A Review Paper on Femtocell Deployment of LTE and its Pros & Cons

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Abstract: **The paper highlights brief on FEMTOCELL deployment. The Femtocell is the most recent evolution of the mobile network base station. Its aim is to provide dedicated indoor coverage, bringing significant improvement in enhanced coverage and improved call quality and data rates. The femtocell concept is applicable to all standards, including GSM, CDMA, WCDMA, WiMAX and LTE solutions. In these paper different aspects such as need, positive/ negative aspects, technical issues and market outline are discussed.**

Key Words: Femtocell, 3GPP HSPA LTE, interference, QoS, Self-organizing networks.

1. INTRODUCTION

The erupting growth and popularity of wireless network service in the past few years has fueled the need for wide bandwidth. The demand for higher data rates in wireless has triggered the design and development of several standard technologies have been developed such as 3GPPs High Speed Packet Access (HSPA), Long Term Evolution (LTE), Ultra Wide Band (UWB) and 3GPP2s Evolution-Data Optimized (EVDO) to provide high speed communication to end subscribers. A femtocell is currently the probable solution for the above said issue. It is designed to be placed in home and offices that enable ordinary mobile handsets to be connected with the mobile network through broadband connections. Besides benefits to end users (consumers) and MNO's(Mobile Network Operators), femto cell is a complex technology and there are number of issues and concerns, although as with the increase number of deployments these issues have largely been addressed.

1.1 Origin

'Femto' meaning a very small cell (area of network coverage). The first attention to femtocells was started around 2002 when a group of engineers at Motorola were investigating new applications and methodologies that could be used to sort the mobile network communication issues.

A couple of years later in 2004, the idea begun to gain some momentum and a number of companies were looking into the idea. Especially two new companies, Ubiquity's and 3WayNetworks were made in the UK to focus on the area of femtocells. Femtocell concept gaining momentum, and many more companies exploring femtocell technology, the Femto Forum was formed in July 2007.

Its aim was to encourage the wide-scale acceptance and implementation of femtocells. With mounting industry pressure to be able to deploy femtocell technology, the role of Femto Forum was to ensure that the standards were decided and released as fast as possible.

1.2 Why Femtocell

Survey on wireless communication network usage shows that more than 50% of all voice calls and more than 70% of data traffic originates inside a home or an office. Voice networks are designed to endure low signal quality, as the required data rate for voice signals is very low, on the order of 10 kbps or less. On the other hand data networks require much higher signal quality in order to provide the very high data rates.

For indoor devices, particularly at the higher radio carrier frequencies, attenuation losses will make low signal quality and hence higher data rate is very difficult to achieve. This raises the one important question; why not motivate the end-user to install a short range low-power link in these indoor locations? This is the core advantages of the femtocell approach.

The user is pleased with the higher data rates and reliability; the operator reduces the amount on installation of their expensive macro cell network, and can focus its resources on truly mobile users. Indoor signals have been a weak point of cellular coverage, since very long. Femtocell offers the possibility of using a device like a broadband router for the enhancement cellular reception inside a home or office.

The most efficient way to increase the network capacity in a cellular network is to shrink the cell size.

