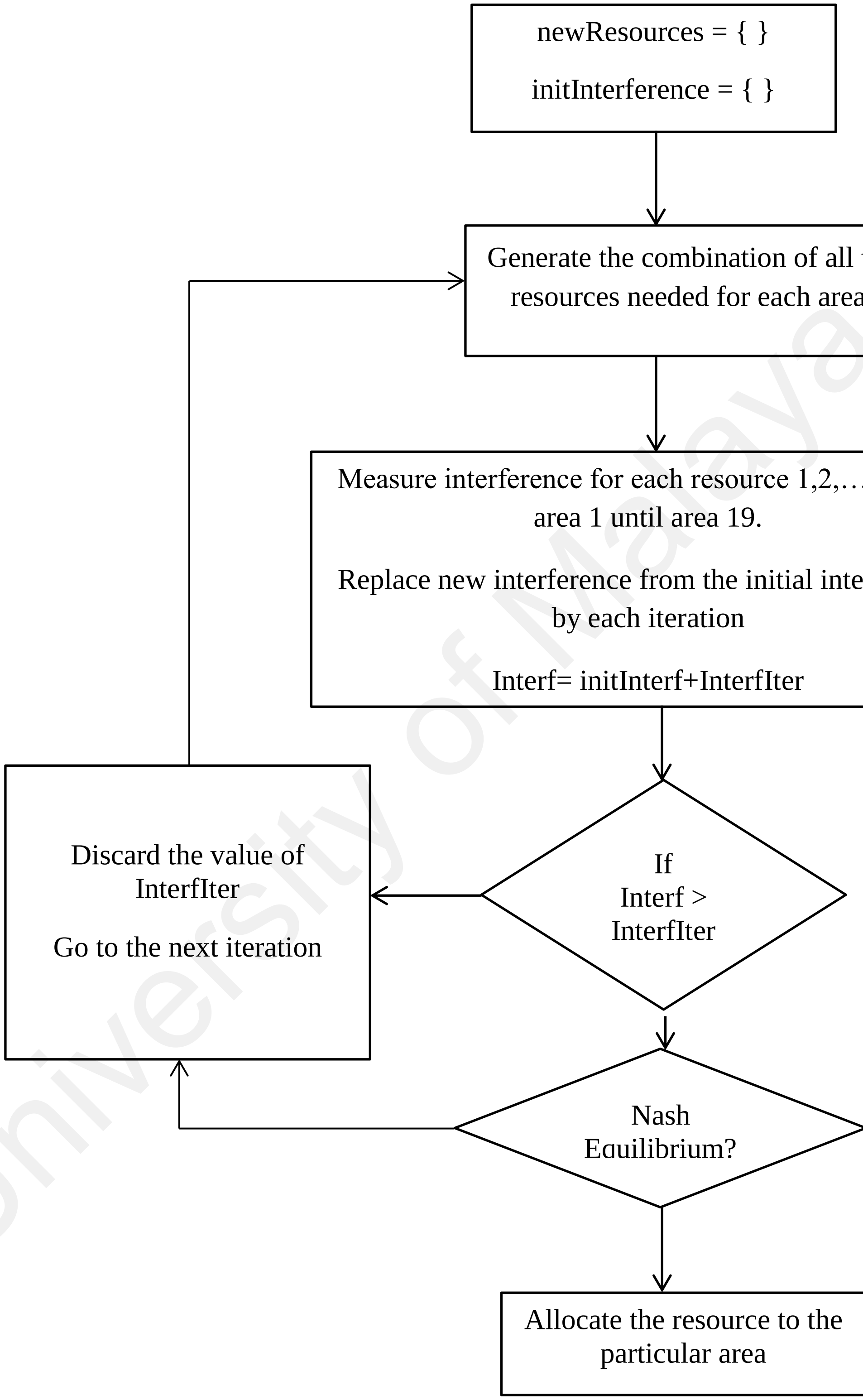


Figure 4.4 : Flow Chart of DRA-IC algorithm

Chapter 5 Result and Discussion

5.1 System Parameters

The system level simulation of MBSFN in LTE is ran based on the following the parameters. The simulation runs in MATLAB.

TABLE 5.1 SYSTEM PARAMETER

Parameters	Value
Carrier Frequency	2GHz
Bandwidth	10MHz
Number of Subcarriers	600
Number of Subcarriers per Resource Block	12
Subcarrier Spacing	7.5kHz
Number of Physical Resource Block	50
Cell Radius	1000m
User Distribution	Random Distribution
Slot Duration	0.5ms
Scheduling Time	1ms per TTI
Number of OFDM symbols per Slot	6
Simulation time	10s
MBSFN area	19 Continuous areas with 7 hexagonal cells
Number of users of each area	5-200 users
Total BS transmits power	16 dB

We developed the MBSFN network system model as presented in Chapter 3. Table 5.1 summarized the system parameters. The SINR calculation has been explained in Chapter 3.

The proposed method performance will be explained in the next section. The first part is the fixed frequency allocation by using genetic algorithm and the second part is the dynamic resource allocation by game theory approach. The system B performance will be of both methods are compared statistically.

5.2 Genetic Algorithm to solve Fixed frequency allocation through the MBSFN area (SFA-GA)

Genetic algorithm will help to solve the frequency allocation to each MBSFN area. In this project, the frequency reuse factor will be varied from 2 to 7. The solution given by genetic algorithm is shown by the figure with an associated color. Furthermore, the genetic algorithm will give more than one solution. As shown in Figure 5.1, SFA-GA scheme could find more solutions with lower reuse factor. This is because of the higher the reuse factor, the harder the algorithm to find the solution.

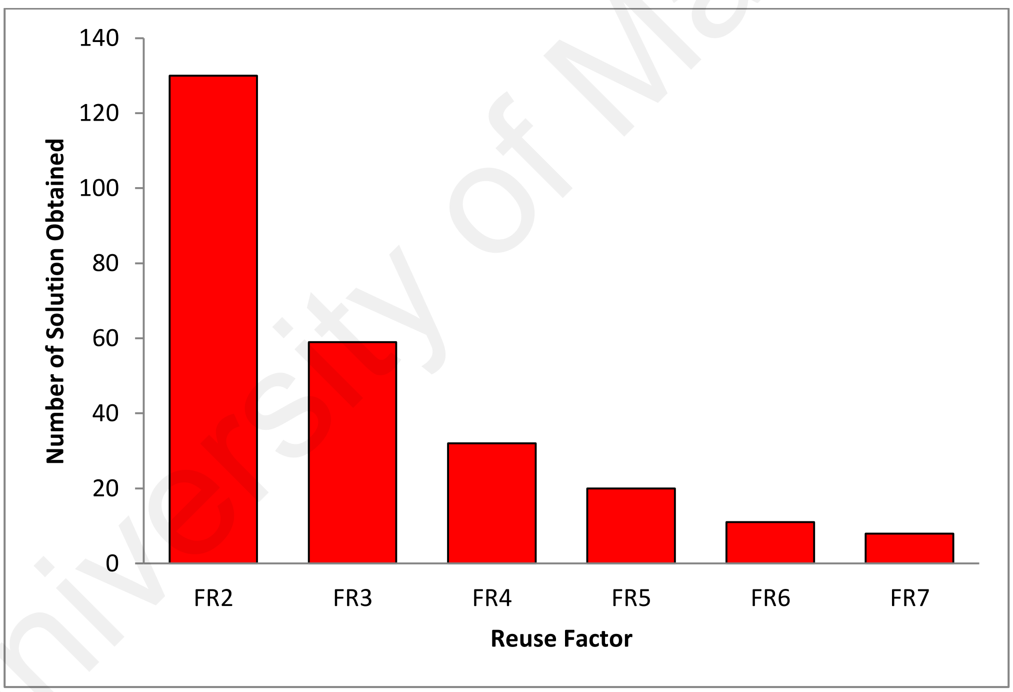


Figure 5.1 : Number of Solution Obtained

Figure 5.2(a) to 5.2(f) show one of the solutions obtained from the SFA-GA scheme for each frequency reuse factor to simplify the results obtained.

