Frequency Reuse Schemes for Interference Management in LTE Femtocell Networks: Issues and Approaches

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Abstract—LTE networks are becoming more and more popular nowadays. There are two main problems in implementing LTE networks - coverage and capacity. Both these problems can be solved by deploying femtocells in LTE networks. Interference occurs between newly added femtocell and pre existing macrocell as macrocell and femtocell share same frequency band. Macrocell-femtocell interference management is biggest issue when we talk about LTE femtocell networks. Effective frequency allocation scheme should be used for macrocell-femtocell interference management in LTE femtocell network. Various frequency allocation schemes used for interference management in LTE femtocell networks are discussed in this article.

Index Terms—Femtocell, Fractional Frequency Reuse (FFR), Interference management, Long Term Evolution (LTE), Soft Frequency Reuse (SFR), User Element (UE)

I. INTRODUCTION

World is moving towards 4G nowadays. LTE-A provides best solution for implementing 4G networks. There are two Options for implementation of 4G networks, WIMAX and LTE. WIMAX was invented earlier and was very popular before invention of LTE. Less communication network [4].

Femtocell can be operated in three different access modes - open access mode, close access mode and hybrid access mode. In open access mode every user in femtocell coverage area is allowed to access femtocell. In close access mode only users subscribed to femtocell in femtocell coverage area are allowed to access femtocell. In hybrid access mode all users in femtocell coverage area are allowed to access femtocell but priority is given to users subscribed to femtocell [1].

LTE is becoming more and more popular. There are 110 service providers of LTE at this time in whole world [11]. In terms of LTE providers, there are total 41 service providers has deployed femtocells in their networks and a total 57 deployment commitments. LTE is a biggest driving force for femtocell technology. According to mobile experts in 2014, LTE will be at its peak and 2/3rd of total LTE service providers will be using femtocell technology [4].

LTE is standard developed by 3GPP (Third Generation Partnership Project). Soon LTE became very popular and it has given tough competition to WIMAX networks. LTE is used for implantation of 3G networks while updated version LTE-A is used for implementation of 4G standards. Main advantage of LTE over WIMAX is that it can transmit both voice and broadband data at 3G/4G speed. This is the main reason why most of mobile service providers are moving towards LTE nowadays [9].

The major two problems in LTE based networks are – capacity and coverage. Both these problems can be solved by deploying femtocells in LTE networks. Femtocell is a small base station that can be placed at subscriber’s home/office to improve indoor coverage. Cost of femtocells is reasonably acceptable. Femtocell provides advantage to service subscribers as well as service providers. Femtocells provide indoor coverage to users when macrocell signals are weak. It increases battery life of mobiles as mobiles do not need to communicate with macrocell at very high distance. Femtocell can be easily deployed at subscriber home as it provides plug and play features. Femtocells reduce traffic on macrocells by large amount. LTE-femtocell combination is very effective solution as a wire

LTE networks are implemented on cellular structure consisting of macrocells. When femtocells are deployed in LTE, system frequency interference can occur as femtocell will share available frequency band with macrocells. Macro-femto interference management is major issue in LTE-femtocell networks as it directly affects system performance. Various frequency allocation schemes can be used for interference management in LTE femtocell networks. Frequency allocation is very important in LTE femtocell networks.

There are basically four type of interference. First interference is between macro base station and femto UE (user element). Second interference is between macro UE and femto base station. Third interference is between femto UE and neighbouring femto base station. While forth, interference is between macro UE and neighbouring macro base station.

LTE uses different multiple access techniques for uplink and downlink. SC-FDMA (Single Carrier
Frequency Division Multiple Access) is used in uplink while OFDMA (Orthogonal Frequency Division Multiple Access) is used in downlink. Both these methods use orthogonal signals so frequency resources can be shared. So frequency reuse schemes are applicable for frequency allocation in LTE femtocell networks.

Many frequency reuse schemes can be used. Reuse-1 is the basic scheme and it provides maximum capacity. Increasing reuse factor will reduce system capacity but will also reduce interference. Soft Frequency Reuse (SFR) scheme has been proposed in [3] while Fractional Frequency Reuse (FFR) has been proposed in [2] because of its advantages over reuse-1 and reuse-3.

