Femtocell: What, Why, and How?

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Summary
In today's cellular networks Femtocell is the air access technology that promises to cope with issues like weak signal strength indoor and it is also regarded as a solution that helps on a larger scale to reduce the cost and operational expenses of a mobile network while improving network's coverage and capacity. With the joint deployment of Femtocells and Macrocells (Femtocells over the top of Macrocells), voice and data communication are carried out using cellular technology with IP backhaul through customer's broadband connection i.e., DSL or cable modem, etc. This study covers an overview of Femtocell mainly in three areas what is femtocell, why do we need it and how is it deployed. We start with a brief discussion about the benefits and challenges related to the joint deployment of Femtocells and Macrocells. Then a few key challenges are for instance the access strategies, access technology, interference, architecture and how femtocell can be connected to 3G discussed in details. The study also contains a brief analysis of the market success of femtocell.

Key words:
femtocell, cellular technology, Wi-Fi, access strategy, handoffs, interference.

1. Introduction

The advance of wireless communications has introduced many technologies, mainly in two different directions i-e cellular networks and Wireless Local Area Networks (WLANs). Cellular networks consist of a dedicated terrestrial backbone while WLANs usually connect directly to the IP network. In cellular systems, one of the major issues is weak or degraded network signal for indoor users in apartments or buildings. To address this issue cells sizes smaller than Macrocell were introduced namely Micro and Picocells. Since these technologies were purely cellular with a basic purpose of providing voice services with mobility these could only increase the network coverage but on the other hand, required many resources for their deployment. Femtocell is a comparatively recent technology and a direct ancestor of cellular technology which can be regarded as scaled-down base station or home node B [9]. In other words, Femtocells are cellular network access points that connect standard mobile devices to a mobile operator's network using existing residential broadband connection such as DSL or cable connections.

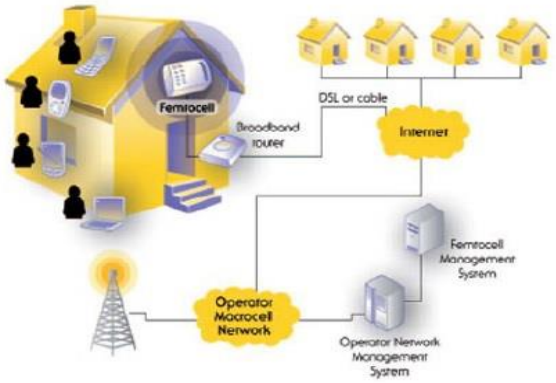

Fig. 1 Femtocell Architecture [4]

Femtocell is a recent technology in the modern telecommunication world. Femtocell claims to improve system capacity according to Shannon's law by reducing the distance between transmitter and receiver and thus improving the Signal-to-Noise Ratio (SNR). Since in today's telecommunication network most the data traffic occurs indoor and Macrocells are not very efficient when delivering indoor coverage due to high penetration losses and thus providing sufficient received signal strength and SNR for indoor users is, in fact, a challenge for network operators. Therefore, using Femtocell Access Points (FAPs) seems a promising approach for coping this problem. As figure 1 shows that the FAP can be regarded as the scaled-down base station (BTS/BSC) extended to allow easier deployment (end-user deployment/plug and play deployment) as autonomous Customer Premises Equipment (CPE). Femtocells connect standard mobile devices to mobile operator's network using residential Digital Subscriber Loop (DSL) or cable broadband connection i-e Femtocells use the IP network as backhaul architecture instead of the conventional cellular network infrastructure [4]. Femtocells allow users to transition seamlessly between the cellular network and a broadband Internet connection in order to make phone calls; this is done with the help of Femtocell access points. These differ from Wi-Fi access points because they basically act as scaled-down versions

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of signal repeaters, but they function in a similar way by broadcasting wireless signal from a broadband connection. In figure 1, the Femtocell and broadband router are shown as standalone devices but Femtocell, broadband router, and a modem can be integrated as a single device but that's again up to the manufacturer's viewpoint. One of the most interesting facts about Femtocell is that it not only increases received signal strength in its coverage area but also improves network capacity by offloading Macrocells' traffic, thus allowing a more outdoor user on Macrocell and thus making more revenue for operators without the deployment of any new equipment.

Femtocells can easily integrate with 2G, 3G, 4G, and upcoming 5G networks, meaning that GSM, UMTS, CDMA, EVDO and other current and future protocols, standardized by 3GPP, 3GPP2 and WiMAX Forum and other wireless broadband users will be able to take maximum advantage of the services in areas where coverage would otherwise be spotty. In other words, Femtocell is a mature mobile technology qualifying standard protocols. In can be of great interest in the countries where 2G is still the widely deployed technology in a way that Femtocell can be introduced with 3G or 4G altogether. In such countries, it can be helpful for an operator for their network planning making better use of their resources. Being direct successors of cellular technology Femtocells operate in licensed spectrum and within parameters set by the licensed operators. When operating in licensed spectrum, operators are able to provide certain assured quality of service (QoS) to customers over the air, interference-free while making efficient use of their spectrum.