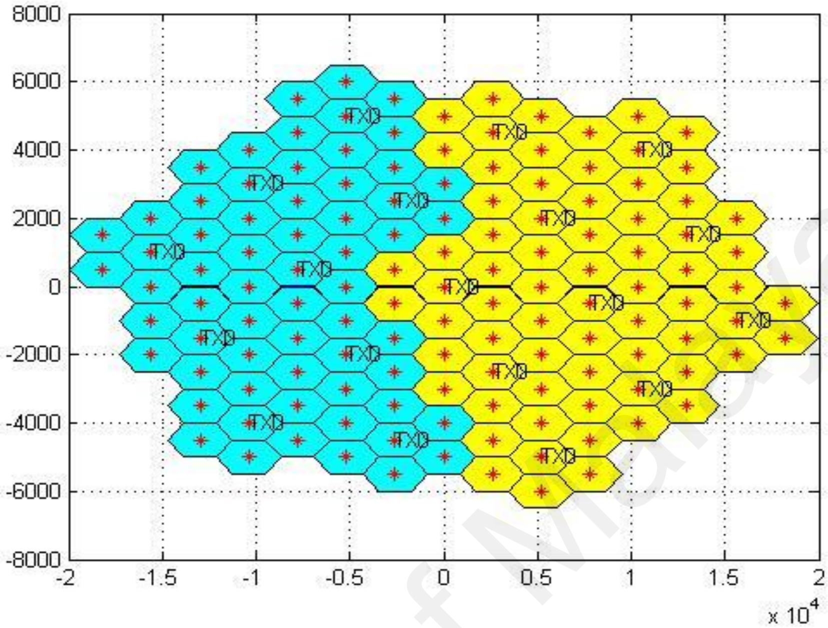


Figure 5.2 (a): Frequency Reuse 2 for 19 MBSFN areas

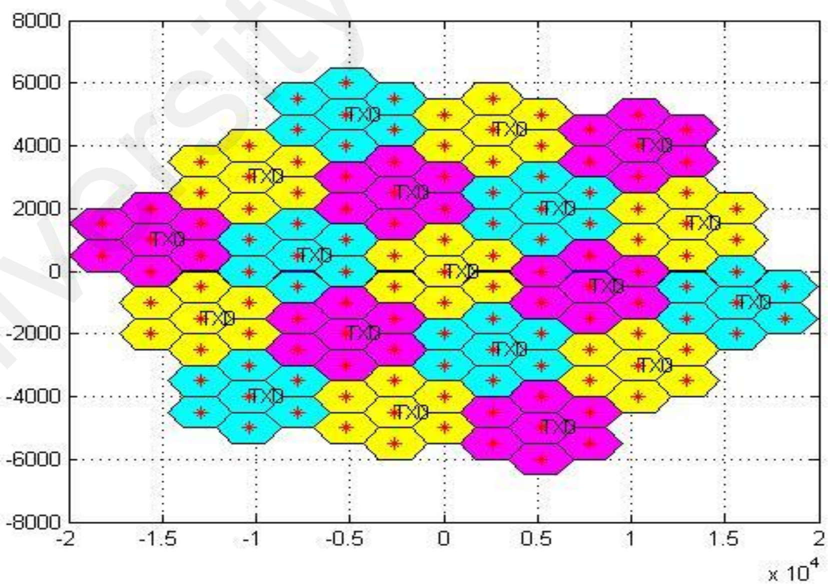


Figure 5.2 (b): Frequency Reuse 3 for 19 MBSFN areas

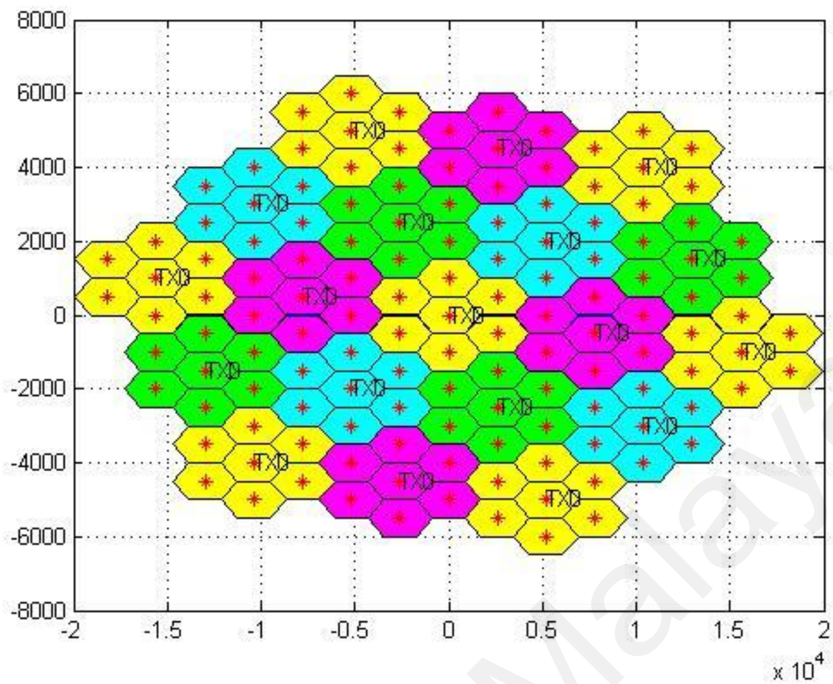


Figure 5.2(c): Frequency Reuse 4 for 19 MBSFN areas

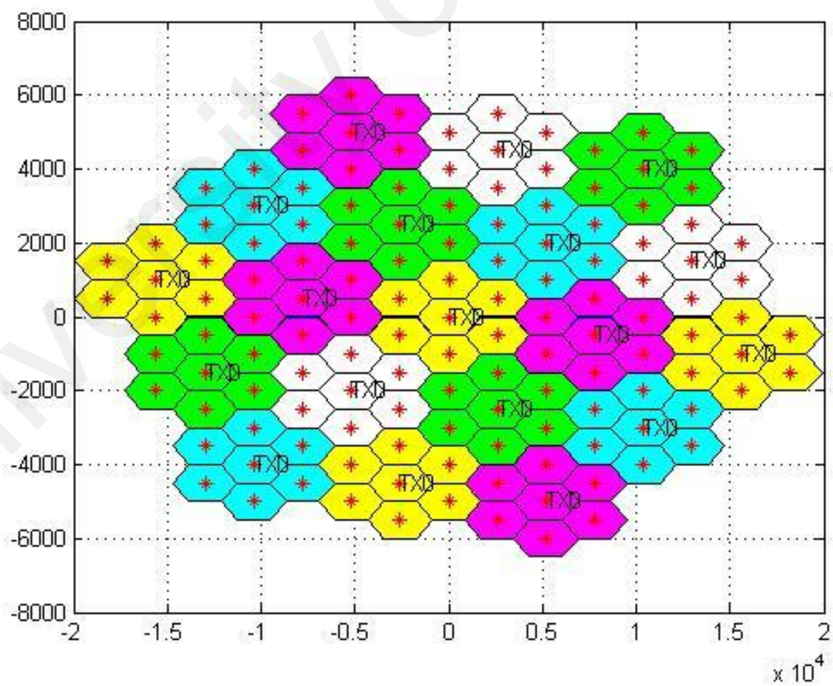


Figure 5.2(d): Frequency Reuse 5 for 19 MBSFN areas

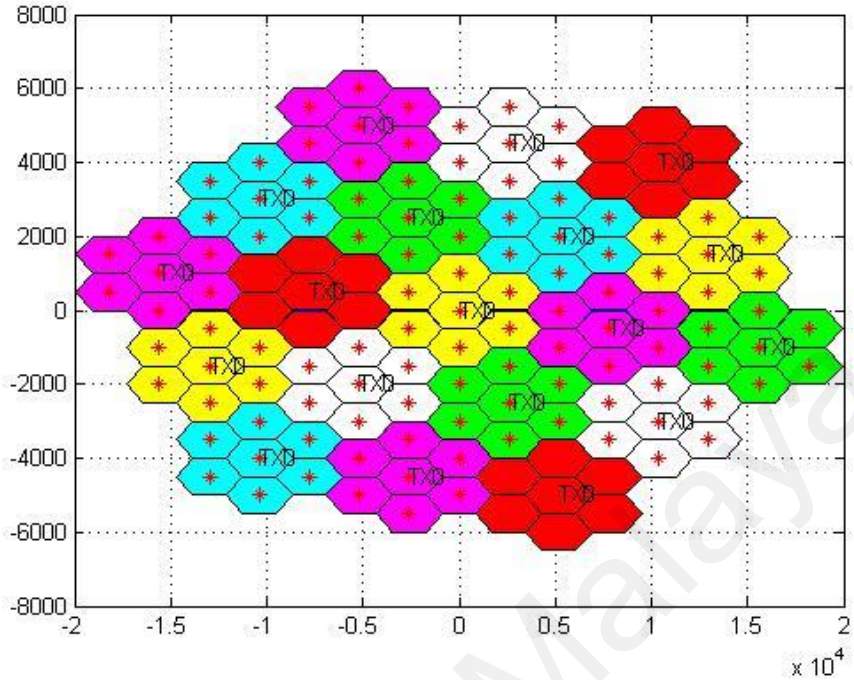


Figure 5.2(e): Frequency Reuse 6 for 19 MBSFN areas

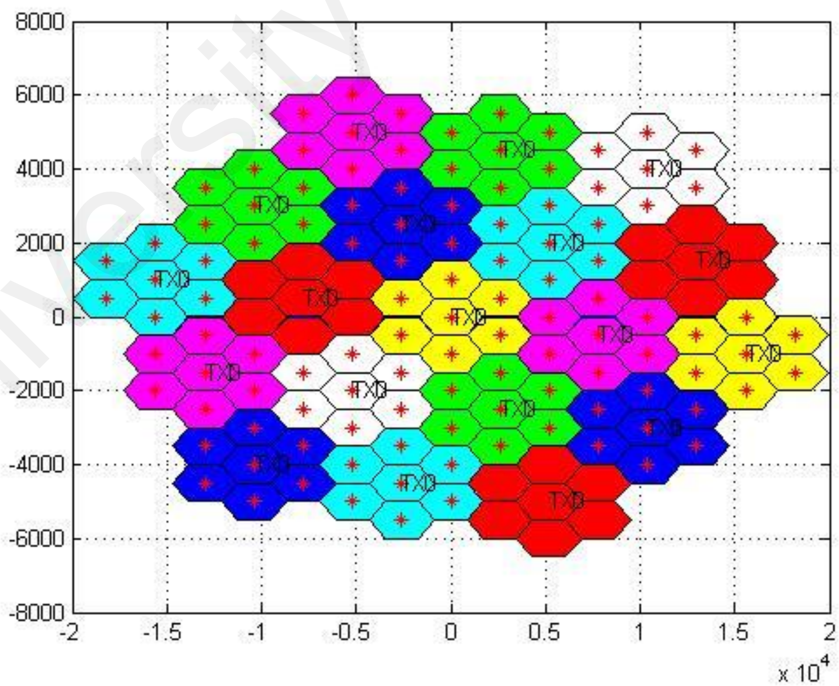


Figure 5.2(f): Frequency Reuse 7 for 19 MBSFN areas

Figure 5.3 represents the SINR cumulative distribution function for the frequency allocation for each frequency reuse in MBSFN system. Frequency reuse 2 shows that it is slightly shifted to the left since it has lower SINR value compared to other coordination scheme. The curve shows that for frequency reuse 3 until frequency reuse 7, the SINR distribution is about the same from 0 to 82%. This explains that, most of SINR values for frequency reuse 3 until 7 are concentrated in the value from 10 dB to 20 