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Avoidance of Interference in Femtocells Through Information Sharing Using Control Channels

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ABSTRACT

Femtocells are gaining importance in the recent years to address the cellular phone coverage problems in interior parts of huge structures and at locations that are faraway from cell towers, where the signal from macrocell tower is not able to reach. But care needs to be taken while allocating the frequencies to these femtocell access points, as they can cause interference among themselves if multiple femtocells of the same geographic location are allotted with same frequency bands. A solution of sharing the available channel information through control channels and making use of geographic location information to avoid allocating same frequency channels to femtocells of same region is proposed here.

Key words : Femtocell Interference, Geographic location, Control channels, Channel allocation

1. INTRODUCTION

In areas where high rise buildings of large dimensions are constructed close to each other, receiving the cellular signals is a challenge inside these structures. Attenuation due to multiple walls and multipath fading are the main causes for these problems. To solve this poor coverage problem, Femtocell concept was introduced, where a device called Femtocell Access Point (FAP) is used to offer indoor coverage to the devices which otherwise could not connect to the cell tower directly [1], [2]. The main cell towers are also called as macrocell towers. A Femtocell Access Point installed in a location can serve a coverage area of 50 to 100 meters and this region is called the Femtocell region of that FAP. Now the cellular devices of this region can connect to the telecom system and Internet through this FAP. Unlike WiFi access points that use unlicensed ISM bands, Femtocell Access Points use licensed frequencies for their operation [2], [3]. The other side of FAP which acts as the feeding side is usually connected with a broadband like connection. Each femtocell access point can provide connections to multiple devices. Faster data transmission rates are possible with FAP as the access point is installed close to the end-user devices, and there is no need to connect to the macrocell tower. It also helps in having long-lasting battery backup to the devices as less power is sufficient to connect to the Femtocell Access Point which is erected in the same area. Figure-1 is the typical diagram of femtocell implementation. As shown in the figure the feeding point of the access point is through broadband connection or a high-speed wireless connection. In the diagram, it is also shown that multiple femtocells can exist in the same geographical region. In such cases, signals of other FAPs also may be present at some end-user devices. These are shown with red color in the diagram. The ellipse-shaped coverage area shown in the diagram refers to the macrocell coverage area of the tower shown in the middle of the ellipse. Three femtocells are shown to exist within this macrocell area. When multiple femtocells are present in the same area, they need to operate at different frequencies such that they don't cause interference to each other. Mechanism of allocating different frequencies to FAPs of same geographic location by passing spectrum information through control channels, is the subject of this work. Section-2 of the paper contains the discussion on interference issues and section-3 contains the details of proposed mechanism. Section-4 presents the simulation results of implementing the proposed mechanism.

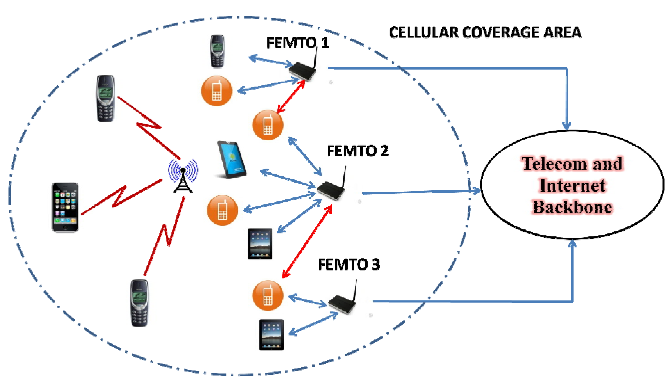

Figure 1: Femtocell Concept

2. INTERFERENCE PROBLEM

Femtocell access points are usually designed to operate in licensed bands of cellular telephone systems. Reason for this is that the devices to which these access points offer their services are cellular phones and other such systems which are designed to operate in those licensed bands only. There are three popular bands of cellular frequencies worldwide. They are in the range of 450 megahertz 850 megahertz and 1.8 GHz. When operating in these licensed bands, these access points have to ensure that their signals do not cause interference to cellular telephone customers of that area who are directly connected to macrocell towers. These access points should also ensure that the signals of one FAP do not cause interference to the signals of other FAPs installed in the vicinity [4]. This scenario is presented in Figure-2, where two Femtocells are shown to operate in a given region and so appear to be overlapping with each other. They are shown as tiny circles filled with red, green and blue colours. It is also shown in the diagram that each macrocell area is divided into three sectors using sectoral antennas. This is shown explicitly here to indicate that the frequencies of other two sectors can be allocated to FAPs in the given sector. Likewise, the frequencies of remaining six cells can be used by FAPs in the given cell.