Femtocell is also one of the concepts came to implement to give better coverage for indoor mobile users. The main goals of this research are to study the concept of Femtocell and the technologies supporting this concept.

2. Technical Challenges and Possible Solutions

When new solutions are introduced to cope with the current issues and problems in the existing systems, technically they have to give the optimum solution to the system to improve reliability in an efficient way as compared to previous version or system. Femtocell also is one of the solutions to give better service to customers where the received signal level is weak or unavailable, in Macro cellular systems, as well as leads to offload the Macrocell traffic. In this section, we have discussed the adopted solutions to the problems and challenges we face when Femtocell is deployed in the Macro Environment. The first section discusses the Femtocell architecture and then we discuss how Femtocells are connected to Macrocell and what the supposed access methods are. Then in this connection RF interference and handoff is discussed.

2.1 Femtocell Architecture

Femtocells are deployed at wireless network customers' home and utilize their broadband connection. Figure 2 shows a typical overview of a Femtocell deployed in a home served by a DSL connection. Since Femto utilize 2G and 3G standards, they are compatible with a wide range of existing mobile devices.

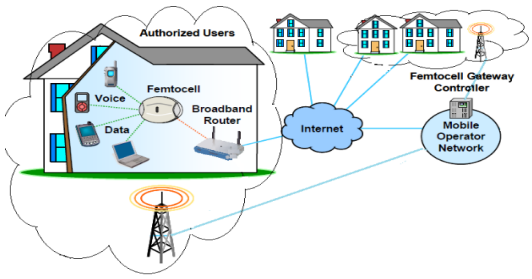

Fig. 2 Femtocell architecture

1) New network elements

The essential new network elements in the Femtocell architecture are Home NodeB (HNB) known as Femtocell, the HNB Gateway (HNB-GW), Security Gateway (SeGW) and the HNB Management System. HNB connect to the mobile network through the HNB-GW. The HNB-GW aggregates a large number of HNBs, acting as a concentrator. This interference is called Iu-h. In addition, this connection goes through a SeGW to ensure a standardized security mechanism. Especially an IPSec tunnel is established and maintained between HNB and SeGW. This means that all Iu-h interface traffic is tunneled through this connection.

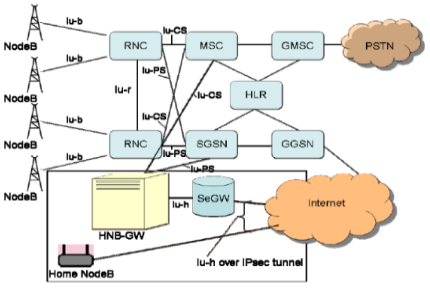

Fig. 3 UMTS basic architecture with Femtocell

2.2 Connection with 3G and Access Strategies

The growing network capacity expectations and intensive competition among operators are constantly driving

vendors to come up with new solutions. Femtocells are a low-cast and easy way to offer capacity and coverage to residential and enterprise environment. Since Femtocells use standard wireless to communicate with the standard mobile devices. Qualifying standards include 2G and 3G technologies. When used with 3G (e.g. UMTS) we face issues like Femtocell integration to the cellular core network, interferences, and spectrum accuracy and also the challenges of handover cases.

2.3 Access Strategies

There still exists many challenges operators and vendors must face in integrating a large number of HNBs with existing Macrocells. Interference still remains among the major problems in Femto-macro hybrid networks, resulting in degradation of the performance of the entire network [22]. In Femto-macro hybrid networks, interference is classified as follows:

- Cross-tier interference is caused by an element of the Femtocell tier to the Macrocell tier and vice versa.
- Co-tier interference may appear between elements of the same tier, for example, between neighbouring Femtocells. The impact depends on the spectral resources allocation techniques for the Macrocell and Femtocell tiers, also on Femtocells access methodology.

Femtocells access control strategy has dramatic effects on the performance of the overall network, mainly due to its role in the definition of interference. Different access approaches have been proposed:

- Closed Access: In this strategy, the Femtocell owner defines the users who can connect to the Femtocell. The Third Generation Partnership Project (3GPP) refers to this model as a closed subscriber group (CSG) [23].
- Open access: in this strategy, all customers of the operator are allowed to make use of any Femtocell.
- Hybrid access: A subset of the Femtocell resources is available to all users of the operator.