dB. Therefore, it shows that by using frequency reuse 3, the interference can be coordinated well enough. The value of SINR is improved if we use a higher frequency reuse scheme such as frequency reuse 5 and above. At 95 % of distribution, we can compare clearly the value of SINR of each frequency reuse scheme. The SINR value will be higher if we use a higher frequency reuse scheme such as frequency reuse 5 and above.

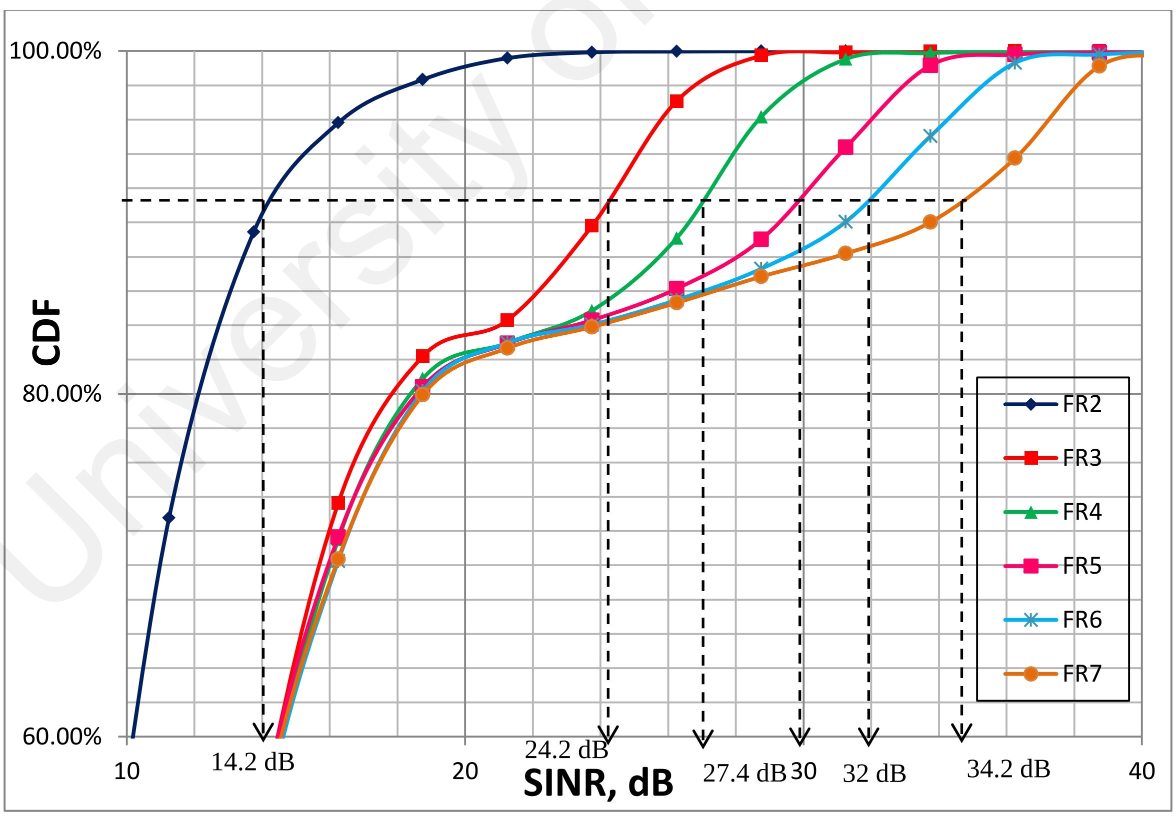


Figure 5.3 CDF for Average SINR for FR2, FR3, FR4, FR5, FR6, and FR7

Figure 5.4 shows the average system capacity for every frequency reuse scheme. Frequency reuse 3 has the highest system capacity compared to other scheme that is about 2.7 Mbps. Even though higher frequency reuse scheme has higher SINR value, the system capacity does not correspond with this value. This is because the system bandwidth of the frequency domain is divided equally into the factor of the reuse factor. Hence, the system would be less efficient. Therefore the FR3 scheme will be selected as to compare the SFA-GA performance with the DRA-IC algorithm.

