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Frequency Management in Wireless Communication Networks

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Abstract:
Nowadays, efficient frequency management is a vital concept in the ICT industry, because of ever increasing growth of cell phone applications. Frequency allocation management could be an interesting tool to avoid interference in frequency in different networks. This paper aims to review important related literature. There are diverse methods to manage the frequency spectrum in wireless network such as dynamic spectrum allocation (DSA), frequency reuse (FR) and dynamic spectrum refarm (DSR). These methods lead to availability time improvement and frequency interference minimization.

Keywords: *Wireless communication network, frequency spectrum, dynamic frequency allocation*

1. Introduction

Wireless communication networks have preferred features compared with fixed networks such as better coverage, higher capacity and improved connections. The higher capacity results in geographically widespread in network. The higher capacity means the user number increasing that have been served by the network, simultaneously. There is a real optimization problem. Any increase in above three features causes to enhanced desirability. The higher network capacity causes of growth in user number and therefor increased data traffic. Its direct impact will be less quality in connections. It is a critical concern of electrical and ICT engineers.

2. Frequency Management in Wireless Network Management

A communication network has a transmitter in a unique frequency spectrum. Ever increased cell phone utilization has caused to limitation of frequency spectrum. This is a vital concern. During the last decade, we observed network progression from traditional antenna to cellular technology. In traditional networks, a powerful antenna is used to cover a wide region. This method results in higher coverage and better capacity. Then, the idea of cellular network utilization presented. In this technology, the given network is divided into many small cells. A weak and short-range antenna copes with sending and receiving signals and make connections. Their important feature is higher capacity and better network coverage. Also, this technology results in higher flexibility and easier and cheaper maintenance. However, the frequency spectrum limitation is still an important problem. The greatest problem in such a network is the frequency interference in boundary users in neighboring cells.

Pedraza et al. [1] studied frequency allocation of a seasonal autoregressive integrated moving average (SARIMA) model, which models the power reception of different channels of the global system for mobile communications (GSM) spectrum band. This model allows to plan, manage and forecast the future channel occupancy status. This model can plan, forecast and manage the occupation time of the network. Figure 1 shows the forecasted occupation time and comparison with experienced values.

The obtained precision of the mean in the prediction of the occupation times is 58%, 77% and 78%; among the real and predicted data, which corresponds to the channel levels of low, medium and high occupancy, respectively. This model includes four steps:

- Error Identification
- Error Estimation
- Error Controlling
- Error Forecasting

