Fair Channel Allocation Scheme for Base Station Cooperative Communication in LTE Mobile Network

Mohd Taha Ismail, Rosdiadee Nordin, Nor Fadzilah Abdullah, Mahamod Ismail, Muhammad Azmin Mohamed Ghazali

Abstract : Unjust provision of channels by base station greatly affects Mobile subscribers. A standard cluster, would be able to serve Many User Equipments (UEs). A typical cluster would contain 3, 7 19, or 21 cells. An issue of ambiguity exist in the demarcation boundary of adjacent cells, thus, radio transmission in a cell from a particular eNode Base Station (eNBs) may leak into neighbouring cells, which causes interferences. Furthermore, the eNBs geographical location is sensitive to obstructions such as towering buildings. The absence of line of sight has a major impact on radio signals, as this would amplify the loss of propagated radio signals, leading to weaken signal strength at the transmitter, that ultimately affecting current the Fixed Channel Allocation (FCA) technique. Despite the effort for fair channel through the current mechanism, users on the edge of the cell experience unfairness. The primary cause for this can be traced to poor received signal power. There are two considered UEs clustered in this simulation scenarios, which is proposed in this paper: (i) random fixed UEs and (ii) 5 step move UEs. A combination of static and dynamic clustering is proposed, thus leading to enhanced channel allocation. From the results, there is a drastic reduction in inter-cell interference, which would increase the performance of the cellular network to become ideal.

Keywords : dynamic clustering; LTE; fair channel allocation; mobility; inter-cell interference.

I. INTRODUCTION

The current cellular network such as Long Term Evolution (LTE) or commercially trademark as 4G network promise to support high data rates up to 100 Mbps and 1 Gbps for mobile and static users respectively [1]. LTE network can be the best candidate to cater to the rapid increase of mobile users in Malaysia. In the report by MCMC (Malaysian Communication and Multimedia Commission), Malaysian mobile penetration rate stands at 144.8 per 100 inhabitants in 2015. When investigated further, more than 20 percent of the total subscribed users are at urban zones in Selangor, which makes it the most populated UEs. While in 2012, ITU produced a report stating that Malaysia has an ICT Development Index (IDI) which is 0.7 more than the average Asia Pacific region. The index stands at 5.04 for that particular year. There are 8 operators in Malaysia which can provide LTE services, namely Digi, Maxis, Celcom, Yes, UMobile, Redtone, Packet1 (P1) and Altel. Through a signal coverage survey conducted using Open signal [4], it was found that both Celcom and Maxis is leading the pack in terms of LTE coverage in peninsular Malaysia but limited to a selected populated area. Moreover, through another survey, Ericsson forecasted that towards the end of 2019, the volume of users on LTE would be at 20 percent [5].

By looking at the figures stated above, the cellular performance is greatly affected due to lack of sufficient infrastructures needed to back UEs operations, in spite of increasing subscription of mobile services. While there is an increase in connectivity to the cellular towers, the Resource Block (RB) or also known as the available number of spectrums are exhausted, leading to connectivity issues. Nonetheless, an approach called time domain can be used to overcome this problem. In this technique, the user is given a time slot to use the channel. When the timer expires, another channel will be taken up by the user. This will be repeated for other users and channels. An interesting point is that when there is a high volume of users present in the cell, this technique proves to be ineffective. This paper proposed channel allocation techniques which assigned channel to UEs in two scenarios: users that are stationary and users that are mobile. The mobile user is simulated at the average speed of 40 km/h, which represent average speed in urban area. Proposed algorithm fair channel allocation which is each eNB served fair channel to UE for every cell. This technique aims to get high performance data rate and to reduce congestion when channel allocation from cell has a high user to reallocate to the neighbour cell have low users.

Manuscript published on January 30, 2020.
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The organisation of this paper proceeds as follows: Section II presents channel fairness and clustering. Section III examines the method suggested, i.e. fair channel allocation for clustered communication in LTE. In the following section, the methodology for evaluation as well as simulation is discussed. The results plus analysis from the simulation is examined in the following section. Lastly, the final section presents the conclusion and future work options.

II. CHANNEL FAIRNESS AND CLUSTERING APPROACH

This section discusses works related to channel allocation, channel fairness and clustering approach in the cellular network, as found in preceding research effort.