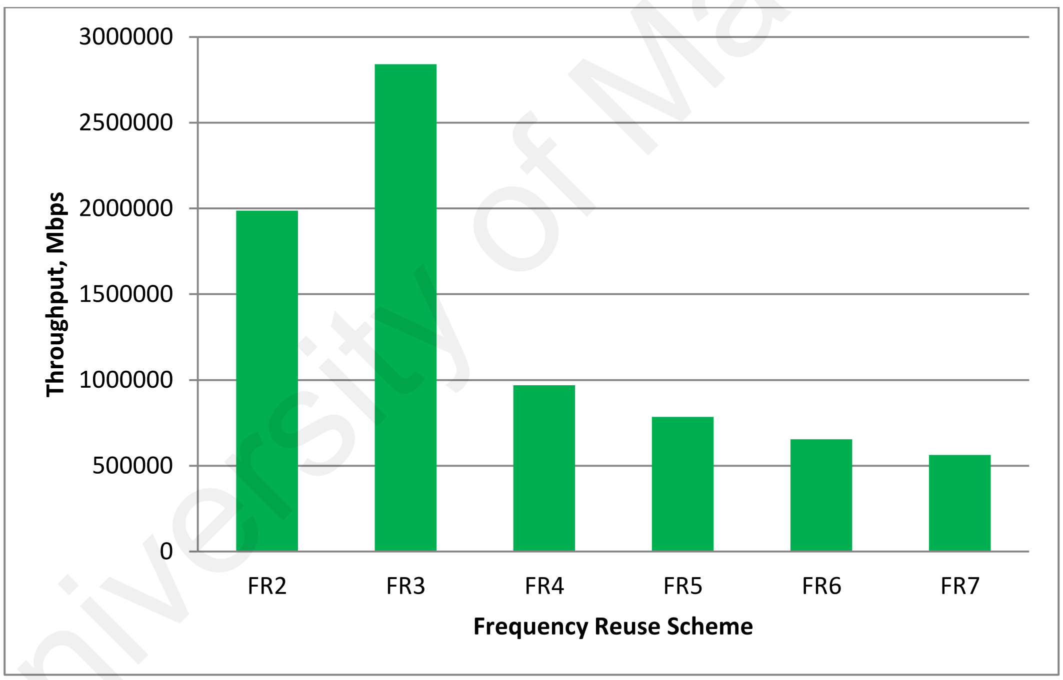


Figure 5.4: Average System Capacity

5.3 Game Theory to solve Dynamic Resource Allocation based on Interference Coordination (DRA-IC)

We have evaluated the merits of DRA-IC method by still using the same system model as explained in Chapter 3 and the system parameters as shown in Table 5.1. The DRA-IC algorithm process starts at a random allocation. The random allocation describes as the resource randomly distributes to the user without the interference coordination process. In each area, we have chosen Di= 8 out of 16 resources to be selected and allocated.

The DRA-IC algorithm will evaluate the MBSFN users average SINR level on an allocated resource over 100 iterations. Every area will select 8 random resources as initial resource allocations. During each iteration, only one area is allowed to select its resource allocations in reactions to the interference level resulting from the previous iteration. Figure 5.5 shows the value of SINR after each iteration.

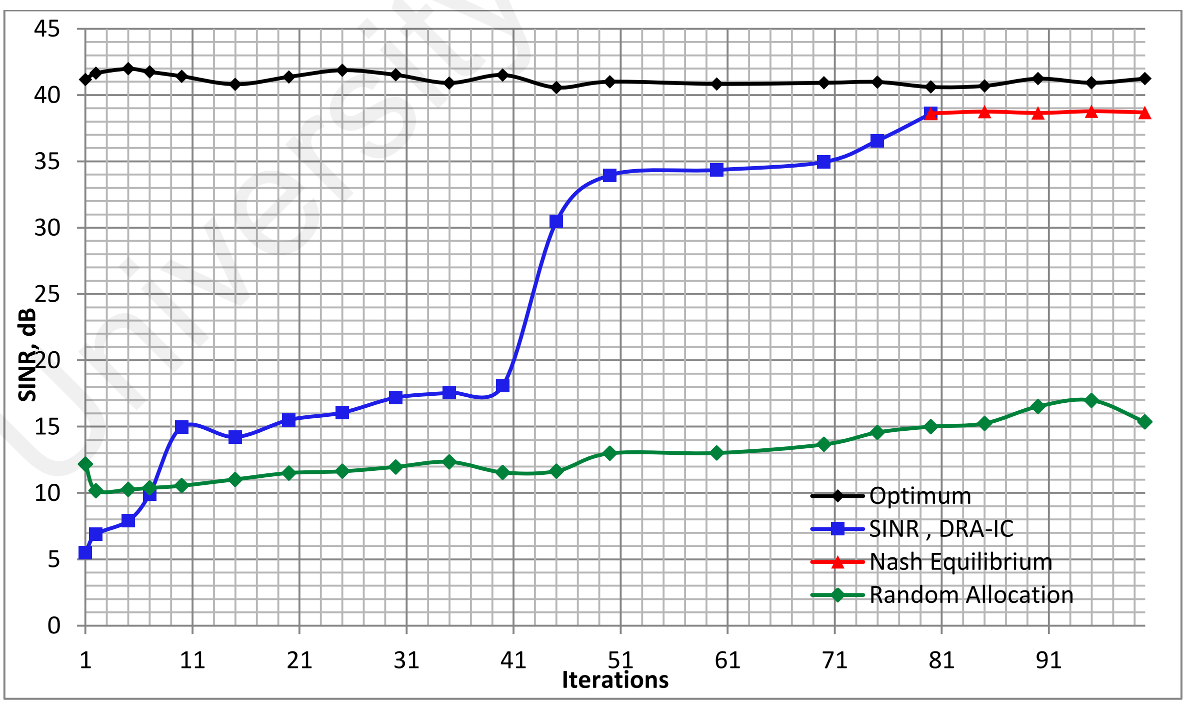


Figure 5.5: Comparison of the convergence DRA-IC over 100 iterations.

We note that the DRA-IC algorithm begins to converge starting from the first iteration with the selected random resource allocation. The interference level in the first 10th iteration is still low because of the random allocation process. After the first 40th iterations, the DRA-IC begins to achieve better interfercence level because the algorithm successfully allocate the correct resources with coordinated interference level. Furthermore, after the 40th iterations, the algorithm starts to increase drastically and found the correct resource allocation. The DRA-IC starts to slow down within the next 50th iterations. This is due to the fact that there are some areas that are still changing and choosing the resources in order to adapt its interference level. The Nash Equilibrium is achieved after the 80th iterations by which the value is approaching the optimum value. The total interference difference between the optimum value and DRA-IC algorithm is about 3dB. The green line represents the random resource allocation without applying game theory algorithm. Its SINR value is not converging and improving by iteration.