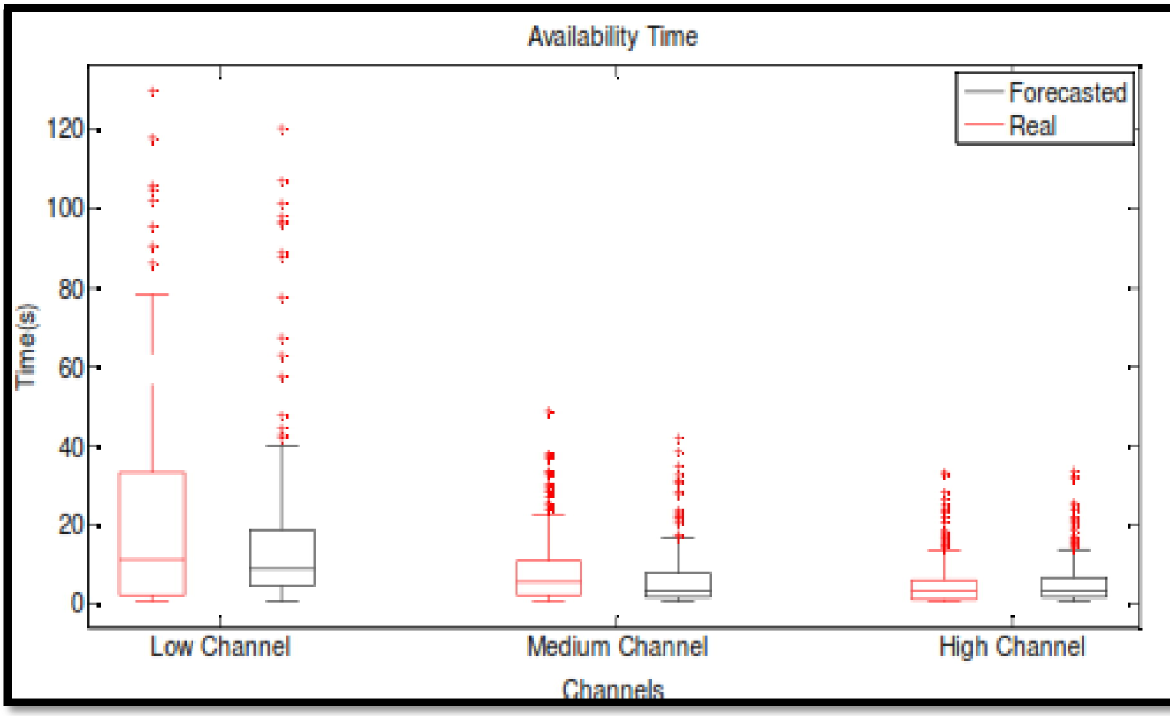

Figure 1: Availability Time of the Channels [1]

This model helps to engineers dividing the frequency spectrum between users, efficiently. This could be performed by the frequency interference decreasing.

Their results are evaluated using different criteria, such as the availability time and channel occupation, different classes of mean absolute errors and, the observation time. The results obtained by the developed model show that for a practical cognitive radio system; it would be feasible to use an observation time less than three seconds. This is in order to accurately predict significant parameters as the received power per channel.

2.1. Frequency Reuse (FR)

Giuliano et al. [2] investigated the WiMAX fractional frequency reuse for rural environments with low population density. Conventional cellular planning methods can be used for point-to-multipoint network design. As an alternative, the fractional frequency reuse (FFR) planning strategy has been recently proposed for cellular systems based on the OFDMA/OFDM radio interface (e.g., WiMAX). They analyzed the FFR scheme in rural areas, evaluating the increase of the overall system capacity. They show that the FFR scheme can provide extra capacity, slightly penalizing the users at the cell edge.

Novlan et al. [3] focused on two important methods to frequency refarm in wireless network: Strict FFR and soft frequency reuse (SFR). Their evaluation parameters were interrupting probability, network efficiency, spectrum effectiveness and cell edge user SINR. Then, they compared two method's results. They concluded that the strict FFR gives better network efficiency and higher SINR. Also, FFR balances interference minimization and resource efficiency.

Figure 2 (left) shows the strict FFR paradigm. This method really is a development of traditional frequency reuse which has utilized in multi-cell networks. Internal users never share their frequency band with the users of the other cells, in this way. Figure 2 (right) demonstrates the SFR implementation in frequency reuse paradigm with $\Delta = 3$. SFR method uses the sectioning strategy of cell edge bandwidth similar to strict FFR. However, the users in a cell can share their bandwidth with the boundary users of the neighboring cells. Although, SFR performs better than the strict FFR about bandwidth, there is a potential frequency interference.