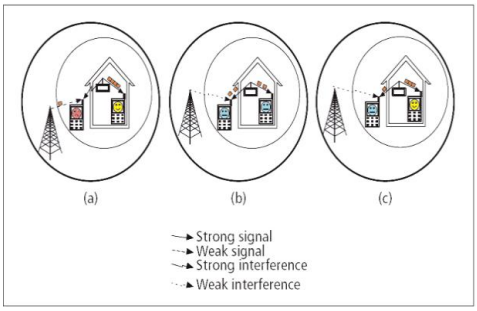

Fig. 5 Access Methods: a) CSG; b) Open Access; c) Hybrid Access

3. Market Penetration

Femtocell dramatically improves indoor wireless signal coverage. The benefits Femtocell offers to both networks operators and users form the most important factor in driving market growth. Significant cost savings in deployment and for backhauling and reduced subscriber nuisance because of better network coverage are some of the benefits for the operators. While some benefits for end-user include better internet connectivity and download speed along with lower call charges.
Instead of enabling WLAN, where wireless signal can't penetrate the building material, the 3G coverage inside homes or buildings can be improved using Femtocell stations.

3.1 Deployment in Pakistan

As it is evident that a standard feature for the deployment of femtocells, the broadband connection of the user is of utmost importance, as it will be used for backhaul connectivity of femtocells with the cellular operator's core network. Since, in Pakistan, the fixed-line access falls under the domain of fixed-line operators, there can be issues while delivering cellular services through using the fixed-line access, such as ownership of the femtocell devices, Femto access network, etc. While in many countries, some service providers provide both fixed and mobile services, it is much easier for them to provide femtocell-based services over their own fixed infrastructure. However, in the case of Pakistan, there can be two options, as under:

- The cellular operator can have an interconnection agreement with the broadband provider for delivery of femtocell-based services to the end-user. The responsibility of broadband will be borne by the fixed-line operator whereas other portions of the network by cellular operators. This also means that the broadband connection is of standard and will ensure uninterruptable services to the end-user.
- Femto base services do not need any agreement with internet service providers ISP as it can be implemented using existing DSL/Broadband internet connection. However, the performance of such services will not be the responsibility of cellular services provider or the ISP provider, however other means to ensure continued service must be thought of.

As per Pakistan Telecommunication Authority, the existing regulatory structure of the Pakistani Telecommunication sector is driven by three main policies, namely, (1) De-Regulation Policy for Fixed-Line sector 2003, (2) Mobile Cellular Policy 2003-4, and (3) Broadband Policy. "Under the current Telecommunication Act, Rules, Regulations and

aforementioned policies, the licensing structure is mainly focused on Service-based authorization, e.g. a Local Loop license for local loop services, LDI license for Long Distance & International service, etc. Apart from this, there are integrated licenses held by PTCL, NTC, and SCO. For elaboration, we take the example of PTCL's license, which covers many services, including, local loop, LDI, and value-added services. Being the incumbent in the fixed-line sector, PTCL's effect on the overall market is significant. This will be the driving factor for the transport of femtocell traffic over broadband. Since we have seen that for the deployment of femtocells, merging of mobile network and fixed network will eventually take place, however, since the existing licensing regime is split over service-based categories, therefore it will be of concern how the two operators (Fixed line and Mobile) will cope up. Possible scenarios could be two, (1) inter-operator service level agreements, (2) mergers & acquisitions.

1) Whereas inter-operator agreements between fixed and mobile are concerned, certain elements of the whole network and services will have to be defined to the extent of responsibilities of each operator towards the delivery of femtocell solution.
2) In the second scenario, we could also see mergers & acquisitions, this could result in companies having both fixed and mobile licenses. Mergers & acquisitions can be seen across the globe, and in a way helpful for those operators who want to provide multiple services and hold multiple licenses, in such an event it will be worth a look at a possibility of introduction of unified licenses.
3) Licensing requirement for femtocells can be considered depending on the regulatory regime being followed in the country. Spectrum holders/license holders can be relieved from having separate licenses for femtocell deployment. Other than this, no other entity can be allowed to establish, maintain or deploy femtocells even if they don't hold a cellular license. However, entities having Fixed local loop licenses having interconnected for backhaul with the cellular operators can be allowed to install such devices having a cellular operator on the forefront for making an application for permission from the Authority" [11].

4. Conclusion

Femtocells may play a major role by providing cellular coverage where the Macrocell coverage is not available as well as by improving service quality. Most of developing country as well as the developing country where 2G and 3G technology used femtocell is a good remedy for them to provide quality of service for their customers. It can bring about a revolution in the wireless communication industry on mass deployment because of its capability to drastically improve QoS at much cheaper rates. The operator will use femtocells to build a new generation of lower-cost, flat architecture network that can utilize the internet as backhaul and deliver expanded capacity for customers. This hybrid mobile network will yield an improved platform for new mobile multimedia services, higher revenue, and new technology introduction. This research-oriented project was helped to improve knowledge of the Femtocell and the technologies supporting this concept, its success and the possibility of competition with Wi-Fi. We proposed a policy server to overcome the load balance problem to improve QoS. Finally, we discussed some positive and negative aspect regarding Femtocell and Wi-Fi after getting better to understand the concepts. We hope that the femtocell will deploy in future networks to give strong coverage with having attractive features. Furthermore, policy server implementation remains for future works due to the time limitation of the project. After implementation, we can confirm that to provide quality service with having priority based on applications.

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