A Comprehensive Study on System Capacity Improvement in LTE Femtocells by On-Request Channel Allocation

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Abstract: ***Long-term evolution (LTE) femtocells represent a very promising answer to the ever growing bandwidth demand of mobile applications. They can be easily deployed without requiring a centralized planning to provide high data rate connectivity with a limited coverage. Femtocell is low-power, very small and cost effective cellular base station used in indoor environment. However, the impact of Femtocells on the performance of the conventional Macrocell system leads interference problem between Femtocells and pre-existing Macrocells as they share the same licensed frequency spectrum. Frequency Reuse (FR) is an effort of manipulating the frequency resource allocation upon terminal's location to improve system capacity. This paper discuss about various aspects of system capacity improvements and a novel frequency planning for two tiers cellular networks using frequency reuse technique is used where Macro base stations allocate frequency sub-bands for Femtocells users on-request basis through Femtocells base-stations to cancel interference.***

Keywords: Frequency Reuse, Chnnel allocation, LTE, Femtocell, Macrocells

1. Introduction

Fourth generation (4G) wireless systems (and beyond) are currently being developed to meet the explosive growth in demand for higher data rates by wireless devices. Due to the appealing characteristics of OFDMA, the major 4G standardization bodies such as IEEE and 3GPP/3GPP2 have adopted OFDMA as the main radio access technology for 4G standards such as WiMAX (worldwide interoperability for microwave access) and LTE (long term evolution). Long Term Evolution (LTE) system is designed to achieve high spectral efficiency using Orthogonal Frequency Division Multiple Access (OFDMA). OFDMA and Single Carrier Frequency Division Multiple Access (SC-FDMA) are used for Downlink and uplink transmission respectively. However, indoor cell phone signal is one of the concerning issue in LTE technology. It has been found that a significant percentage of voice calls and data traffic are originated from the indoor environment. In fact indoor environments contribute for more than 50% of voice calls and more than 70% of data traffic services. Nowadays, the main base station (BS), known as Macro BS (M-BS), has the problem of maintaining strong signals after penetrating through the walls in order to provide satisfactory services for indoor users. LTE assumes a full Internet Protocol (IP) network architecture and is designed to support voice in the packet domain. It incorporates top-of-the-line radio techniques to achieve performance levels beyond what will be practical with CDMA approaches, particularly in larger channel bandwidths. Multimode devices will function across LTE/3G or even LTE/3G/2G, depending on market circumstances. Currently, UMTS networks worldwide are being upgraded to High Speed Downlink Packet Access (HSDPA) in order to increase data rate and capacity for downlink packet data.

The radio spectrum is the range of frequencies used for wireless applications such as broadcast television and radio, cell phones, satellite radio and TV, wireless computer networks, Bluetooth, GPS, police dispatch, and countless other general and specialized applications that we use every day. For the most part, its difficult for these applications to utilize the same frequencies at same time. For example, if a local broadcast TV station used the same frequency as your cell phone, our cell phone would not work very well due to interference from the TV station, or your TV picture would be fuzzy due to interference from your cell phone, or perhaps both. To help avoid such conflicts, radio spectrum is carved up into different portions, and each portion is allocated to one or more services that, generally speaking, may be able to co-exist with each other.

A Femto-cell is a type of cell for use in the home, or in an office or some other smaller location. A cell is a part of the wireless network that makes up all of the coverage for mobile phones, including smart phones. A Femto-cell is a very useful piece of technology that improves the coverage of mobile phone networks in areas where cell signal can be weak. A femto-cell is a very low-range, low-power base station, able to be deployed in a home, home office or office. It is usually provided by a mobile network operator, and operates in licensed frequency bands. Femtocell is the most recent step towards increasing the network capacity of a wireless network and improving the quality of service for cellular users. A conventional cellular network overlaid with femtocells can provide better improved coverage, quality of service, and system capacity. Femtocell base stations are user-deployed which are low-power, low-cost home base stations that enhance the cellular network. A Femtocell BS (F-BS) is installed by end users at homes or offices which provides a wireless interface for subscribers and it connects a small number of cellular users and the core Telephony Network via wired internet. It is used for the purpose of indoor network access. The typical indoor coverage of a Femtocell is in the order of ten meters. A Macrocell covered by M-BS can contain hundreds of F-BSs.

