Removing Inter-Cell Interference in Cellular Network through Implementation of FFR Scheme

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Abstract— In cellular network, both the homogeneous and heterogeneous cellular networks there are some problem known as issues. Those issues are concentrated and forwarding steps are taken to overcome the issues. For minimizing the demerits, at each level their performance level is monitored. From certain proposed results, heterogeneous cellular is best for networking. In homogeneous cellular networks, numerical results both upper and lower bounds of optimal BS density are consequential. The heterogeneous cellular networks is revealed as the best type of cellular network in networking. In cellular system, inter-cell interference (ICI) reduces system capacity by aggravating receiving performance of cell edge user. Therefore, to mitigate ICI is very important issue in cellular system. To overcome this ICI problem, fractional frequency reuse (FFR) is introduced. The FFR is performed by separating one cell into three FFR regions and allocates different frequency to each region. By doing this, each user can ignore interference from adjacent cell since it is interference control technique.

Key words: Base Station (BS) density, heterogeneous cellular networks

I. Introduction

With the rapid increase of mobile subscribers as well as the traffic demand, cellular networks have experienced several significant evolution, from the first generation to the current CDMA-based 3G cellular networks. To handle the ever growing traffic requirement and minimize the network cost, both LTE and WiMAX standard groups have been proposed the “micro” BS concept, such as Femto-cell and Pico-cell, which will bring heterogeneous into cellular networks [6]. Femtocells have gained attention due to their advantages in terms of infrastructure cost saving and improved user experienced in indoor environments. Some technical challenges are about to face by femtocell technology to overcome before they can be deployed on large scale. By doing so, how to plan heterogeneous cellular networks becomes an important issue, especially for capacity extension through deploying more BSs based on existing networks [2]. It is different from the traditional cellular network planning.

Conventionally, the cellular network deployment has been primarily designed for outdoor coverage area, which are achieved by overcoming the stochastic nature of the radio propagation environment [1]. The stochastic geometry Model (Statistical) can capture the network-wide performance of a non-uniform network deployment, but includes only stochastic effects that are mathematically traceable [15]. In the past decade, there has been an exceptional growth in mobile data demand. This has led to revolutions in the multiple access technology, as well as an increase in cell density and spectrum reuse. The 3rd and 4th generation of the cellular networks mostly employ full bandwidth reuse (reuse pattern one), and the cell density in urban areas is excess.

Mobile data demands in the cellular networks occur predominantly (70%) in indoor areas, while the traditional radio-planning strategy is ill-equipped to address this issue. The indoor coverage issue is especially challenging for large buildings such as shopping malls, hotels, enterprise and offices, where multiple indoor surfaces of different electromagnetic properties impede signal propagation [3]. There are three factors to motivate cell planning optimization and they are: interference, user location, and radio propagation.

In [4] from http://www.umtsworld.com Wideband Code Division Multiple-Access (W-CDMA) is one of the main technologies for the implementation of third-generation (3G) cellular systems. The implementation of W-CDMA will be a technical challenge because of its complexity and versatility. W-CDMA link-level simulations are over 10 times more compute-intensive than current second-generation simulations [7].

On the other hand, the cellular networks are consumed in wide range. Due to the increased user, data traffic is also occurred. Some researchers are demonstrated to overcome these traffic. It is shown by adapting the BS density through turning on or off the actual traffic load and it is more effective [5]. Recent researches about cellular network planning mainly focus on the practical deployment design. There are so many studies based on energy efficiency of heterogeneous cellular network [12]. In order to assist the capacity extension and switching of dynamic BS for heterogeneous cellular network, mostly BS density problem is focused [16]. Though the precise location problem is solved, it can provide valuable information about the type of BS and number of BS required. By switching of BS during traffic load is low may give better result for energy saving.

Cellular networks can however more broadly considered by type of infrastructure for mobile distributed in general. Since communication over the wireless links takes place in a shared medium. In cellular network, inter-cell interference (ICI) decreases the system capacity by annoying the receiving performance of the cell edge [10]. To deal with ICI problem, fractional frequency reuse is introduced among the other frequency reuse schemes.

The cellular network using here is heterogeneous networks which consists of two different types of nodes: Base Stations (BS) and clients as cell nodes [18]. The base stations acts as servers that are interconnected by an external fixed backbone network. The clients are connected through radio links to base stations. Totally the base stations forms an infrastructure for distributed applications running on the clients.

The interference can occur at a client if it is within transmission range of more than one base station. In order to prevent such collisions, coordination among the conflicting base stations is required. In common this problem is solved by combining the available frequency spectrum into channels.