The remaining part of the paper is organized as follows. System model is described in Section II. Various frequency allocation schemes are explained in Section III. Section IV includes conclusions of study.

II. SYSTEM MODEL

In a model, we will represent each macrocell by a hexagon cell, femtocell by a circle and UE (User Element) by a triangle. BS (Base Station) of macrocell is represented by a small circle in the center of macro cell.

III. FREQUENCY ALLOCATION SCHEMES

There are various frequency reuse schemes. Some of them are explained below.

a) Reuse-1
b) Reuse-3
c) Soft Frequency Reuse(SFR)
d) Fractional Frequency Reuse(FFR)

a) Reuse-1

In this scheme whole band of frequency is used in one cell and then reused in all the other cells in a system. Here there is no band division so each cell can use entire band so user capacity per cell is maximum. It provides maximum Spectral efficiency because there is no band division. Here in each cell, femtocell also can use entire band. Entire band is reused in femtocells and macrocells hence interference is maximum in network.

b) Reuse-3

In this scheme available frequency band is divided in three equal sub bands. Then these sub bands are allocated to cells in a manner that there is no interference at edges of cells.

For example, as shown in figure 3 available band is divided in 3 sub bands A, B and C. Now the sub bands are allocated to cells as shown in Figure 4. First sub band A is allocated to center cell and other 2 sub bands are allocated to the cells at the edges of center cell. Here there is no interference at cell edges. Femtocells are allocated frequency on the basis of the macrocells in which they are operating. Suppose femtocell in center cell can not be allocated frequency in sub band A, it will be allocated frequency from sub band B or sub band C as shown in Figure 5.

Interference in this scheme is less as compared to Reuse-1. Edge performance is improved as compared to Reuse-1. But user capacity per cell will be less as compared to Reuse-1 as each cell occupies one third of available band.
c) Soft Frequency Reuse (SFR)

This method is combination of Reuse-1 and Reuse-3. In this scheme, each cell is divided into 2 regions, center region and edge region. Now, available frequency band is divided into 2 sub bands. Then 1 band is allocated to center region in each cell. The other sub band is again divided into three sub bands. Now these three sub bands are allocated to edge regions of every cell in a system in a way that no interference can occur at edges of cells. So SFR uses Reuse-1 in center region and Reuse-3 in edge region as a combination of Reuse-1 and Reuse-3.

For example as shown in Figure 5 first available frequency band is divided into two sub bands. Then one sub band is allocated to center region while remaining band is again divided into three different parts of edge region. Here if a femtocell is in the center region then it will be allocated frequency from sub band B, C or D. And if femtocell is in the edge region then it will be allocated frequency from sub band A.

In this scheme edge performance is better as compared to Reuse-1 and Reuse-3. But because band division is more user capacity per cell is less as compared to Reuse-1 but more than Reuse-3.

d) Fractional Frequency Reuse (FFR)

In this method each cell is divided into 2 regions, center region and edge region. Then edge region is again divided into three parts. Frequency band is divided into two sub bands. One sub band is allocated to center region of all the cells. And remaining band is again divided into three sub bands and these sub bands are allocated to three parts of edge region in a manner that no interference can occur at cell edges.

Interference in FFR is less as compared to Reuse-1, Reuse-3 and SFR. User capacity per cell is more than Reuse-3 and SFR. Main disadvantage is that we need four base stations in each cell for four regions. Complexity of system is more and band division is also difficult.
IV. CONCLUSION

LTE-femtocell combination provides very effective solution for wireless communication networks. Choosing a frequency allocation scheme is very difficult question in LTE femtocell network. Main aspect to consider here is macrocell-femtocell interference but the parameters like user capacity per cell, system complexity should also be taken into consideration. The main objective should be to provide best services to users. As we can see FFR is the best solution in terms of interference reduction but practical implementation is very difficult as it requires four base stations per cell and band division is also very difficult. We cannot predict exact number of users or traffic in a specific region of cell. In that way we can say that Scheme that can provide least interface may not be an appropriate option as other parameters are also affected.

REFERENCES