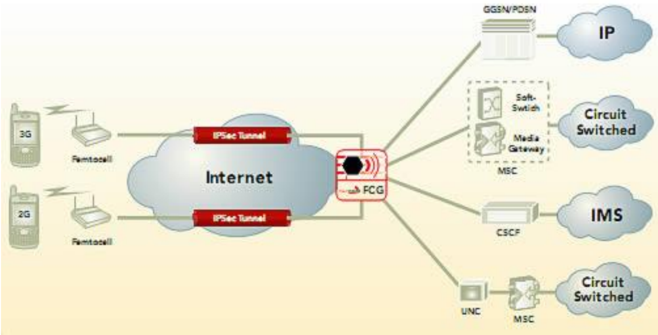

Figure 1: Femtocell co-existance

2. Scope and Objective

Mobile service providers have been working considerably hard to create innovative solutions in meeting the expanding network demands and the unprecedented growth rates in demands. Some of the solutions that have been provided are the use of small cell like microcells and nanocells to gain increased capacity in more populated areas, basements, underground motor ways, high building areas and so on. The use of the microcells and nanocells solutions offered effective solution but the relative cost in planning with corresponding equipment cost, power supply does not make these the best approach in combating the growth demand.

In eliminating the relative cost and offering a highly effective way for meeting the high rate demands, femtocells have been introduced. The use of the femtocells in the offloading of traffic has helped to free considerable capacity and creates an improved user data experience. Femtocells (also known as Femto Base Station, FBS) are characterized as ”inexpensive compact base station that provides equal radio access interface as a common macro-cellular base station (MBS) towards User Equipments (UEs)”. They are very small, low cost base stations with considerable low transmit power.

Although, femtocell is significantly useful, there are concerns on how to improve the femtocells standard over the growing technology releases from LTE to LTE-Advanced. More importantly, in achieving peak data rates and support for larger bandwidths, femtocells need to grow and make use of the opportunity the LTE development offers. This thesis examined and investigated the future of the LTE technology by looking at the femtocells perspective in correlation.

Usually a server station can be received by server stations in other cells. In this case, mutually interfering stations must employ different communication channels (i. e. frequency bands, time slices or codes from an orthogonal set), in order to avoid co-channel interference (interference caused by transmissions on the same channel). In its simplest (and most unrealistic) form, the channel assignment problem is equivalent to the Euclidean graph coloring problem, hence it is NP-hard. This problem can be treated with simple greedy heuristics [ES84] [BB95] [BBB99]. Because a server station must communicate with several mobile hosts at once, however, we must assign more than one channel to each server. When this problem is handled with graph-coloring heuristics, we need to substitute every node with a clique of cardinality equal to the required number of channels, in order to give the appropriate number of channels to each transceiver while respecting the interference constraints. This approach causes, however, the quadratic explosion of the problem.

2.1 Problem Statement

Interference between femtocell and macrocell users is increased when using same sub-band at the same sectored subarea. Thus, the objective of allocating frequency sub-bands for femtocells is how many sub-bands are allocated to Femtocell users in each sub-area. An OFDM system is used with a number of Resource Block (RB).

2.2 Objective

Objective of this paper is to develop a simple and efficient interference mitigation technique by allocating on request PRBs to Femtocells user through Femtocells base station under sectored-FFR OFDMA two tiers Macro Femto cellular system has been proposed. FFR is one of the solutions to reduce co-channel interference between Macrocell and Femtocell. So, it focuses on the interference mitigation between the Macrocell and the Femtocell by improving system throughput using 'On Request' channel allocation method in FFR approach.

3. System Model and Considerations

The proposed idea of this scheme is to mitigate downlink interference from Femtocell BS to MUEs and FUEs through on request channel allocation. Soft Frequency Reuse (SFR) method is considered here. For SFR usually the cell-center users are not affected by other cell-center users even though they share the same PRB because cell-center users are limited to a lower level power and the distance between a cell-center user and the adjacent eNode Bs is usually long enough to ensure large path loss, thus further reducing the received interfering power. Therefore, we only consider the mutual interference between serving cell-edge users and cell-edge users from different cells while simultaneously using the same PRB is considered here.

Femtocells, however, do create an issue for emergency number calls because they do not incorporate the same infrastructure as the macro network to pinpoint a subscriber’s location. (A similar problem occurs with DAS calls.) Most femtocells require a GPS signal to set up the base station, but do not require GPS for continued operation after setup.

Femtocells utilise the broadband connection, which may also be used for other applications such as video streaming. There can be problems when the provider of the broadband service differs from the mobile network provider. These relate to Quality of Service guarantees. A further issue relates to interference. Although the deployment of femtocells suggests that interference with other femtocells is not a huge issue, there is still some controversy over whether this will continue to be the case. The use of femtocells is part of a more general trend in mobile communications toward smaller cell sizes. Whilst there are some drawbacks to femtocells, the advantages of using them could be seen in homes and in small offices or home offices.

A number of randomly distributed indoor and outdoor environments with Macrocells, Femtocells and mobile stations are defined. A cell layout consists of seven hexagonal Macrocells environment, each of them is divided by central zone and edge zone. Edge zone is divided into three sectors.