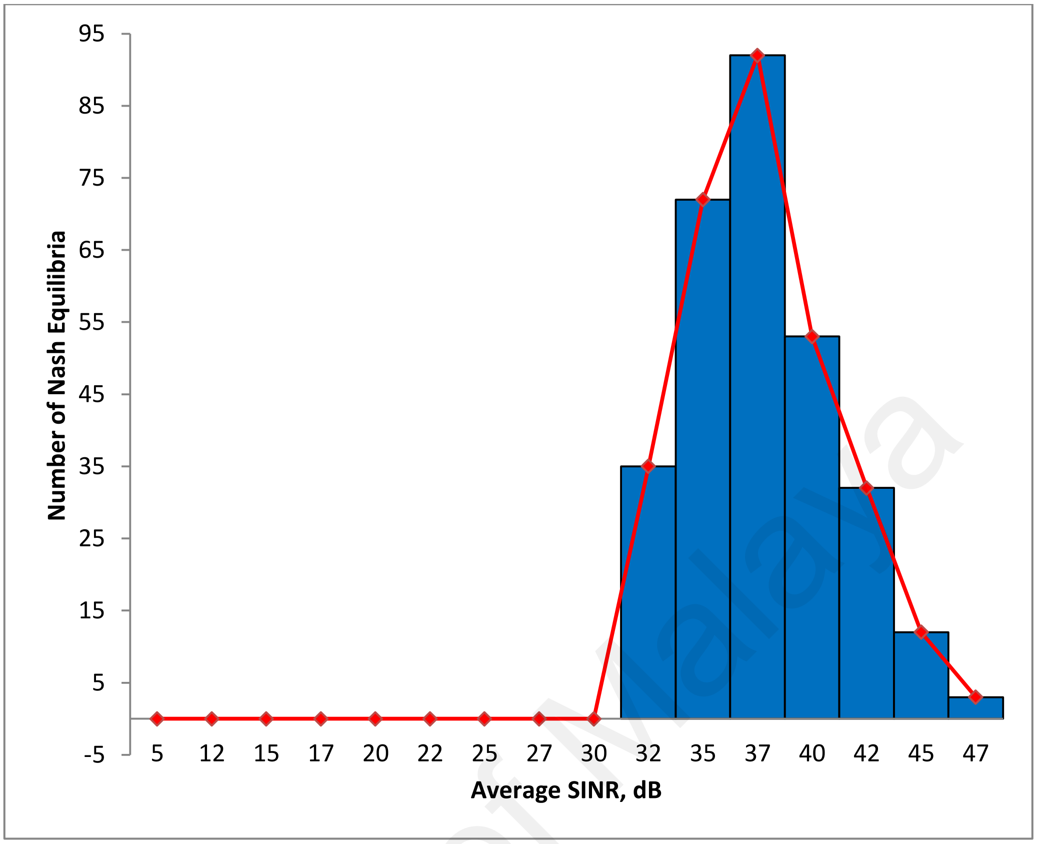


Figure 5.6: Number of Nash Equlibria vs Distribution of Average SINR

Figure 5.6 shows the distribution of Average SINR levels for Nash equilibria obtained in 500 played games and 200 iterations of DRA-IC scheme. The same scenario is used which consists of 19 MBSFN areas with *Di=8* out of 16 resources. We could say that the DRA-IC could achieve highest number of Nash equilibria in the range of 35 dB – 37 dB. The Nash equilibria does not exist at the lower values of average SINR. Furthermore, the DRA-IC still could achieve some Nash equilibria in the range of 40 dB – 47 dB. This proves that the DRA-IC continuously search for the Nash equilibria at higher SINR.

5.4 Comparison between 2 proposed methods (SFA-GA) and (DRA-IC)

Figure 5.7 shows the SINR CDF comparison between random allocation, SFA-GA, DRA-IC and optimal allocation. The graph shows the DRA-IC is always better than SFA-GA algorithm since the DRA-IC will find its own resource allocation with better interference level. The SINR distribution for DRA-IC is almost approaching the optimal value of the difference of 3dB. At the 50% distribution, the difference SINR value for SFA-GA and DRA-IC is about 5 dB. The average SINR gain by random allocation is about 28% improvement if the user undergoes SFA-GA scheme. However, the average SINR gain is much larger if the user chooses DRA-IC scheme with the 48% of improvement. Thus, the DRA-IC scheme is the best algorithm with better interference level and better SINR value.

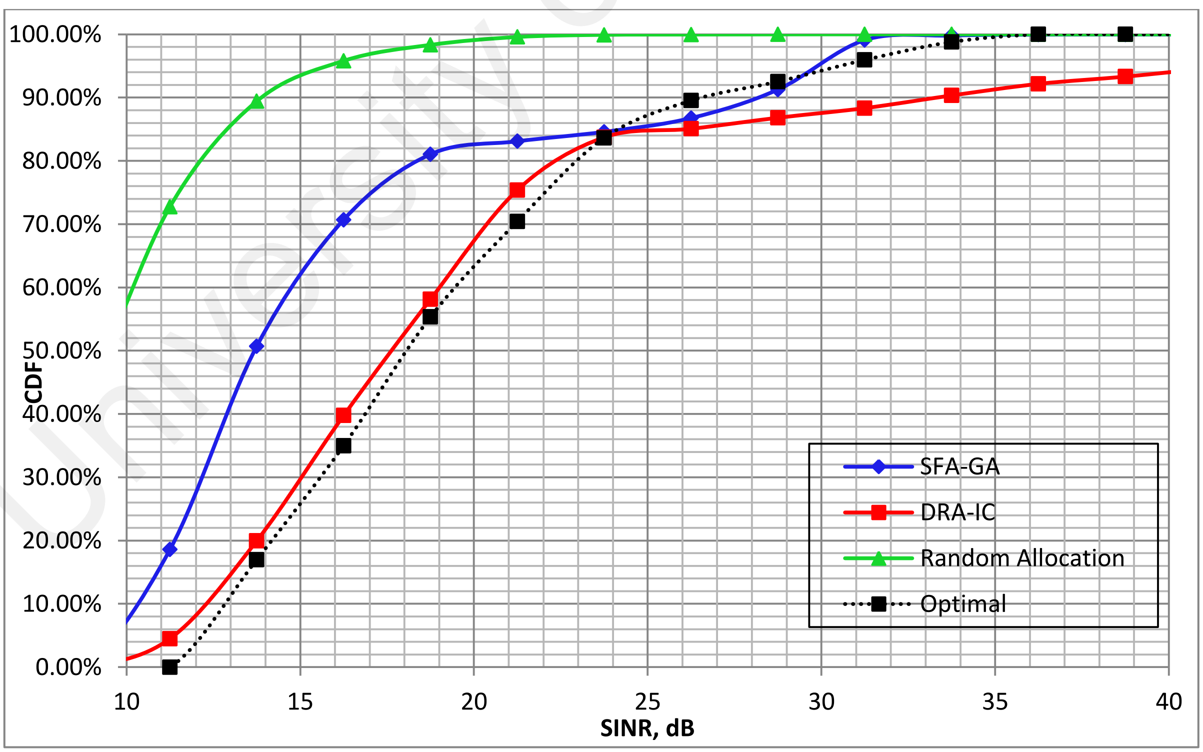


Figure 5.7: CDF for Average SINR for Random Allocation, SFA-GA, DRA-IC, and Optimal Allocation

Figure 5.8 shows the comparison of average SINR value between the proposed allocation scheme and the optimal value. The DRA-IC scheme contributes to better interference coordination as its approaching the optimal value. The average SINR for DRA-IC scheme is still acceptable even with higher traffic load than the SFA-GA scheme. SFA-GA scheme drops drastically to 17 dB at higher traffic load. It shows that the interference level of SFA-GA scheme in higher traffic load is very poor since the interference coordination process does not compromise the traffic load. The random allocation scheme shows the poor average SINR value since there is no interference coordination process involved. Hence, DRA-IC scheme contributes to a better interference coordination even with higher traffic load.