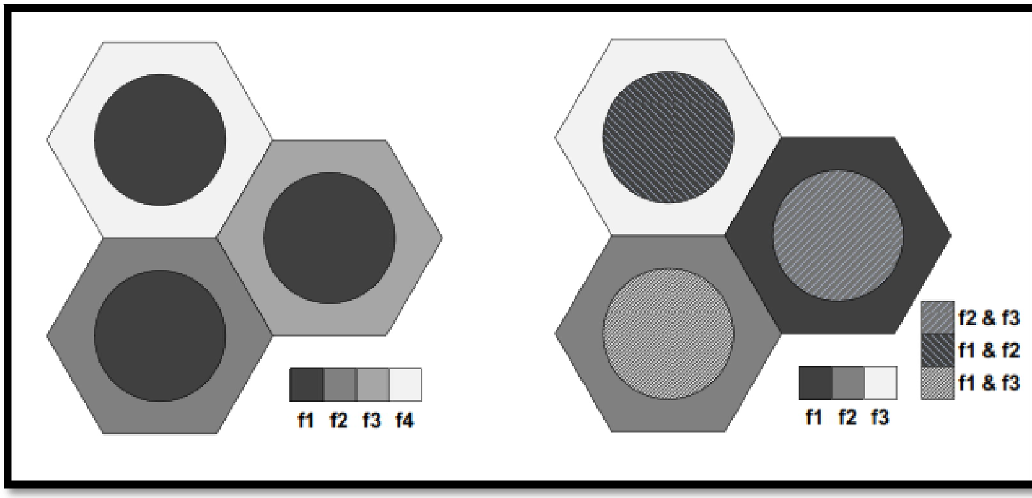

Figure 2: Strict FFR (Left) and SFR (Right) Deployments with Δ = 3 Cell-Edge Reuse Factor in A Standard Hexagonal Grid Model, the Poisson Model Maintains the Resource Partitions, but They Are No Longer of Uniform Geographical Size or Shape [3]

Figure 3 shows the SINR threshold of four different systems having diverse frequency versus the coverage probability. They also compared their results with Monte Carlo simulation results. As SFR allocates frequency spectrum between a cell users and boundary users, increased interference and decreased network coverage have observed.

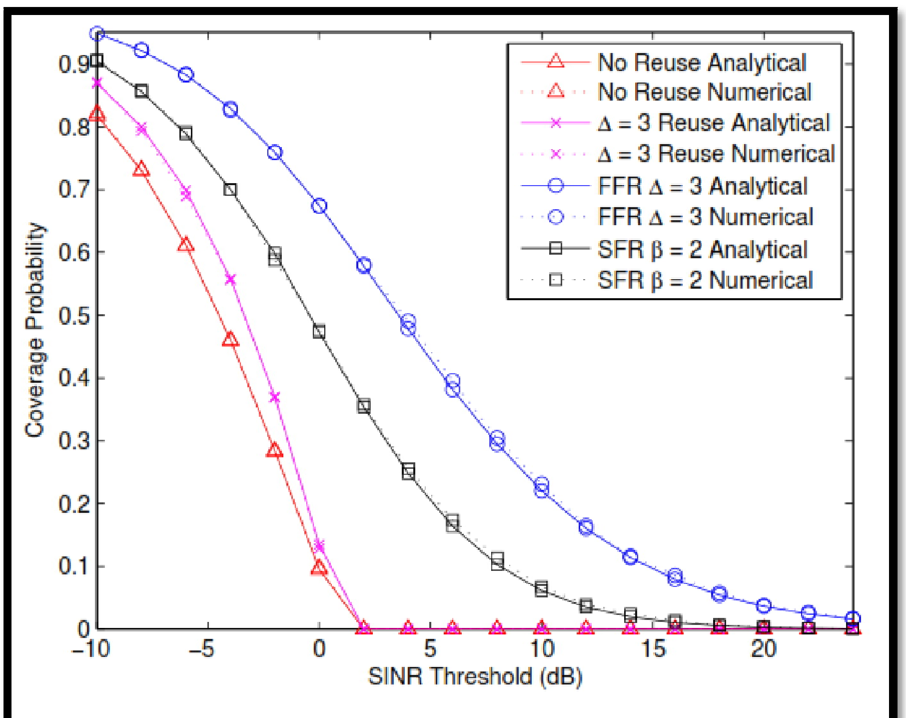

Figure 3: Comparison of Analytical Coverage Probability Expressions for Edge Users Using the Poisson Model versus Monte-Carlo Simulations

Saquib et al. [4] studied the frequency reuse method in an LTE communication network. There are two important challenges in 4G cellular wireless network progress: the cellular coverage and the network capacity. In this context, hierarchical layering of cells with macro base stations coexisting with low-power and short-range base stations (corresponding to picocells or femtocells) in a service area is considered to be an efficient solution to enhance the spectral efficiency of the network per unit area. Also, such a hierarchical cell deployment, which is referred to as a heterogeneous network, provides significant improvement in the coverage of indoor and cell edge users and ensures better QoS to the users. Interference mitigation between different layers is one of the key issues that needs to be resolved by more investigations. They simulated the network performance by some algorithms. Their results show that this method gives better spectrum efficiency that strict FFR.