Each sector has 500 meters radius with 10 MHz bandwidth. The Macrocells are located in residential area where Femtocell base stations are installed in a random location within Macrocells range. Femtocell ranges are around 10 meters. Only one Femtocell user for each Femtocell BS is considered in an indoor environment. Each Macrocell contains a three floor building with a number of apartments. There is a street between the two stripes of these apartments. Assume that the Femtocell BSs from different blocks are not too close to each other. All Femtocells users are located within Femtocell range and Macrocell users are normally located randomly throughout the cell. Also some Macrocells users are located within Femtocell range. Each Femtocell operates in a closed subscriber group (CSG). CSG is chosen because when a Macrocells user enters within Femtocell range and if the user receives stronger signal at the time from the Femtocell base station then interference occurs.

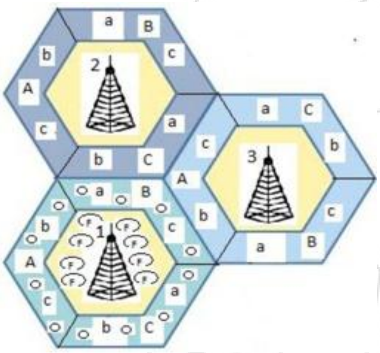

Figure 2: Femtocells deployment in Macrocells

The Macrocell coverage is divided into centre zone and edge zone. Edge zone has three sectors covers 120 degree each denoted by sub-area A, B, C. Each sub area has 60 degree virtual sub sectors denoted in small letters a, b and c which are allocated as the same frequency sub-band and power of A, B and C respectively. For Macrocell, different frequency subband (PRBs) is allocated to the each Macrocell sub-area according to the FFR. Consider the total number of PRBs is N. Number of PRB allocated for center zone is 2/3N and for edge zone is N/3. Also consider N/3 is the sum of PRB allocated for sub-area A, B and C respectively. As mentioned above, only edge zone is considered and it is focused on only one sector, i.e. A for PRB allocation. The other two sectors are treated in a similar manner. The total number PRBs of N1 can be used at Macro layer.

In the proposed scheme, PRBs for centre zone is two third of total PRBs. The PRBs allocated by A can be used by the users of virtual sector 'a' and the PRBs allocated for B can be used by the user of virtual sector 'b' on-request basis. Femtocells and cell edge users can use only the PRBs 'a', 'b' or 'c'. Number of cells under consideration is seven. Cell radius is selected according to LTE 3GGP standard i.e., around 500-600 meters. Maximum transmission power allowed for a Macro Base Station is 43dBm or 20 Watts and maximum transmission power for femtocell base station is 20mWatts. Total number of available Physical Resource Blocks (PRBs) is 24 for a bandwidth of 10MHz.

When a Macrocell user or Femtocell user attempts to make a call, it then measures the signal strength receiving from nearer BSs. Say, T1 signal is received from its serving BS and T2, T3, T4 signals are received from other BSs.

If T1» T2 or T3 or T4 in terms of signal strength then user is allocated PRBs from its serving BS.

If T1 > T2 or T3 or T4 OR T1 < T2 or T3 or T4 in tenns of signal strength then user is allocated PRBs from either virtual sub-sector a or virtual sub-sector b on request basis.

4. Conclusion

Long Term Evolution (LTE) is a radio platform technology that will allow operators to achieve even higher peak throughputs than HSPA+ in higher spectrum bandwidth. LTE is part of the GSM evolutionary path for mobile-broadband, following EDGE, UMTS, HSPA (HSDPA and HSUPA combined) and HSPA Evolution (HSPA+). The overall objective for LTE is to provide an extremely high performance radio-access technology that offers full vehicular speed mobility and that can readily coexist with HSPA and earlier networks. Because of scalable bandwidth, operators will be able to easily migrate their networks and users from HSPA to LTE over time.

This project evaluate fractional frequency reuse (FFR), and soft frequency reuse (SFR), that are used as inter-cell interference avoidance techniques in the OFDMA cellular downlink with varying input parameters for femto cells. In eliminating the relative cost and offering a highly effective way for meeting the high rate demands, femtocells have been introduced. The use of the femtocells in the offloading of traffic has helped to free considerable capacity and creates an improved user data experience. The co-existence of the macro cell and femto cell results in interference due to resource allocation problems. This projects limits the interference that will arise in a het-net system.

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Author Profile

Jayasankar.S received the B.Tech degrees in Electronics and Communication Engineering from University of Kerala in 2013. Currently pursuing M.tech in Communication Engineering in Mount Zion College of Engineering under M.G University. He works with Mobile Communication field and studying the same field for the last 3 years.