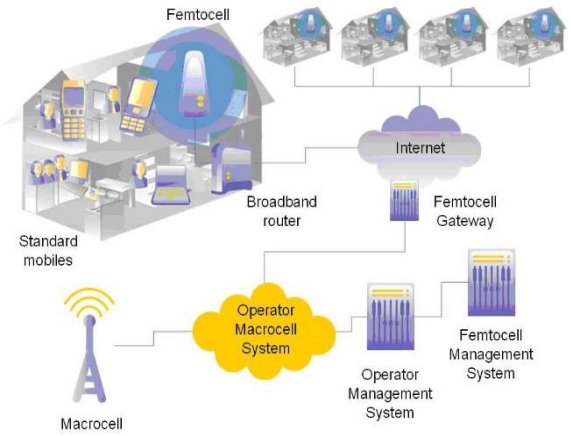
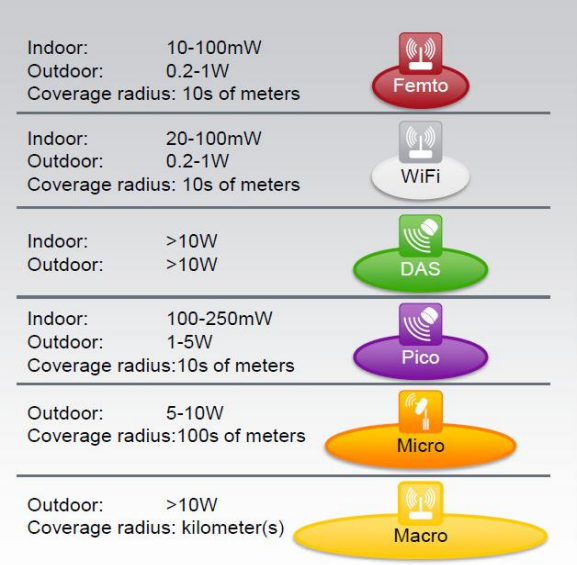


Figure 1: Femtocell Network Structure

*Macrocells***:** A Macrocell provides the largest area of network coverage within a mobile wireless network. The antennas can be mounted onrooftops or other elevated structures and must be high enough to avoid hurdles. Macrocells provide radio coverage area over varying distances, depending on the frequency used, the number of calls and the physical landscape. Typically they have a power output in tens of watt. Macrocells are conventional base stations with power about 20W, that use committed backhaul, are open for access and there range is about 1 km to 20 km.

Table-1: Various Wireless Network Cells



Microcells: Microcells provide supplementary coverage and capacity in areas where there are high numbers of users, i.e. urban and suburban areas. Microcells cover around 1/10th the area of a Macrocell. The antennas for microcells are installed at street level, are smaller than Macrocell antennas and can often be disguised as building structures so that they are less visually unpleasant. Microcells have lower output powers than marocells, usually a few watts. Microcells are base stations with power between 1 to 5W, that use committed backhaul, are open for access and there range is about 500 m to 2 km.

Picocells: Pico cells provide more confined coverage. These are usually found inside buildings where coverage is poor or where is a number of users are huge such as in airport terminals, train stations and shopping centers. Pico cells have low power base stations with power ranges of about 50 mW to 1W, that use dedicated backhaul connections, which is open for public access and range is about 200 m or less.

Femtocells: Femtocell's base stations allow users to make calls inside their homes via their Internet broadband connection. Small coverage are solutions are provided which are operated at low transmit powers. These are consumer deployable base stations which utilize consumer's broadband connection as backhaul, and it may have restricted association and power is less than 100 mW.

1.3 3GPP LTE Femtocell

3GPP is now focused on Long Term Evolution (i.e. LTE, formally 3GPP Release 8 onwards) and LTE-Advanced technologies (LTE-A, Release 10 onwards). WiMAX marcheson, including femtocell standardization activities, but its impact in developed markets figures to be small. The physical and MAC layer impact of femtocells on LTE and WiMAX are quite similar, due to their comparable physical and MAC layer designs, which are based on orthogonal frequency division multiple access (OFDMA).

Since LTE is likely to be thedominant cellular data platform for the foreseeable future, thesmooth integration of femtocells into LTE is particularly important. A key difference in OFDMA (both LTE and WiMAX) is the large quantity of dynamically allocated time and frequency slots. This considerable increase in the flexibility of resource allocation is both a blessing and a curse. Because femtocells can be allocated orthogonal resources to nearby pico and macro cells, the possibility for fine-tuned interference management exists, whereas it did not in GSM or CDMA.

That is, in theory, a complex network-wide optimization could be done wherebyfemtocells claim just asmuch resources as they "need", with the macro cells then avoiding using those time and frequency slots. And therein lies the curse: potentially a large amount of coordination is necessary. A popular compromise is fractional frequency reuse, whereby frequency (or time) resources can be semi statically allocated to interior, edge, or small cell users, with power control on top to lower the throughput disparities experienced in each of these scenarios. Alternatively, a semi-static partition could simply be made between femtocells and macro cells.

