Femtocell Technology – Present and Future

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Abstract - This is a review paper on the recently developed and rapidly evolving field of femtocells. Quite often, it isnoticed that cell-phone signals are strongly attenuated, when indoors, leading to call dropping or poor call quality. Femtocells are mini base stations that are deployed in users' homes so that the user can directly connect to the cellular network through the femtocell instead of the outdoor macrocell, thereby increasing call quality. In the later stages of the paper, we also discuss the various interference issues that the femtocell faces.

Keywords : Femtocell, Interference, Services,Uses.

I. INTRODUCTION

The last few years have seen tremendous growth in the fields of wireless networks and telecommunications. There are over four billion mobile phone users in the world today, and the numbers continue to rise. However, cellular phones continue to face issues such as poor signal strength and call quality when used indoors. At the same time, there has also been a huge development in Voice over IP (VoIP) applications. This technology allows users to make free calls through the internet, thereby acting as a potential threat to mobile operators around the world. In order to ensure customer loyalty and satisfaction, with a view to improving signal- strength in restricted areas, mobile operators needed to come up with an efficient solution. The deployment of femtocells was one such solution. Femtocells [1] are small base stations installed in homes. They are similar in size to a router and offer excellent signal coverage indoors, thereby reducing the load on the external macrocell. In order to avail the features of a femtocell, a user must have an internet broadband connection. The user must then, purchase the femtocell from a mobile operator and simply plug it to the connection. It is imperative that a femtocell remains a simple plug-and-play device, as a complex installation process is likely to prevent users from adopting it. When the user enters their home, the femtocell will detect the mobile handset and vice versa, and a connection will be established. All calls are then made via the femtocell. This technology is being tested by mobile operators around the world and is thought to be the technology that will revolutionize cellular communication around the world.

However, unlike Wi-Fi, femtocells operate in the licensed spectrum. In most countries, mobile operators are allotted three, licensed 5 MHz frequency bands [2]. In order to maintain customer satisfaction and maximize profits, operators need to utilize these bands intelligently and efficiently. Since both femtocells and macrocells are required to operate in these limited bandwidths, there are bound to be interference issues. A few proposed solutions that can help alleviate these drawbacks are seen in the later part of the paper.

II. IMPLEMENTING THE FEMTOCELL

i OPERATION OF THE FEMTOCELL

As mentioned in the previous section, a broadband internet connection is a prerequisite for connecting a femtocell. The femtocell enables encryption for all voice calls and data sent or received by the mobile phone. This makes it impossible for an external user to break into a user's home network.

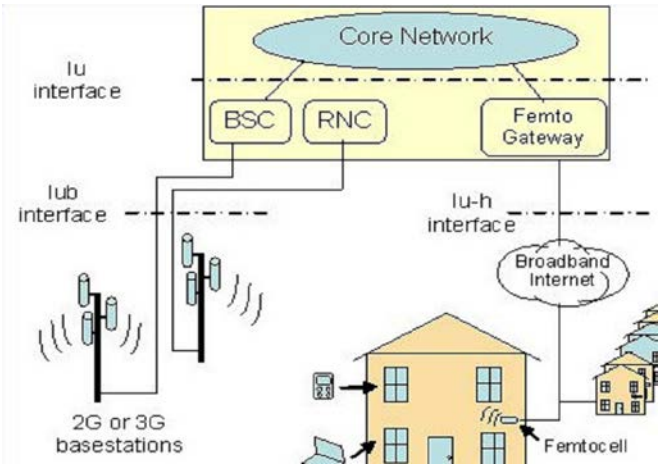


Fig. 1

To a standard 3G cellular phone, the femtocell appears as another cellsite or macrocell, hence communicating with it as it would with a macrocell, when the mobile phone is used outdoors. Since femtocells operate at very low radio power levels, battery life is high. Also, as the distance between the

femtocell and the mobile handset is short, call quality is excellent. Figure 1. Femtocell deployment[3].