A. Distribution of Channels and Fairness in Mobile Systems

As stipulated by the regulating authority, the spectrum for cellular radio is divided into several different bands with different operating frequency. Looking at the nature of how radio transmission will overlap between adjacent cells, it is important that each adjacent cell use different frequencies within the cluster. The operating Frequency is reused due to the fact that frequency band is limited for cellular communication. While doing this, it is important to avoid interferences by maintaining separation distance between adjacent cells. The formula below shows the correct separation distance that is required between the adjacent cells denoted by 'reuse distance' [6]:

$$r_u = \sqrt{3C} \times R \qquad (1)$$

where;
r_u = reuse distance
C = cluster size
R = length of the cell side

Fig. 1 shows the reuse distance between adjacent cells and clusters. As mentioned earlier, due to the high numbers of cellular users requiring high speed data access, this proved challenging to the limited band available for cellular broadband. As a result, there would be a limitation on the cell in terms of accommodating volume of users, since the allocated number of channels for a given cell is typically fixed.

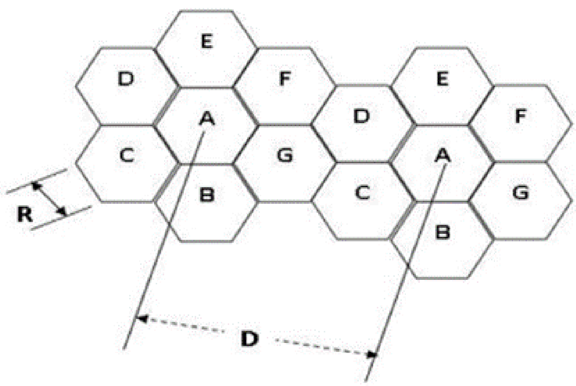

Fig. 1: Reuse distance

Service providers often tackle this issue by reducing the size of each cell, thus incurring additional cost in terms of equipment, as well as cell towers in order to serve an area. By doing this, it will have an impact on the handover method. The need to reserve bandwidth will reduce as the frequency of handover traffic substantially surge due to the decreased number of cells. It is not an overstatement to say that the handover process is vital in any cellular operation which directly impacts the mobile user. In a mobile communication environment, the effect of cell size reduction to the handover method is huge. In an example scenario of a user moving from one frequency channel to another, an active session would be difficult to sustain if a poor handoff mechanism is used. Nonetheless, instead of pooling the whole of a cluster's capacity, the issues of co-channel interference and provision can be addressed by implementing a dynamic scheme which is balanced and well designed.

B. Clustering

In a nutshell, Clustering is often referred to as a mechanism to improve spectral efficiency and there are two broad categories of clustering technique [7]. In one approach, it is based on unifying cells, which is channel allocates to the multiple cell share on each other. One method suggest that clusters are split into fixed-size, smaller cells to serve more user. Generally, an algorithm is implemented to the current cellular network, which is known as hierarchical clustering [8], this algorithm will a create a set of network groups. The algorithm will create a 'dendogram' – a hierarchical tree which defines correlation between clusters. It will then be pruned at required level, creating disjointed clusters inside the cellular network. Clustering method includes (i) static clustering [9], (ii) semi-static clustering [10], and (iii) dynamic clustering [11]. Regardless of the advantage offered by clustering, a bad cluster design will increase interference. In other word, it hinders radio transmission in other clusters by using improper clustering technique. Another pressing issue with clustering is that the performance of radio signal will deteriorate at the cluster's edge. This will affect users moving away from the centre towards the boundary of the cluster.

C. Clustering Method for Base Station Cooperation

Clustering methods introduced by Jian Zhao et al. [12], depends on the cooperation of eNBs. Joint processing technique in a coordinated multipoint (CoMP) transmission downlink were calculated to serve the adjusted channel allocation. In this approach, variety of user's data will be distributed fairly between all the eNBs. As a result, there was a significant increase in signaling and data exchange between the user and base station via a backhaul of the eNBs and other eNBs. Although such an approach, the reduction of traffic exchange depends on the needs of a particular QoS (quality of service) and power constraints. The authors proposed CoMP transmission optimisation technique which can increase it by twofold, first using the Signal-to-Leakage Ratio, secondly by strength of channel. Both methods can improve the fairness of the channel.