The results indicate that even with dense femtocell deployments, most resources should go to the macro cell, since each femtocell only needs a small number of resource blocks to provide comparably high throughput to their user(s).

Figure 2 shows, adaption of consumers for Data services over voice and data services are mainly used in indoors.

Figure 2: Expected Exponential Wireless Data Growth.

2.1 PROS- in favour of Femtocell

There are number of advantages for the deployment of femtocells to both the user and the mobile network operator. The advantages provided to the user are, the use of a femto cell within the home enables far better coverage

to be enjoyed along with the possible cost benefits. For the network operator, the use of femtocells is very cost-effective means, improving coverage, and providing additional revenue from the provision of additional services. The points in the favor of femtocells are the mentioned below:

Better Coverage and Capacity

The huge advance of smart phones, broadband-enabled laptops, and other data-hungry devices has mobile data traffic doubling from one year to the next. Many are originated at home and in the office, and the devices used in outdoors are difficult to meet indoor bandwidth demand. It will take a lot of more macro cells to deliver indoor coverage and sophisticated services. But most service providers want to reuse legacy sites.

Lightening the macro network's traffic load freed up the capacity. The very efficient and economical way of doing this is by deploying femtocells. As a fringe benefit, the femtocell improves radio performance, treating users to a more satisfying experience.

Due to their short transmit and receive distance, femtocells are able greatly to lower transmit power, increase the handset battery life, and achieve a higher signal-to-interference plus-noise ratio(SINR). These result into improved reception—the so called five-bar coverage and higher capacity. Because of the reduced interference, more users can be access the internet into a given area in the same region of spectrum, thus increasing the area spectral efficiency, or equivalently, the total number of active users per Hertz per unit area.

Femtocells are aimed at delivering best 3G coverage to a household and by doing so can provide a very good end-user experience within the home environment. As a result, the capacity of femto cells is upto 6 end users.

The potential of femtocells can be verified rapidly through Shannon's law, which relates the wireless link capacity (in bits per second) in a bandwidth The SINR is a functionof the desired transmission powers and interfering transmitters, path losses.

Path losses cause the transmitted signal to decays Ad-α, where A is the fixed loss, d is the distance between the transmitter and the receiver, and α is the path-loss exponent.

By increasing the capacity the reception is enhanced between intended transmitter and receiver pairs.

Penetration loses insulation of the femtocells from surrounding femtocell transmissions. Let us assume the fixed receiving power target having a path-loss propagation model (no fading), and denoting α (resp. β) as the outdoor (resp.indoor) path-loss exponent, overlaying an area of L2 with N femtocells resulting in a transmit power reduction of the order of

$$[10(\alpha-\beta)\log10\ L + 5\ \beta\ \log10\ N]\ dB$$

The capacity benefits of femtocells are attributed to:

1. Reduced distance between the femtocell and the user results to a higher received signal strength.
2. Lower transmit power, and reduction of unpleasantness of interference from neighboring macrocell and femtocell users because of outdoor propagation and penetration losses.
3. As femtocells serve only 1-4 users, they can give a larger portion of their resources (transmitting power &bandwidth) to each subscriber. A macrocell, on the other hand, has a large coverage area (500m-1 km radius), and a more number of users; providing Quality of Service (QoS) for data users is difficult.

Reduced subscriber turnover

Poor coverage causes customer dissatisfaction; hence they switch the operators, or maintain a separate wired line whenever indoors. Hence the femtocells provide enhanced home coverage which reduces the possibility of the user to switch their operators.

Improved macrocell reliability

The traffic originated is absorbed in the femto cell networks over the IP backbone.

Better reception to mobile users can be provided by the macrocell BS.

Cost Benefits

A femtocell deployment reduces the operating and is economical for operators. A typical urban macrocell costs upto$1K per month in site lease, and additional costs for electricity and backhaul. A recent study tells that the operating expenses are from $60K per year per macrocell to just $200 per year per femtocell.

There is significant competition for access solutions in the home space. Operators

Low-impact

Femtocells must be physically small, ideally pleasing and should be easy to position. Furthermore, they should also be silent in operation, generate low levels of heat output and is inexpensive to run.