2.2. Dynamic Spectrum Allocation

Leaves et al. [5] investigated the spectrum management problem in a wireless communication network using dynamic frequency allocation method. They also considered the probability of dynamic spectrum allocation in different networks. They showed that different ICT regulators in the world tend to manage frequency spectrum, dynamically. In such a network, the frequency allocation could be adapted regarding user requests, spatial and temporal. Figure 4 shows three frameworks to manage network frequency spectrum. A wireless network with fixed framework, a wireless network with dynamic contiguous framework and a wireless network with the fragmented framework are shown at left, center and the right side of the figure, respectively.

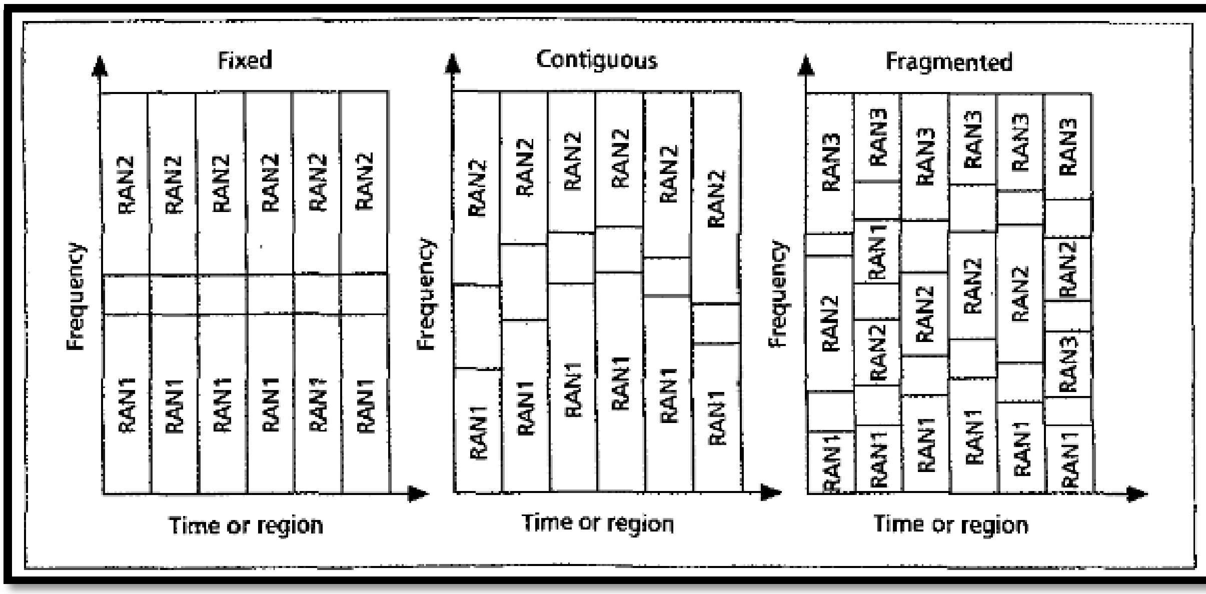

Figure 4: Fixed Spectrum Allocation Compared to Contiguous and Fragmented DSA [5]

Contiguous assignment uses contiguous blocks of spectrum allocated to different RANs, and these are separated by suitable guard hands, much as in fixed assignment. However, the width of the spectrum block assigned to a RAN varies in order to allow for changing demand. This scheme will only allow the spectrum partitioning of a RAN to change at the expense of the spectrally adjacent RANs spectrum. Therefore, if a RAN wishes to increase its allocated spectrum, it will not be able to do so if the spectrally adjacent RAN will not release the spectrum, raising fairness issues [5].

In dynamic spectrum allocation method, a RAN can use some released frequency band by another RAN in the network (not only the neighboring RANs). This could be useful for neighboring saturated RANs. However, the frequency management is still difficult and the interference is a critical concern. Their results show that the contiguous dynamic allocation gives a higher network efficiency than the fixed framework.

Zhao et al. [6] proposed a distributed coordination approach that handles spectrum heterogeneity without relying on the existence of a preassigned common control channel. Their approach carries potential to provide robust operation under network dynamics. While this approach can be implemented by upgrading the legacy protocol stack without modifying the MAC protocol. Their results show that the proposed distributed coordination scheme provides 50% of delay reduction.