The study also showed a significant reduction in the exchange of data among base stations in the backhaul with a slight increase in the number of transmit power incurred in the base station.

M. Hajjar et. al. [13] introduced technique for clustering nodes into small groups with low power, which will enable the available frequency to be reused and thus expanding the capacity of the network.

The author proposed clustering technique from two combination algorithms, namely K-means and the Hierarchical Agglomerative Clustering (HAC). This technique increased the capacity of the cell, which is necessary to avoid data or call blocking due to increase in number of users requesting services in a cell.

D. A Hybrid Clustering Approach in Coordinated Multi-Point Transmission System

A CoMP transmission technology is proposed by Cui Zeng et. al. [14] that will allow spectrum utilisation to be enhanced particularly at the edge of the cell. Even though there is a high distance of separation between eNBs and UEs, it allows improved data transmission speed. The mechanism used the CoMP in a hybrid cell clustering method plus the transmission is coordinated in a dynamic manner. When compared with the technique previous discussed, it is found that this is more efficient and practical. Broken down into three sectors which is known as intra-cell, intra-cluster and inter-cluster, it allows the non-coordinated approach, static approach as well as dynamic approach to be utilised by the users in each sector. Interestingly, the author also recommends a technique that allows identification of user association categories. This is vital to match the best coordinated approach to each user. After running simulations, it is found that it is able to get the best cell edge spectral efficiency when compared to static or even dynamic clustering [7].

III. FAIR ALLOCATION TECHNIQUE FOR CLUSTERED CELL IN LTE

This section discusses the operation of fair channel allocation techniques for clustered cooperative communication in LTE. The fair channel scheme proposed in this paper consists of two main scenarios: Static and Dynamic channel allocation, which is illustrated in Algorithm 1. Static allocation assigned channel by eNBs based on strong signal strength (RSSI) received, simulation calculation using free space environment. The problem will make certain eNB have high UEs will drop performance because of load congested.

$$RSSI = 20\log(d) + 20\log(f) + 32.44 - G_{tx} - Grx \quad (2)$$

where:

Gtx = overall transmitter antenna gain including feeder losses

Grx = overall receiver antenna gain including feeder losses

For the dynamic allocation, eNBs assigned a fair channel to UEs base on threshold maximum channel can allocate from each cell. Threshold channel can calculate from total users divided by total eNB. Detail of proposed algorithm is summarized in Algorithm 1.

$$\text{Threshold Channel} = \frac{\sum_{k=1}^{M} UE(k)}{\sum_{j=1}^{N} eNB(j)} \quad (3)$$

Algorithm 1: Channel allocation based on fair channel scheme

1: Generate:
  : 7 cells with defined parameters from Table 1
  : Random UEs (Scenario 1 – static UE)
  : Mobile UEs (Scenario 2 – mobile UE)
2: Calculate:
  : RSSI value from Eq. (2)
  : maximum channel served by eNB
  : threshold channel from Eq. (3)
3: Assign : channel to UEs from higher value of RSSI
4: For : eNB channel serve > threshold channel
  : reassign channel UE to nearest neighbour eNB
  : Repeat step until channel serve = threshold
5: End : fair channel allocation achieved all eNBs

IV. METHODOLOGY AND SIMULATION SETUP

Two small groups of clients (users) are studied. The first consist of clients with differing mobile speed and the second group consist of stationary clients. The conducted experiment also examines each user in terms of signal receptions and fairness of channel allocation. Conducted in MATLAB, it is similar to previous research works [15] and can be divided into two; users which is statically positioned and users that is moving about. The parameters related to this study is presented in Table 1. Average values are based on 10 simulation runs with varying user location and hence varying path loss parameters. eNBs will allow connectivity with UEs closest to it, and the base station will allow the data stream to be accessed. In order to mimic actual traffic conditions and the stress test, the data used on each user are diverse. The software also revealed the impact of clustering against the backhaul in terms of transmitted data volume.

Table 1: Simulation parameters

Parameter	Value
Cell radius	500 m
Number of base station (eNBs)	7
Number of mobile station (UEs)	50
System bandwidth	10 MHz
Transmitted power	46 dBm
Transmitted antenna gain	26 dB
Receiver antenna gain	3 dB

Figure 3 shows the users mobility which are generated in random fashion. It is found that the mobility characteristic for each user is unique, and this is shown in the plotted diagrams. Then, their distance to the nearest base station needs to be measured in terms of signal strength.