By applying this method interference is prevented and in addition such that none of the base stations will not overlap in transmission range. In the early years of wireless systems, when the number of users was small compared to the available frequencies, interference was not a problem. However, when the number of user has dramatically increased, and a severe reuse of the spectrum is needed. In WiMAX or LTE networks, intra-cell interference may be neglected due to the sub-carrier orthogonally in OFDMA [8] [9]. With the basic features necessary to support heterogeneous Networks now being incorporated into LTE-Advanced and next is to look forward the future evolution of heterogeneous networks.

The review of the current LTE-Advanced capability and support by specified deployments of heterogeneous network now provide operators which is an important tool to address growing traffic demand beyond the planned initial network rollout. The path towards advanced heterogeneous network topology and hopefully taking a lead to step near optimum performance. From the explanation heterogeneous network deployment will rapidly increase as LTE deployment gets fully underway around the world. Therefore, operators must cope with inter-cell interference in order to enhance the network capacity and performance. To overcome inter-cell interference, OFDMA networks are flexible in terms of radio resource management techniques.

Supporting different Frequency Reuse Scheme (FRS), which in turn, may decrease inter-cell interference and increase network performance. Because of easy cell planning and high frequency efficiency, universal frequency reuse method is definitely reasonable one. Especially, the performance of cell edge user can be increased significantly because without FFR, they experience large amount of interference.

The Universal frequency reuse means that frequency reuse factor (FRF) is 1. In other words, all sectors within a cell and all cells within a same system operate on the same frequency channel. Due to the use of same frequency band, the inter-cell interference is occurred which is a defect.

II. CELLULAR SYSTEM MODEL

In this paper, both homogeneous and heterogeneous cellular network are considered. The homogeneous cellular network are numerically solved using the upper and lower bound of the optimal BS density. By the same way, heterogeneous cellular network consists of two types:
(1) macro BS with high transmit power and high unit cost and (2) micro BS with low transmit power and low unit cost.

A. Homogeneous Cellular Network:

In homogeneous cellular network, since the transmit power of all the BSs are same the users are located to their nearest BSs. Poisson voronoi (PV) tessellation is the final process stage till the nodes get on to contact. The tessellation is predicted by gamma distribution and the coexisting user follow poisson distribution. From the distribution result, the density problem of BS is summarized using the binary search algorithm. By calculating the upper and lower bound of BS, the result is close to the optimal.

B. Heterogeneous Cellular Network:

The heterogeneous cellular network is comprised of two types of base stations. They are micro and macro base station (BS). Compared to homogeneous cellular network, heterogeneous cellular network operates in effectively way. Since the homogeneous network uses one parameter which is called as BS density. Whereas the heterogeneous cellular network depends on BS density and it's transmit power.

1) Cell Size Distributions:

The heterogeneous cellular network does not work on PV tessellation because the user may select a macro BS for far away as his home BS, nor the nearest micro BS, due to their different transmit power. By reducing transmit power can greatly reduce the total energy consumption in this EARTH model, it is beneficial to have denser network with lower transmit power [13]. Operating as a typical cellular network, interference is limited. Since the interference dominates the noise power and thus the noise is not considered.

Due to the ignorance of the noise, the transmit power does not get changed. Despite of different transmit power and unit cost are the difference between macro and micro BSs. At last it is resulted by different antenna heights and gain.

2) Allocation of Frequency Reuse:

Universal frequency reuse is adopted in both homogeneous and heterogeneous cellular network, either the macro BS or micro BS occupies the whole system. The heterogeneous cellular network is an extension of the current 3G network.

The frequency reuse is a promising frequency planning solution for heterogeneous network to meet the high data rate requirement. By limiting the coverage area within the cell boundaries, the same set of frequency channel may be used to cover over different cells separated from one another by a distance large enough to keep the interference level within the tolerable limits. The technique usually adopted is to use a fraction of the total frequency band in each and every cell such that no two neighbor cells use the same frequency.

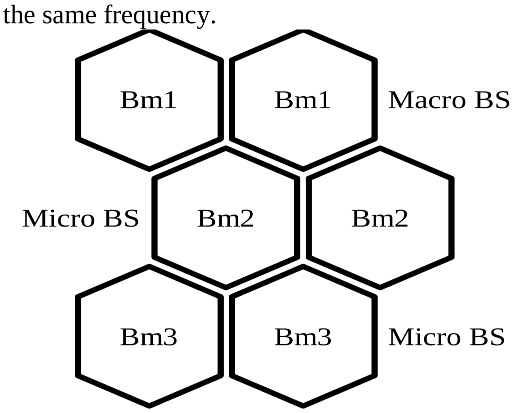

Fig. 1: Frequency band splitting in cellular network

Fractional frequency reuse (FFR) is introduced for multicellular mobile WiMAX system. FFR is interference management technique. It divides one cell into two concentric regions according to distance and allocates different FRF to each region. Inner sub-cell uses universal frequency reuse. On the other hand, outer sub-cell uses frequency reuse policy, FRF of which is 3. In other words, outer sub-cell is divided into three FFR regions and separate frequency is allocated to each region. By doing this, signal of each FFR region doesn't interfere in the receiving signal of the other FFR regions.