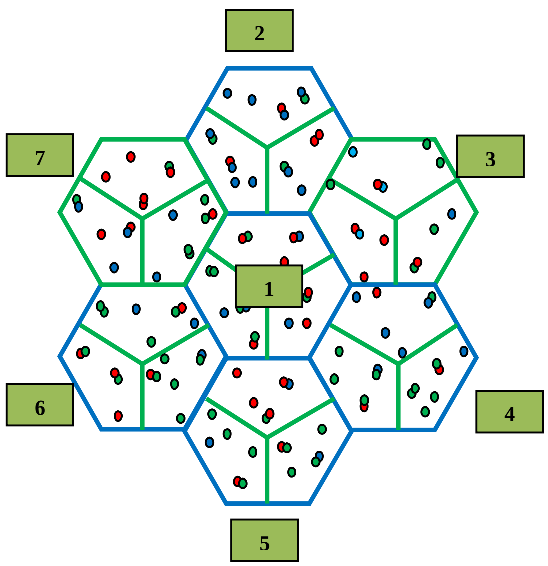

Figure 2: Femtocells within macrocell regions and interference

In some installations, where the femtocell access points are provided by cellular service providers, the operators take care of allotting different channels to the different FAPs located in the same surroundings. But in the context of more general scenarios, where the FAPs are procured and installed by individuals, choosing the channel frequencies that do not cause interference to other users needs to be carried out independently. In some of the earlier works, cognitive radio based solutions were proposed where the femtocell access point does the sensing operation of the spectrum and finds out vacant channels that can be used by the FAP. But these kind of situations have some limitations in terms of sensing accuracy, reentry of licensed user after a channel is chosen etc [5], [6]. Other things like hidden terminal effect between the access point and the device is also to be considered. Hence more robust solution will be needed to address this problem. In this work, a solution is proposed based on the concept of using the control channels to carry the vacant channel information. It is similar to carrying signaling information through SS7 like protocols of telephones and the forward/ reverse control channels of the cellular systems that carry some control information back and forth from the cell phones.

3. SHARING THE CHANNEL AVAILABILITY INFORMATION

As mentioned above, a frequency band that is used for cellular systems only needs to be chosen for the operation of femtocell access point, as the end-user devices are designed to operate in those frequencies only. In the more general case, where the end devices are not cell-based systems, vacant channels of other bands like the TV white spaces and FM radio bands can also be explored. But in the context of femtocell access points that are meant to offer end user connectivity to cellphone-like devices, the vacant channels of cellular bands only can be proposed to be used [7], [8], [9].

Then making available the information of such vacant channels to the femtocell access point is the task in hand. As each cell is configured to use a few channels of the total number of channels allocated to a cellular operator in a circle, those other frequencies that are not in use in this macrocell can be considered as vacant channels for using them for the FAPs in this ell. In a typical 7-cell pattern, about one-seventh of the total channels are used in each cell. So leaving those 1/7 channels, remaining 6/7 of the total number of channels can be used by femtocell access points in this macrocell region. These channels are considered to be vacant in the context of FAP only [11], [12]. They can not be treated as vacant in the context of original macrocell. The theories of cochannel interference and adjacent channel interference are used to describe the interference in macrocell context. For cell-1, the interference from cells 2 to 7 is called as adjacent channel interference. This can happen due to improper filters of the cell equipment that spills some signals into the frequencies of other cells. Cochannel interference is the one that is caused by another cell that uses the same frequency channels that are in use in the given cell. In cellular systems, care is taken to avoid or minimize both these interferences [13], [14]. Power of devices in a cell is adjusted in such a way that these signals do not reach another cell of the same number, that uses the same frequencies. Precise filtering can solve the problems of adjacent channel interference. In the context of femtocells, all the frequencies of adjacent channels that is 2 to 7 are considered as vacant channels only. They can be used for femtocell operation in this cell, that is cell-1. Even within the cell also, the frequencies of other two sectors of the cell can be used by FAPs that are located in the third sector.

So far, the discussion was about the frequency channels of one operator. Likewise, the allocated frequencies of multiple operators can be analyzed and thought to be used with FAPs. Now the details of all these vacant channels that can be used by an FAP are made available to it. This can be offered in a way that is similar to that of control channel operation in cellular systems through which paging information is broadcasted to cellular phones. In the context of FAP, this information can reach it through the network feeding that it has, like the broadband connection.

This information can be maintained in the network of servers meant for this purpose and gets updated dynamically based on the information received from the BSCs of various operators. As this information is stored with respect to various geolocations of each cell tower, then the vacant channel position at various locations can be found out and broadcasted to all the femto access points of that region through their network feedings. Now, when an FAP decides to avail some free channels, it can choose one or more of the available vacant channels through some backoff algorithms like athe binary backoff algorithm used in Ethernet. Through this, it can avoid the possibility of neighbouring devices choosing the same channels. It is important that geographic location of femto access point is to be used while accessing the vacant channel or claiming for them. It can be done with the help of GPS devices embedded with FAPs.