In another important study, Subramanian et al. [7] investigated the spectrum allocation problem in cellular networks under the coordinated dynamic spectrum access (CDSA) model. In this model, a centralized spectrum broker owns a part of the spectrum and issues dynamic spectrum leases to competing base stations in the region it controls. The broker allocates channels to them with an objective to maximize the overall revenue generated subject to wireless interference in the network [7].

They proposed approximate algorithms to achieve near-optimal solutions. The greedy algorithm plays a key role in the simulation, based on hexagonal tiles (GAHT). They divided the network into hexagonal tiles with different colors (Figure 5). In this way, there are no neighboring tiles with same colors. Any color presents a specific spectrum and the node-channel couples have selected using the repetition method. They finally developed the best frequency spectrum allocation for each channel. Their results show that these algorithms perform efficiently in large scale wireless communication networks.

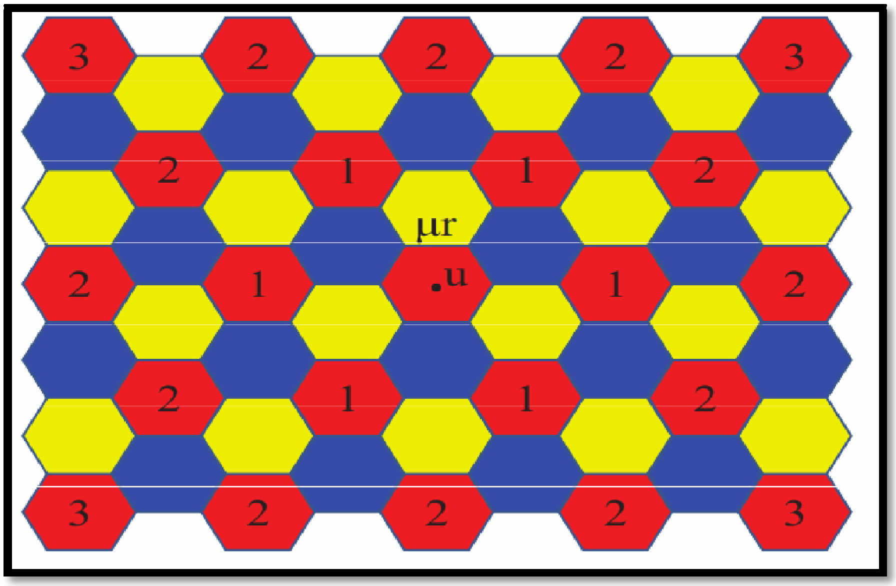

Figure 5: Hexagonal Subregions Colored Using Three Colors Such That Adjacent Subregions Have Different Colors, the Red-Colored Subregions around the Subregion Containing Node Have Been Partitioned into Hierarchical Levels; the Numbers Denote the Hierarchical Level

2.3. Dynamic Spectrum Refarming (Dsr)

Han et al. [8] studied the application of the dynamic spectrum refarming method in a wireless communication network. Spectrum refarming refers to a radio resource management technique which allows different generations of cellular networks to operate in the same radio spectrum. They proposed an underlay SR model in which an Orthogonal Frequency Division Multiple Access (OFDMA) system refarms the spectrum of a Code Division Multiple Access (CDMA) system through intelligently exploiting the interference margin provided by the CDMA system. Their simulation results show that the spectrum refarming algorithm efficiency is high. Their proposed frequency refarming needs to a minimum information flow from CDMA to the OFDMA. This causes the increased spectrum efficiency in cellular wireless networks.

Ghamari et al. [9] considered the dynamic frequency refarming method in different wireless networks. They proposed a new heuristic method for sharing spectrum between two different radio access technologies (RAT) in an intra-operator scenario. They also designed a new dynamic spectrum manager that aims to prevent overload in RATs and improves spectrum utilization of RATs. Their approach contains two complementary phases of action, the first phase tries to prevent overload of a RAT in a proactive manner, and the second phase tries to solve an overload situation in case the proactive phase fails to prevent it [9].