An example of this can be demonstrated in fig. 4, where UE-A will connect to cell 7 due to its proximity to the cell. As such, the algorithm will calculate the proximity of each user to every base station available in the cluster, in terms of separation distance. The nearest user to the base station will be allotted the lowest number.

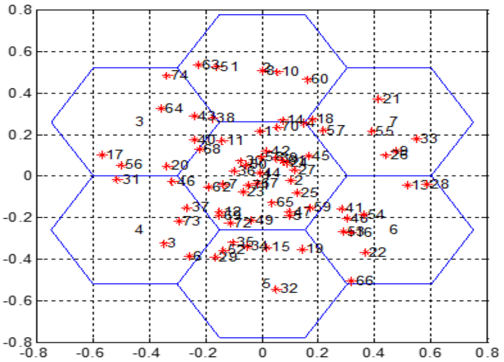

Fig. 3: Mobility user randomly generated

Then again, the furthermost user to the base station will be incapable of any communication with it. The user will be assigned a channel by the system when it's connected the closest eNBs. Following this, the total channel number in each base station is measured up against the average number of users in the cluster using a fair allocation scheme algorithm (algorithm 1). In this scenario, there are 7 cells with 75 users.

For static channel assignment technique, channels are assigned according to UEs distance from eNBs as well as the signal strength. When compared to dynamic channel assignment, the base station's fair channel load threshold is determined before channels can be re-allocated. There are two ways to look at this. First, in static approach, channels are randomly generated to the UEs. This is done by allocating the channel frequency to it. Second, in dynamic approach, it is dependent the number of channels assigned to UEs in every eNBs. The LTE network topology considered in the simulation is as illustrated in Figure 3. As a result, to measure fairness in relation to the cluster, the sum of channels allocation is divided with the sum of eNBs.

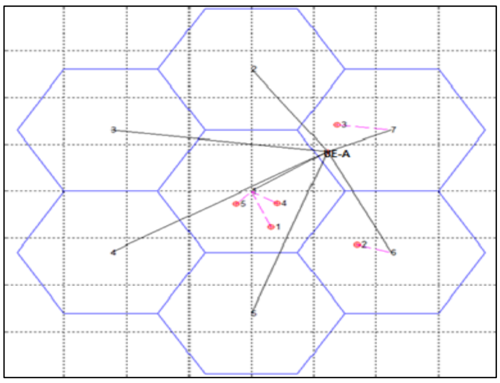

Fig. 4: Separation distance of mobile user to 7 BSs

Then, if there are adequate channels, which simply means there are more channels than the number of users, channels will be distributed fairly to the remaining users. Should the situation be the opposite where channels are insufficient, the network will be noted as imbalanced by the system.

V. RESULTS AND ANALYSIS

According to the conducted trial, each cell is found to have unevenly allocated quantity of UEs. Further demonstrated in Fig. 5(a), the greatest concentration of UEs is at the cluster's centre, thus, the distribution of channel might not be fair. In addition to this, user movement is not considered, therefore inferior performance owing to numerous handoffs is never reflected.

It can be determined that a user will likely get the best reception according to its proximity to a base station by looking at the Received Signal strength value. In this case, we can expect ideal condition for data services such as 3G and LTE. It is also shown in Fig. 5(a) that by having a high UEs concentration will hamper signal transmission to every user. This is clearly the case in the cell at the Cluster's centre. The user's distance from the eNB may also have an impact in this.