Fractional Frequency Reuse (FFR) is interference management technique [17]. It splits one cell into two concentric regions according to distance and allocates different FRF to each region Fig. 1. Inner sub-cell uses universal frequency reuse. Therefore, it allocates same frequency for every mobile station (MS). On the other hand, outer sub-cell uses frequency reuse policy, FRF of which is 3. In other words, outer sub-cell is divided into three FFR regions and separate frequency is allocated to each region. By doing this, signal of each FFR region doesn't interfere in the receiving signal of the other FFR regions. On this account, receiving performance of users can be fairly increased. Especially, receiving performance of cell-edge user can be increased significantly because without FFR, they experience large amount of interference.

III. PROBLEM FORMATION

There are two important issues in heterogeneous cellular network and they are:
(1). Capacity extension through base station deployment and
(2). Energy saving through base station switching.

In energy saving, the BS sleeping is a feasible option to reduce the energy consumption. One may decide how many macro and micro BSs can be switched when the traffic load is low.

A. *Energy Saving:*

By considering the existing cellular network which consists of macro and micro BSs with different densities, the result is given as if the BS is sleeping in a feasible option to reduce the consumption of energy, one could decide about the number of BSs can be switched off when the traffic load is low. To avoid the coverage BS caused by BS sleeping some macro BS called coverage.

B. *Capacity Extension:*

By considering the cellular network which is already deployed with macro and micro BSs with two different densities the capacity can be extended. To extend its capacity, it is needed to increase the QoS requirement and a direct approach is to arrange more BSs. For minimizing the total cost, one would concern how many macro and micro BSs should be added [20]. The optimal result can be achieved by numerically through Binary search algorithm. To exploit the impact of system parameter on the optimal base, the upper and lower band is made in closed form.

IV. IMPLEMENTATION RESULT

In this paper, the node localization and their operating stages are explained. Initially the different types of cells are classified as follows: femto cell, pico cell, macro cell and micro cell. In the cellular network, depending upon the area selected for the node to be located is noted. Since the localization of nodes deals with the coverage of BSs operation and the transmission result. The types of cell used are shown in the Fig. 2 and those cells are described as follows.

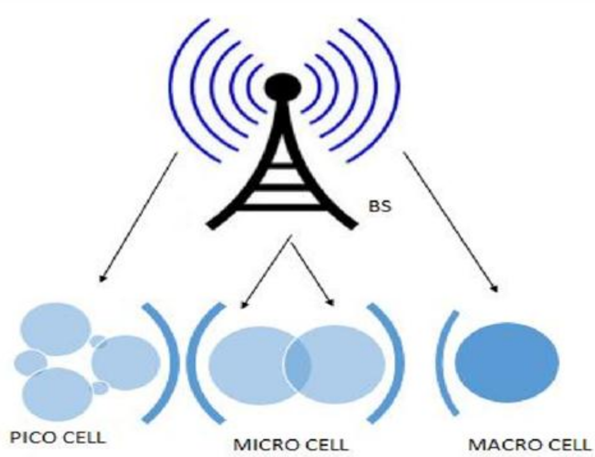

Fig. 2: Cell distribution along with Base Station (BS).

A. *Micro Cell:*

This cell is operated at a network which is serviced by a low power cellular base station (tower) covering limited area. A micro cell uses power control to limit the radius of its coverage area.

B. *Macro Cell:*

This is operated by high power cellular base station (tower). The macro cell describes the widest range of cells.

C. *Femto Cell:*

The name 'femto' denotes very small cell. These are the smallest cell and most limited in capacity. It is small cellular base station, also called as wireless access point that connects broadband and the coverage area [11].

D. *Pico Cell:*

They are covering small area such as building o more recently in aircraft. They are typically used to extend the coverage to indoor area or to add network capacity.

The cells are distributed randomly on the region along with the presence of base station which is shown in Fig. 2 [14]. Normally the cells are represented in hexagonal shape since the other shapes are not suited to the cell performance. Once the desired path is enabled, the cell nodes communicate by transferring data between each node. During communication the cell may collide and it would not give the best result.