Figure 6 shows the total number of users that have served by RAT1 and RAT2. Also, a comparison performed between the total number of users with and without using DSR system.

Served users represent the number of users that successfully terminated their session during the operation time plus the number of users currently served by the system. They observed that the total number of users in a network using a DSR system is noticeably higher than those without DSM system.

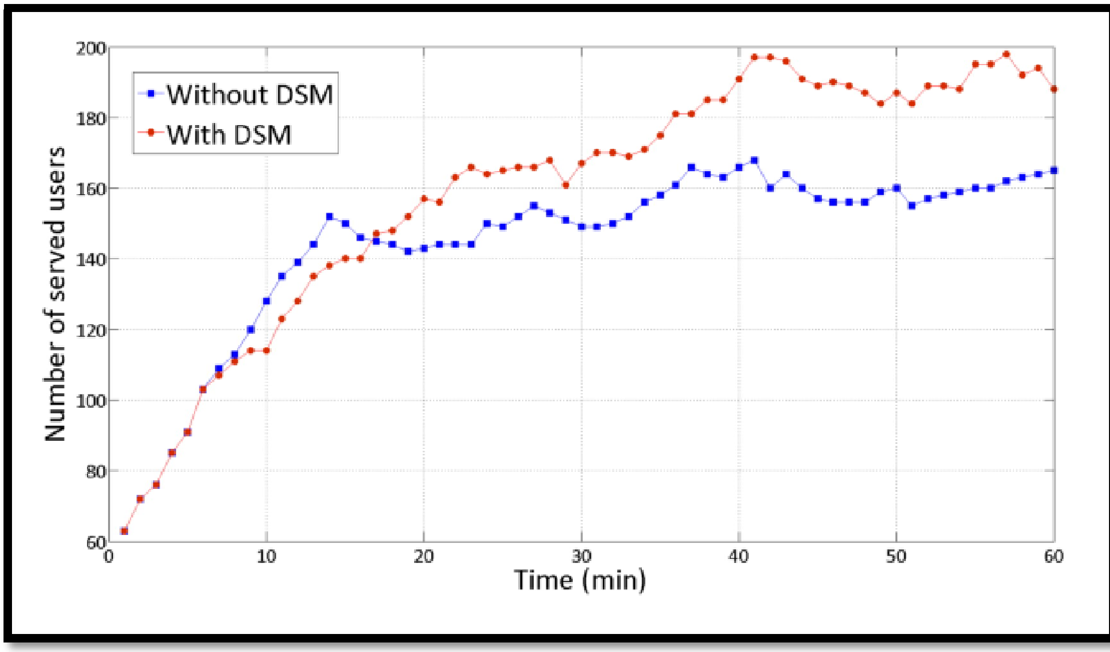

Figure 6: Total Number of Served Users by RAT 1 and RAT 2 [9]

The simulation results show that DSR can prevent overloading in a RAT and balance the total load between users and operators in a wireless network. Also, they observed that DSR method cause to increase the total number of users.

Guskov et al. [10] proposed a new model to efficient frequency refarming in an LTE network, based on the frequency interference exception. They developed a method to compare the allocated frequency to achieve the better frequency spectrum and also to satisfy QoS requirements. Their results show a refined network performance of DSR system. The proposed algorithms decrease the loss probability 15 times than the static algorithms.

Lin and Viswanathan [11] studied dynamic frequency refarming in an LTE wireless network. They used a similarity method to reuse the code division multiple access for the smaller cells in an LTE network. They simulated and analyzed the results. This approach is the best paradigm to study the smaller cells superposition on the larger cells performance in a wireless communication network.

3. Conclusion

Ever increased global trend to utilize the modern communication methods results in advanced communication network growth. However, there is still a much limitation in frequency implementation. The diverse networks with different capacities use a frequency spectrum in a specific geographical region. This paper reviews the important literature about efficient frequency spectrum management to achieve a higher quality, a lower interference and a larger number of served users in a network. There are different methods to manage the frequency spectrum such as dynamic spectrum allocation (DSA), frequency reuse (FR) and dynamic frequency refarming (DSR). The results demonstrate that three above-mentioned approaches give acceptable performance in frequency spectrum management.

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