The mobile operator's telephone switch and data switch 10communicate with the femtocell gateway in the same way as for other mobile calls. Therefore, all services including phone numbers, call diversion, voicemail etc. all operate in exactly the same way and appear the same to the end user. The connection between the femtocell and the femtocell gateway is encrypted using IPSec, which prevents interception. There is also authentication when the femtocell is installed for the first time to ensure that the access point is a valid one. Inside the femtocell are the complete workings of a mobile phone basestation. Additional functions are also included, such as some of the RNC [8] (Radio Network Controller) processing, which would normally reside at the mobile switching centre. Some femtocells also include core network element so that data sessions can be managed locally without needing to flow back through the operator's switching centres.

The extra capabilities of a femtocell demand it to be self-installing and self-configuring. This requires considerable extra software which scans the environment to determine the available frequencies, power level and/or scrambling codes to be used, thereby increasing complexity to a certain extent. This is a continuous process to adapt to changing radio conditions.

ii Femtocell radio technologies

The most commonly used implementation of the femtocell, makes use of the 3G [5] UMTS standard. However, other radio technologies are also being tested with femtocells and could be successfully launched in the near future. The most commonly used radio technologies [5] are as below:

a. GSM (Global System of Mobile Communication)

The most commonly used wireless technology, GSM accounts for 85% of the current mobile

market share. GSM cellsites are termed as picocells rather than femtocells because they are not auto-configuring. They require the operator to get these cellsites up and running for use.

b. UMTS (Universal Mobile Telecommunication System)

This technology is an evolution of GSM; hence it is also known as 3G. It was derived from GSM by replacing the standard GSM radio sub-system, with one based on the CDMA technique. It offers a much larger capacity as compared to GSM and also requires a lesser number of cellsites. UMTS networks are usually used in combination with GSM technologies.

c. HSPA (High Speed Packet Access)

This is an improved version of UMTS obtained by increasing coding on radio transmissions, thereby improving throughput to a large extent. They provide data rates of upto 21Mbits/sec. They work satisfactorily with UMTS equipment. However, new handsets would be required to take advantage of the high data rates provided by HSPA.

d. CDMA (Code Division Multiple Access)

This standard grew in popularity at its launch but did not achieve the global assimilation that was expected of it. The first phase of CDMA was termed '1xRTT', an efficient technology for voice and text services.

e. LTE (Long Term Evolution)

This is a joint undertaking by GSM and CDMA vendors in order to develop a common standard for mobile communications. This is a 4G standard and is capable of achieving data transfer rates of upto 100 Megabits per second. It uses the orthogonal frequency division multiplexing (OFDM) scheme, in order to tackle issues such as multi-path propagation.

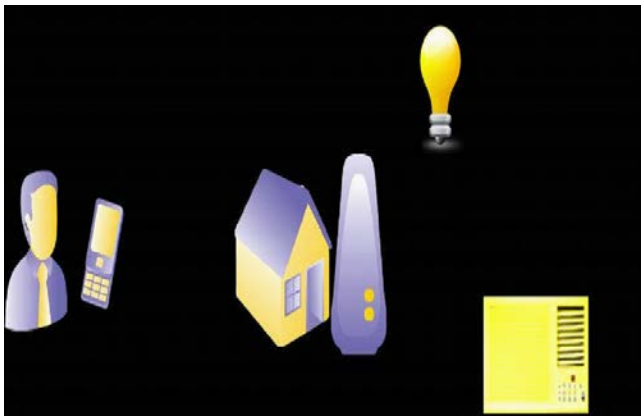
f. WiMAX (Worldwide Interoperability for Microwave Access)

This is a standard that is used to provide wireless broadband services in regions where it is infeasible to set up fixed telephone systems. It makes use of OFDM technology and is the biggest competitor to the LTE system mentioned above. It supports data rates of upto 75 Megabits per channel, making it an excellent alternative for femtocell implementation.