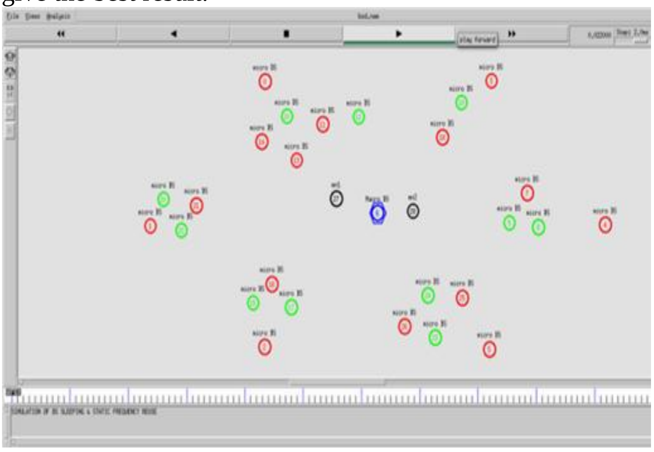
Fig. 3: Locating cells on the region for data transmission using TCP connection.

In shortly this issue is known as interference and in total it is called as Inter-cell interference (ICI). This interference is minimized by using frequency reuse scheme. From the different types of frequency reuse scheme, the best scheme is selected.

The stimulator being selected is due to the wired networking, ad-hoc routing, and mobile IP and sensor network. In the wired networking, routing, transportation, traffic sources are focused. Routing denotes unicast, multicast or hierarchical. The transportation is performed by TCP or UDP. The traffic sources are web, ftp, telnet, cbr, etc. From the simulator result the graph can be traced.

By setting up the connection between cell nodes using TCP protocol, the cell node gets initiated to response within the cell range Fig. 3. It is said that the described node is enabled and communication is taking place. When that cell node gets out of their cell range, the cell node gets disabled and a new node in the region will start approaching that cell range.

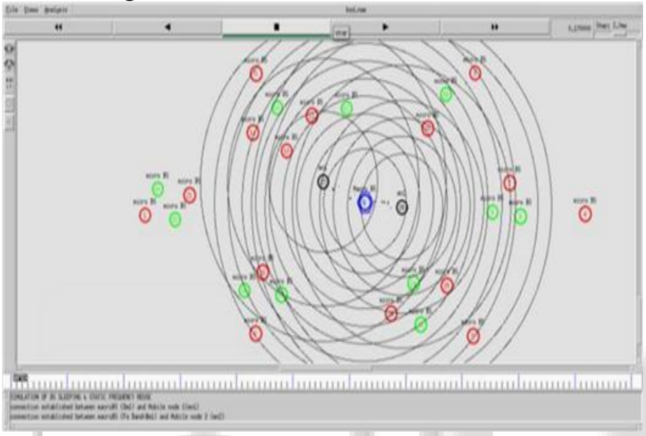

Fig. 4: Data communication between the Base Station (BS) and the cells located on the region

At sometimes, two nodes may get on to that range and it would create a collision which is resulted in failure state because the frequency range will be same for both nodes Fig. 4s. Though the capacity and energy performance is improved, there is presence of interference.

Interference has been proven to be the major problem of wireless communication systems, because of the following two reasons. They are:

- Limited resource in radio frequency spectrum.
- The number of users rises adequately.

When two different users are using the similar portion of the spectrum at the same area and time, the system suffers from interference. Due to this, the quality of the performance is degraded. The nature of the interference is due to the Co-channel or Adjacent-channel interference. When two different cell having same range gets interfered Inter-cell interference is occurred. By using the frequency reuse scheme, the inter-cell interference is reduced and it could perform in graceful way. In our analysis we formalize the task of reducing interference as a combinatorial optimization problem. For this purpose we model the transmission range of a base station having chosen a specific transmission power level as a set containing exactly all nodes covered thereby.

V. CONCLUSION

In this paper, the problem known as interference is focused and steps are taken to reduce the interference. The interference occurred is called Inter-Cell interference (ICI). For minimizing the interference, frequency reuse scheme is used. Among the different types of schemes the best reuse scheme is used in this paper. The static frequency reuse scheme cannot be used since its frequency band is stable and it cannot be accurately used. The dynamic frequency scheme can also be not used for reducing interference since its frequency spectrum band will be in floating stage [19]. Among the reuse scheme, Fractional Frequency Reuse (FFR) is suitable for the avoidance of interference. Because in FFR, the frequency spectrum is fractionally divided within the cell region with the frequency reuse factor. From this the optimal base station are combined using the frequency reuse scheme.

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