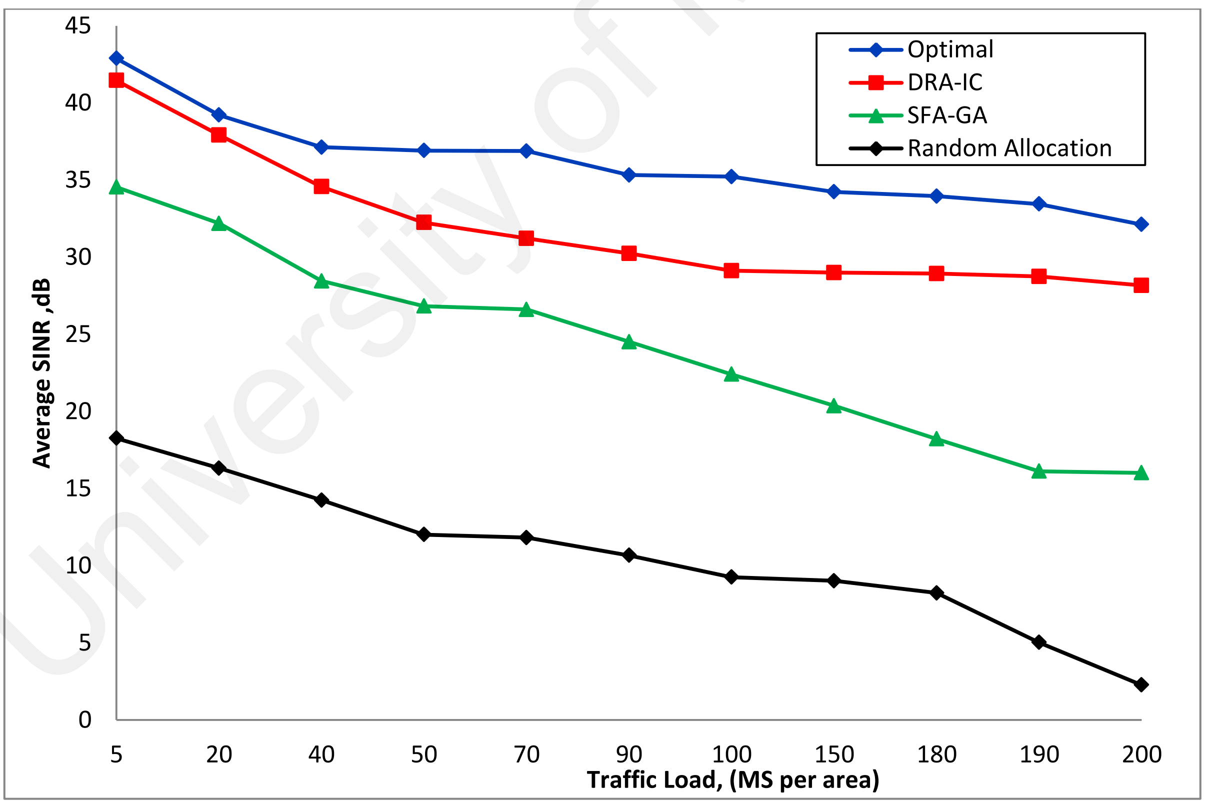


Figure 5.8: Average SINR vs. Traffic Load

The average throughput of the proposed scheme is compared in figure 5.9. The DRA-IC scheme shows the best performance compared to SFA-GA scheme and random allocation scheme. The average throughput for DRA-IC scheme still high with higher traffic load compare to SFA-GA. SFA-GA scheme shows poor performance at higher traffic loads due to more serious interference. The random allocation scheme shows the worst performance due to the uncoordinated interference. The DRA-IC scheme shows that the interference is coordinated well enough and give a better system performance for MBSFN network deployment.