III. FEMTOCELL SERVICES

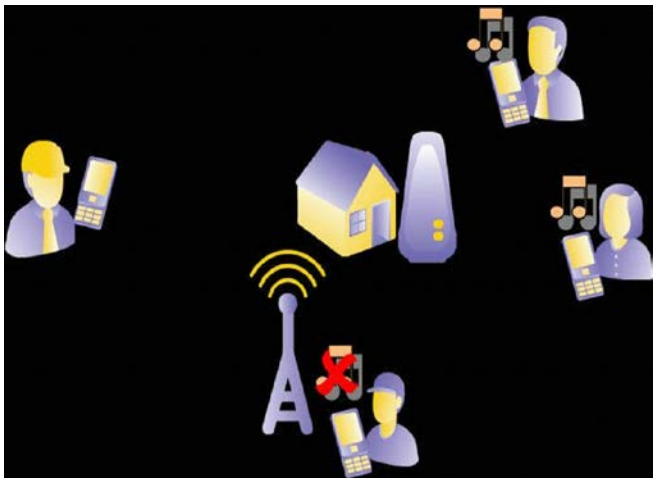
i Secure home access :

This is a very unique service of femtocell technology in which all the home devices are controlled by your mobile phone.



ii Virtual home phone

Provide access to the home devices whether there is the network available or not. User can communicate through femtodevice instead of using the actual network.



iii Virtual fridge notes

This service allows the user to send a message as sms to another user when the cell arrives under the specific location like fridge notes.

IV. INTERFERENCE ISSUES IN FEMTOCELLS AND INTERFERENCE MITIGATION

Although the growth of the femtocell could see a sharp rise in the popularity of cellular phones, there are still concerns regarding interference between femtocells and the external macrocell as well as similar such devices. Since the femtocell and the macrocell operate in the same range of frequencies, there is bound to be interference. The main problem of interference arises from the fact that femtocells are installed in an ad-hoc manner, or independent of the structure of the cellular network. One simple solution discussed, was for the femtocell to operate on a different carrier frequency with respect to the macrocell. However, this solution is not simple to implement since most mobile operators are allotted a fixed spectrum to provide their services, as mentioned earlier. Another effective solution that successfully tackles femtocell interference for outdoor mobile users connected to the macrocell is suggested in [15]. To find an effective and logical solution to this drawback, the Femto-forum13 has been involved in conducting research into mitigating the problem of interference in femtocells. In the 3G architecture, most operators are allotted 2 frequencies for use. So, interference could also be reduced by allowing femtocells to transmit on the unused second frequency. However, this still does not resolve interference that may arise between two femtocells that operate on, say two floors of a building. This scenario may also affect the quality of service and capacity of each individual femtocell. Another alternative suggested, was for mobile operators to implement a two-tier femtocell network, by sharing spectrum rather than splitting spectrum between the two. As per studies conducted by the Femto-forum the main, forms of interference that arises in femtocells are mentioned below:

Femtocells interfering with base-stations on the same frequency.

Base stations interfering with femtocells on the same frequency Femtocells interfering with each other Cell phone signals received by both, macrocells and femtocells

All the scenarios mentioned above, can lead to degradation of the capacity of the overall network, thereby reducing the quality of service offered by the network. On account of the different types of interferences that arise in femtocells, different techniques must be implemented in order to bring down interference to acceptable levels. One such technique has been suggested in [4]. In this paper, Chandrashekhar and Andrews have developed an architecture that helps in

limiting cross-tier interference between femtocells and macrocells. This helps in increasing the uplink capacity for a shared spectrum network. A few more proposed to help reduce femtocell interference are as below:

i. Adaptive Pilot Power control
ii. Dynamic receiver gain management
iii. Mobile phone uplink power capping
iv. Extended dynamic range for femtocell receiver

V. CONCLUSION

The promising femtocell is being tested extensively by mobile operators around the world.However, there are still some issues that need to be worked on for femtocells to be implemented as fault-free devices. In the years to come, femtocells may also be able to operate efficiently using EDGE [5] standards. A number of hardware evolutions are required before high usability and quality of service standards are achieved. This may take a few years to achieve. Mobile operators must continue partnering with internet service providers, so as to make the femtocell a reasonable means of improving cellular communication indoors. There is still sufficient capacity available in the macro network, so there is still no immediate need of femtocells to help alleviate the pressure on macrocells. However, femtocells can be of immense help in rural areas where the distances between homes and the nearest macrocell, could be many miles. The development of femtocells can also help speed up the evolution of Universal Mobile Access.

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