4. SIMULATION OF PROPOSED SYSTEM

The proposed system is simulated in MATLAB. Three different scenarios of 30, 60 and 90 femtocells are considered. Each FAP is considered to be of 100 meters coverage radius and they are initialized with their latitude and longitude values. 25 MHz each of forward link and reverse link bandwidths are considered. Normal distribution is used to decide the transmission needs of each FAP. Minimum allocation of one minute is used so that the simulation results can be presented for 1440 minutes.

Distribution of service requests by FAPs for an average period of 10 days is considered, which is shown in Figure-3. Number of requests serviced are shown in Figure-4 and blocking probabilities of Femtocell requests are shown in Figure-5. Blocking can happen if the available bandwidth is already taken by other FAPs which are also operating in the same region and are in the interference range. As the simulation is carried out for high number of FAPs, it can be observed that blocking probabilities are also high. Hence these probabilities are very high for the scenario of 90 FAPs compared to the scenario of 30 FAPs. It is around 50% for the scenario of 30 femtocells. That means half of the requests are not serviced. This probability is around 70% for 60 femtocells and 80% for 90 femtocells. It can be concluded from this that as blocking takes place for 30 femtocells itself, then all additional FAPs added further add to the blocked list in the same quantity.

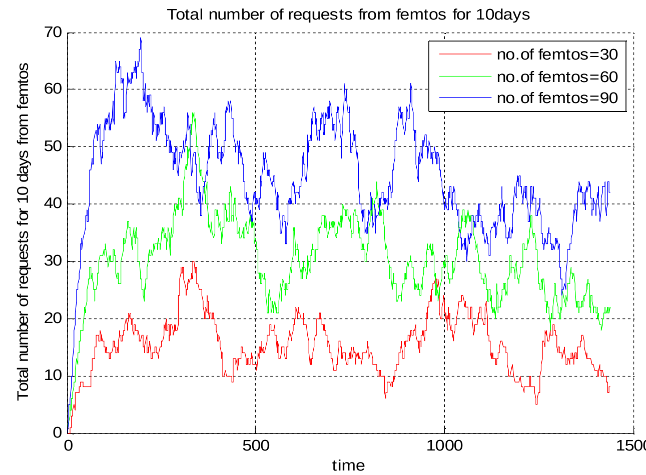

Figure 3: No of Requests from FAPs in 10 Days

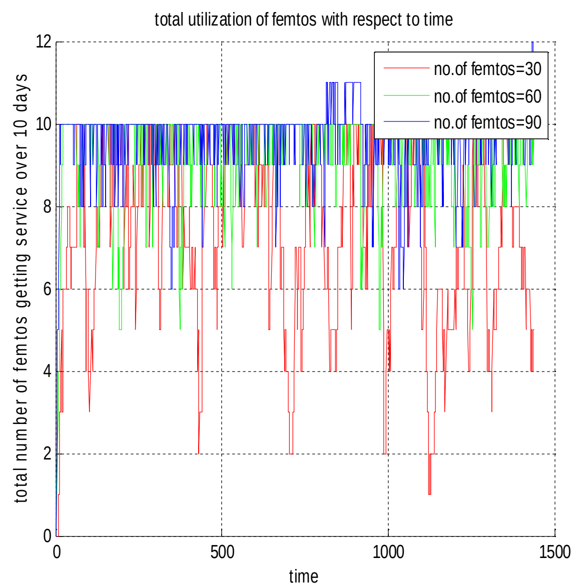

Figure 4: Total number of FAPs got serviced in

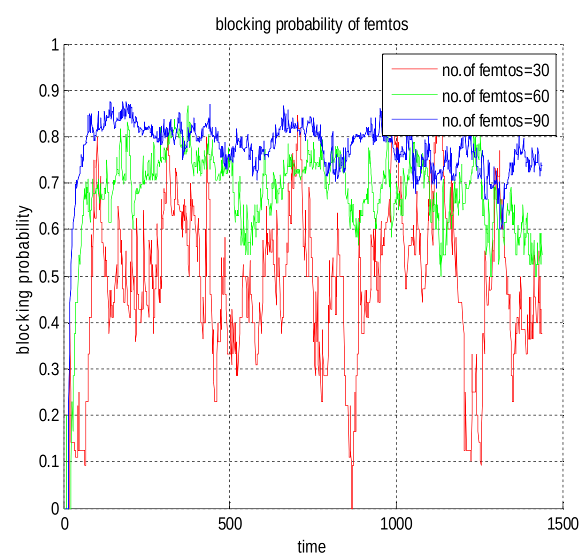

Figure 5: Blocking Probability of FAPs

5. CONCLUSION

A solution for interference avoidance in femtocells is proposed here. It makes use of geographic location information of the femtocell access point and communicates with channel allocation servers with this information. Then care can be taken at the servers not to allot same frequencies to the femtocells of the same region. Three scenarios of 30, 60, 90 interfering femtocell regions are simulated. Blocking probabilities due to the non-availability of channels is observed for the three scenarios. Blocking probabilities are observed to increase with increased number of femtocells operating in the same region.

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