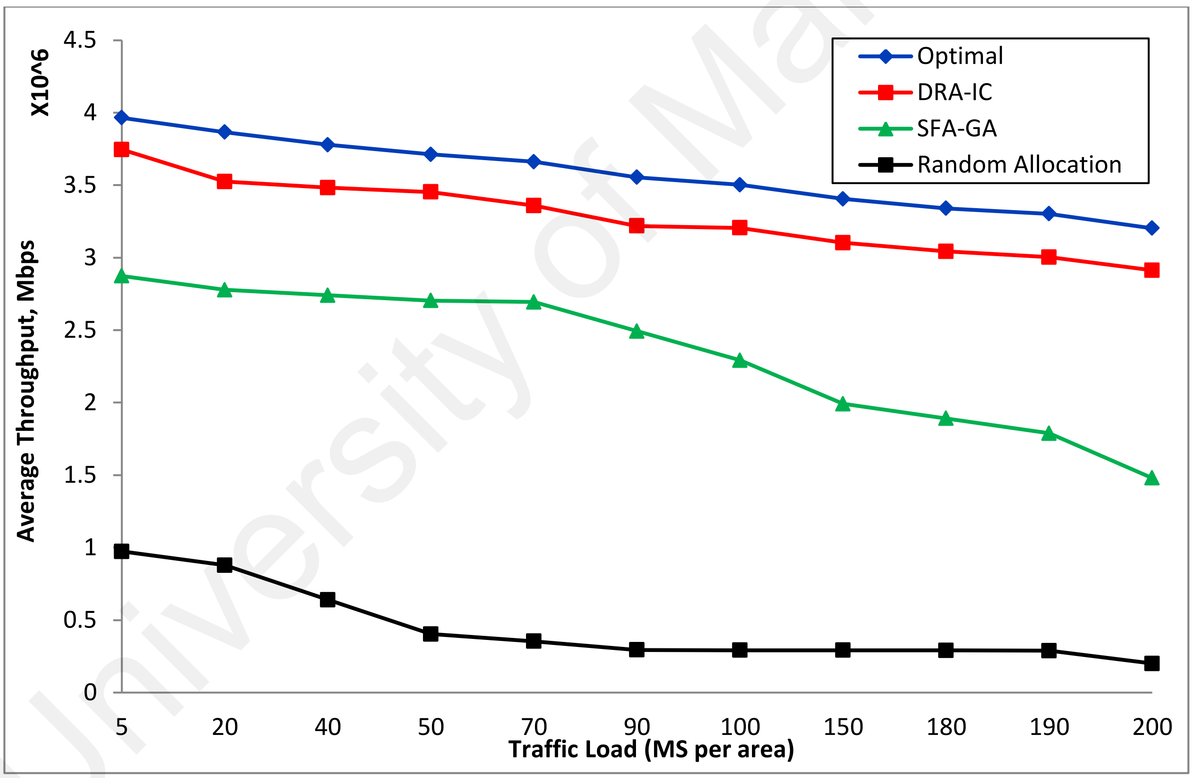


Figure 5.9: Average Throughput vs. Traffic Load

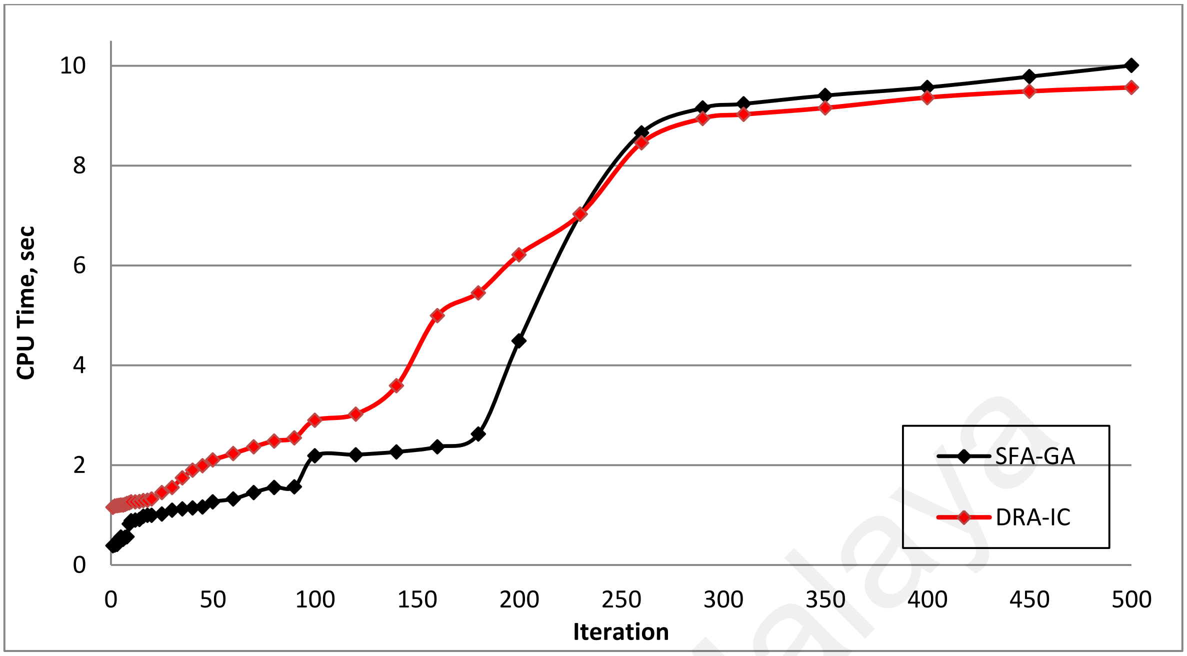


Figure 5.10: CPU Time vs Iteration

Figure 5.10 shows the CPU time for both SFA-GA and DRA-IC scheme based on the number of iterations. For the first 250 iterations, the DRA-IC takes a longer CPU time than the SFA-GA scheme does. This is because, the DRA-IC scheme takes a longer steps to achieve the Nash equilibrium. The CPU time for DRA-IC scheme is getting better after 250 iterations. Within this stage, the DRA-IC algorithm had achieved the Nash equilibrium state. However, the SFA-GA scheme is getting slow when the number of iterations is increasing. This is due to the fact that the GA process takes a long time to search for a new value since it has to generate a new population over and over again. Both schemes have shown that the CPU time taken is in the acceptable range. Hence, both schemes are suitable for the MBSFN network implementation in the real network.

Chapter 6 Conclusion

6.1 Summary of work

In this dissertation, the literature review on interference coordination has been explained and elaborated. Then, the description of proposed schemes of interference coordination on MBSFN network is presented. There are two proposed schemes adopted aiming at allocating resources with interference coordination ; Fixed Frequency Allocation by using Genetic Algorithm (FFA-GA) and the Dynamic Resource Allocation by using Game Theory (DRA-IC).

In chapter 3, the deployed MBSFN network has been explained. The SINR calculation for MBSFN network is described and formulated based on reference paper. The system parameter of MBSFN network such as channel model, propagation model and path loss model are briefly explained in order to evaluate the interference in term of SINR. Each MBSFN area has a random distributed users and all users are assumed to be the MBSFN subscriber.

We have developed two methods of allocating the resource with coordinating the interference level for the MBSFN subscribers. The first method is developed by adopting the static frequency allocation with genetic algorithm approach (SFA-GA). The algorithm contributes to search the correct allocation for each MBSFN area. The algorithm shows that using the average SINR and average throughput is better if frequency reuse 3 scheme is used. However, the performance of SFA-GA declines with higher traffic load due to the fixed allocation of the resource. Hence, the second algorithm has been developed with dynamic allocation by adopting the game theory (DRA-IC) . The DRA-IC will dynamically allocate the resource to each MBSFN area and will coordinate the interference as formulated in chapter 4. The scheme will iteratively calculate and search the best interference level and allocate the resource to the respective area. The scheme has shown the better performance gain compared to SFA-GA even though in higher traffic load. This is due to the fact, the DRA-IC will continuously calculate its best interference level from time to time. We have compared the proposed method with the optimal and random allocation. The DRA-IC has shown that the performance is very near to optimal values. However, with random allocation where there is no interference coordination, the performance of the scheme is very poor. These results are very encouraging as it shows that the interference coordination can be achieved dynamically in the eNodeB by executing the simple implementation of the DRA-IC algorithms based on local information only. The CPU times recorded shows that the DRA-IC algorithm is possible to be implemented thus can save costs and time.

6.2 Future Works

This project can be extended in some possible topics as a follow up from our current research. This project only concentrates in MBSFN network deployment only without the possibility the user unsubscribe the MBSFN connection. It will be more challenging if the flexibility of subscriber changing its MBSFN connection to point-to-point connection. Therefore, the MBSFN area will continuously change by depending to its number of subscribers. Furthermore, the performance of each proposed method can be extended research by delivering the scalable video such as MPEG-4. The performance of the resource allocation method can be observed from the successful delivered video to the subscriber. This will require the new formulation of the algorithm and the knowledge of the scalable video coding.

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APPENDICES

A. LTE Architecture

The LTE overall architecture consists of cell sites or E-UTRAN Node Bs (eNBs), mobility management entities (MME), and serving gateways (S-GW). The eNBs provide the user interface towards mobile phones and devices, and they are interconnected with each other through X2 interfaces and they are connected to the backhaul or evolved packet core (EPC) through S1 interfaces.

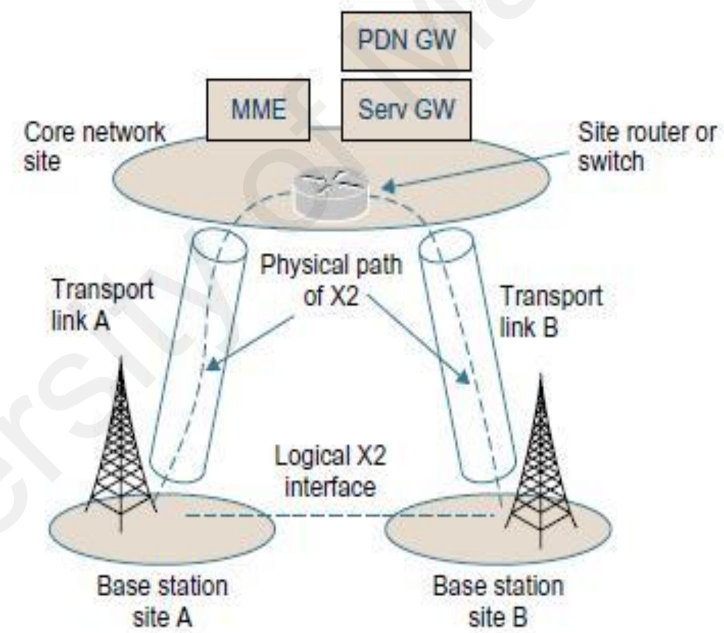

Figure 1 LTE Overall Architecture

Entity	Function
Serving Gateway (S-GW)	• Local mobility anchor for inter-eNB handover, inter 3GPP mobility • E-UTRAN idle mode downlink packet buffering and initiation of network-triggered service request procedure. • Lawful interception • Packet routing and forwarding • Transport-level packet marking in the uplink and the downlink • Accounting on user and QCI granularity for inter-operator charging. • UL and DL charging per UE, PDN and QCI
Mobility Management Entity (MME)	• NAS Signalling, security; AS security control;inter-CN node signaling for mobility between 3GPP access networks • Idle-mode UE reachability • Tracking area list management • PDN GW and serving GW selection • MME selection for handovers with MME change • SGSN selection for handovers to 2G or 3G 3GPP access networks • Roaming, authentication • Support for ETWS message transmission

eNB	• Radio resource management: radio bearer control, radio admission control, connection mobility control; dynamic allocation to UEs both uplink and downlink (scheduling);measurement for mobility and scheduling; scheduling and transmission of earthquake and tsunami warning system (ETWS) messages • Routing of user plane data towards serving gateway • Paging messages • Broadcast information • Load balancing; inter-cell interference, handover error indication.

B. LTE Physical Layer

The multiple access schemes in LTE use orthogonal frequency division multiple access (OFDMA) with cyclic prefix (CP) in the downlink and single-carrier frequency division multiple access (SC-FDMA) with a cyclic prefix in the uplink.