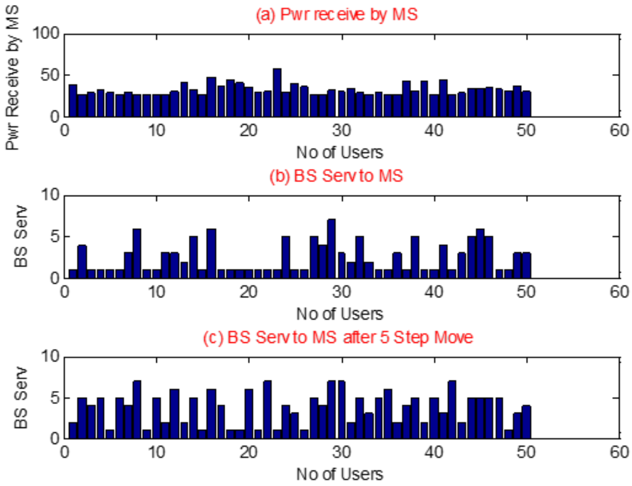

Fig. 5: eNBs association for distribution of UEs in a cluster

During later part of the simulation, we evaluate the UEs and eNBs connectivity while the users are under a fixed speed mobility. To represent the average speed in the urban area, the speed was set to 40 kilometres per hour. Fig. 5(b) and Fig 5(c) shows two random simulation results, which are documented and plotted to a graph. It exhibited the relation of eNBs and UEs at two occurrences, which is randomly constructed.

As an example, User 1 is associated to eNB 1 in Fig. 5(b), however, when User 1 crossed the cell edge, the signal will be handoff to eNB 2. There should also be a variation of the received signal strength. Since the result is not of a significant to the analysis, it is not presented. However, it is noted that, there is a substantial variation in received power signals when compared to stationary user simulation in Fig 5(a).

In the first scenario of the simulation experiment, it demonstrated the random channel allocation technique. Fig. 6 displays random UE channel allocation served by eNBs. In contrast, Fig 6 presents the channel allocation after the suggested fair channel allocation technique is used.

The second scenario in Fig. 7 show the UEs move for 5 step for both random and fair channel allocation.

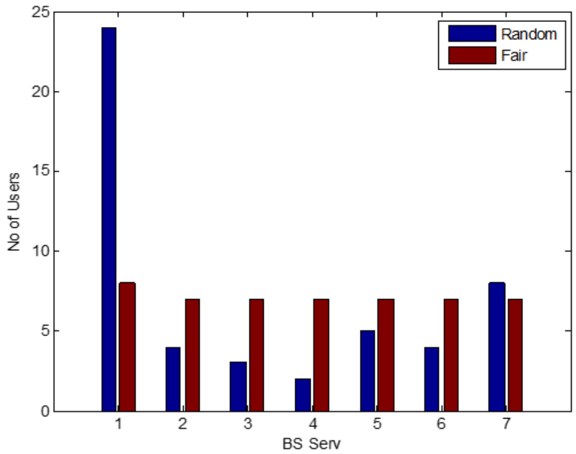

Fig. 6: Channel allocation serve by eNB for random fixed UEs

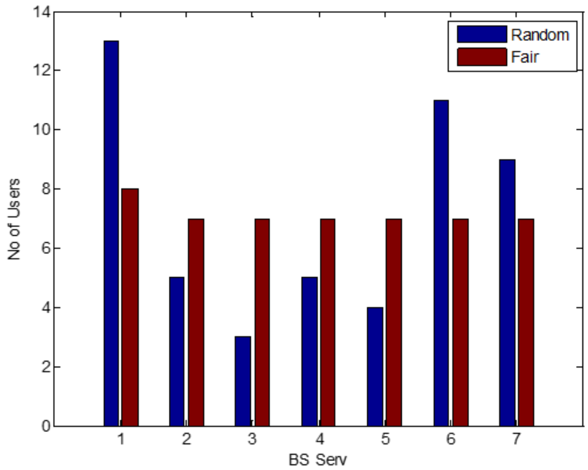

Fig. 7: Channel allocation serve by eNB after UEs move

By looking at the findings of simulation above, it is found that every eNBs are capable of handling almost equal number of users in every single cell. In view of this, irrespective to the user location, the dissemination of channels in the cluster can be done in a fair manner.

VI. CONCLUSION

In this paper, it is found that certain users may be exposed to a cellular communication which is sub-par, particularly while connecting to the base station (cell tower). Cell spectral deficiencies clearly have an impact to users on the edge of the cell.

Furthermore, the network performance can be severely affected in a heavily populated zone with soaring data traffic. The paper proposed a fair channel allocation method to address this matter. It can re-allocate channel evenly to users outside the cell. In a nutshell, the idea is to use dynamic clustering, coupled with fair channel allocation. Outcomes from the experiment demonstrated enhanced performance, mainly attributed to the reduction of inter-cell interference. The proposed scheme can be further enhanced by including distribution of traffic as well as increasing collection of data in the suburban region.

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