The resource allocation in the frequency domain takes place with a resolution of 180 kHz resource blocks both in uplink and downlink. The uplink user specific allocation is continuous; it enables single-carrier transmission while the downlink uses resource blocks which are spectrum independent. LTE enables spectrum flexibility where the transmission can be selected 1.4 MHz and 20 MHz depending on the available spectrum. The following figure shows an example of frequency allocation in LTE downlink and uplink transmission.

The 20 MHz bandwidth downlink in a 2 X 2 MIMO configuration. The uplink data rate is 75 Mbps.

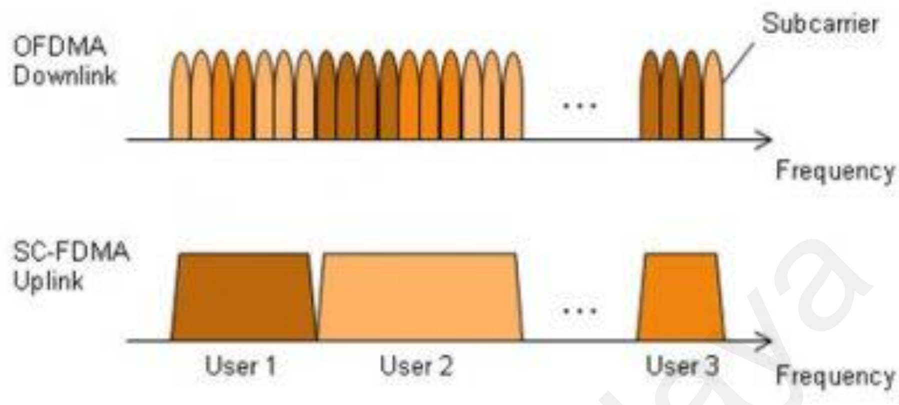

Figure 2 LTE multiple access schemes

C. LTE Downlink

The LTE downlink can be set on six different frequency profiles, as follows:

Table 1: LTE downlink profiles

Channel Bandwidth [MHz]	1.4	3	5	10	15	20
Transmission Bandwidth [MHz]	1.08	2.7	4.5	9	13.5	18
Transmission Bandwidth [RB]	6	15	25	50	75	100

The differences between transmission bandwidth and channel bandwidth is shown in the following figure:

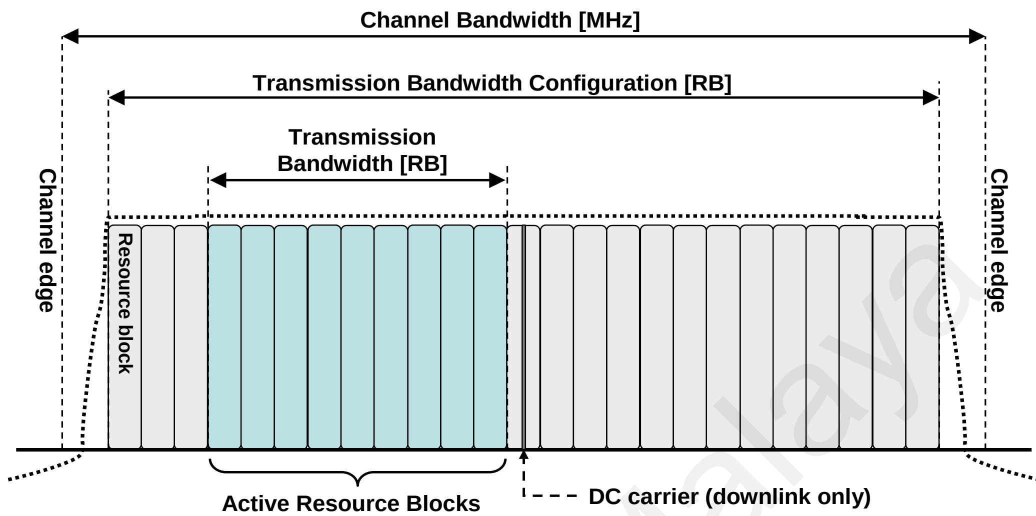

Figure 3 LTE channel bandwidth and transmission bandwidth [3GPP TR25.943,2011]

Figure 3 shows the relation between the Channel bandwidth ($BW_{Channel}$) and the Transmission bandwidth configuration (N_{RB}). The channel edges are defined as the lowest and highest frequencies of the carrier separated by the channel bandwidth, i.e. at F_C +/- $BW_{Channel}$ /2.

Transmission bandwidth is smaller than the channel bandwidth due to unused resource blocks. For example, each resource block occupies 180 kHz in frequency domain. If we used a 10 MHz signal, it can transmit 55.56 RB (10 MHz/180 kHz). However, 50 resource blocks are used for the 10 MHz LTE channel and it occupies 9 MHz bandwidth (50x180 kHz). Therefore, transmission bandwidth is the reference for all measurements.

In general, each subcarrier is allocated in a 15 kHz interval but for MBSFN transmission, each subcarrier is allocated in a 7.5 kHz interval. Thus, 12 subcarriers will occupy a bandwidth of 180 kHz (180 kHz/15 kHz) for each resource block. The minimum allocation unit for system resource allocation is a resource block. Therefore, the transmission bandwidth is obtained by the number of resource blocks multiplied by 180 kHz.

Figure 3 shows the frame structure of an LTE signal in FDD mode. One LTE frame has an overall length of 10 ms period. It consists of 20 slots of 0.5 ms each. Two consecutive slots are defined as one subframe.

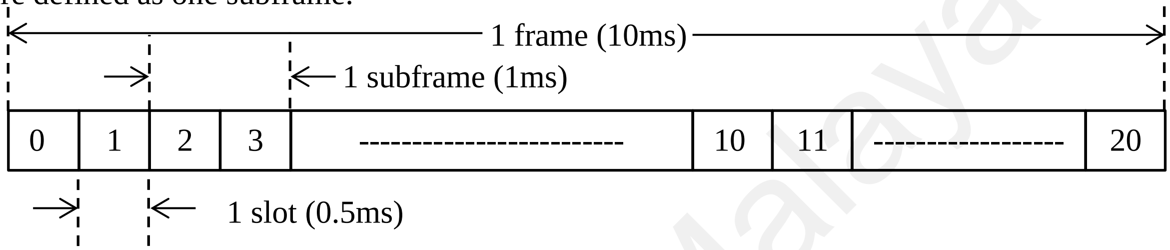

Figure 3: LTE frame structure (FDD)

Each slot is represented as a resource block (RB) consisting of 6 or 7 symbols by 12 subcarriers in time domain. As viewed from frequency domain, 10 MHz channel bandwidth transport is occupied with 50 resource blocks. Therefore, there are 1000 resource blocks per LTE frame (50x20).

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Proceeding in International Conference on IT and Multimedia (ICIMu), UNITEN November 2011

1. Azman, M. F., Tuban, N. F., Noordin, K. A., & Ismail, M. F. (2011). Genetic Algorithm Approach for Solving Radio Resource Allocation for Overlapping MBSFN Area, *1*(November), 1-5,2011 *International Conference on IT and Multimedia(ICIMu)*

2. Tuban, N. F., Azman, M. F., Noordin, K. A., & Ismail, M. F. (2011). Genetic Algorithm Approach for Dynamic Configuration of Multicast Broadcast Single Frequency Network Deployment in LTE, (November). *International Conference on IT and Multimedia(ICIMu)*

Publication (Submit and in reviewing process) to **International Journal of Innovative Computing, Information and Control**

1. Nurul Faiza Tuban, Mohd. Fahmi Azman , Mohammad Faizal Ismail and Kamarul Ariffin Noordin, Dynamic Configuration of Multicast Broadcast Single Frequency Network in LTE using Genetic Algorithm, 1-17.