Low RF power

The RF power output of femtocells is low; between10 and 100 milli-watts. Put in perspective, it has lower power level than number of Wi-Fi access points, which can be up to 1 Watt of output power. Additionally, close to the femtocell the 3G handset is able to transmit lower power levels than it might otherwise have to when on the macro network.

Energy offset - Low-power consumption

If the end-user has to pay bill for the electrical energy consumed by the femtocell base-station then the estimation cost must be low enough not to raise concerns as to its impact on the fuel bill.

Easy end-user installation

Similar to cable modems and DSL routers, femtocells will be installed by consumers and activated through service providers. Now, Operator no longer has to employ installation teams or have to send members whenever anew femtocell is "deployed". From the user perspective the unit must be as simple as "plug and play" installation with minimal amount of interventions required.

Backhaul via broadband
Femtocells uses Internet protocol (IP) and flat base-station architectures. Backhaul connection to Operator networks will be wired broadband Internet services existing in the homes such as DSL, cable, or fiber optics as available. No connections required to the broader cellular network other than through the IP core. It will benefit Operators by effectively removing traffic that would otherwise be on the macro-layers directly onto the internet from the femtocell.

Worldwide cellular network standards support
Many end-users appeal for Femtocell products around the world. As a result different model scan be developed and offered to satisfy the number of needs from the different regions. Products will support their respective and existing (3GPP) UMTS and (3GPP2) CDMA standards, and even emerging standards such as WiMAX, UMB and LTE.

Support for existing 3G handsets and devices
Support in existing handsets is a very important consideration for the end-user and Operator. In each technology, market femtocells will support existing handsets and devices of 3Gservices and femtocells in particular.
Due to numerous advantages, femtocells represent a tremendous market opportunity for telecommunication service providers and a great boost in the cellular network performance for consumers. Many operators have launched Femtocell service including Vodafone, AT&T, Sprint Nextel, Verizon and Mobile Tele Systems.

2.2. CONS- Femtocell de-merits
Femtocells is a complicated technology and number of issues and concerns re encountered.
Interference
Interference is main issue associated with femtocell development which have needed to be investigated and solutions.
The issue arises because femtocells will utilize the spectrum already allocated for cellular telecommunications. The femtocells will be deployed in what may be termed an ad-hoc fashion. As a result there is very real the possibility that interference will arise. This could cause problems like poor levels of performance due to which not only femtocell users, but other users who are communicating through the main cellular network. As a result a considerable amount of work has been done to ensure that femtocell interference issues do not a rise and should prevent their widespread deployment.
There are a number of methods that have been developed to ensure the easy minimization of interference so that femtocells can be installed by users without any technical problems.

Synchronization
Femtocell synchronization is an important part of their designing. Many aspects of their operation require reasonable levels of femtocell synchronization. 3GPP specifies that the base station frequencies are required to be very accurate, and there needs to be close synchronization with precise clock signals. Although Releasing 6 of the 3GPP standard relaxed the requirements for femtocell synchronization methods of providing sufficient femtocell synchronization is a challenge.

Quality of Service (QoS)
As femtocells serve around 1-4 users can devote a larger portion of their resources (transmitting power and bandwidth) to every subscriber instead macro cell has a larger coverage area (0.5 km -1 km radius), and a larger number of users; providing Quality of Service (QoS) to data users is more difficult.

Cell Association and Biasing
A key challenge in a heterogeneous network with a wide variety of cell sizes is to assign the users to appropriate base stations. However, simulations and field trials declared that approach does not increase the overall throughput as estimated, because many of the small cells.
Despite a potentially significant SINR hit for that mobile station, this is a win-win potential because the mobile gains access to much larger fraction of a small cell time and frequency slots.
An immediate challenge introduced by biasing includes the usage of overhead channels, which are typically common to all BSs in the time and frequency and so a biased user would not be able to even hear its channel assignments, for example. This can be solved by introducing time-slotting for the control of channels or interference cancellation.

Mobility and Soft Handover
Since the coverage area for an individual femtocell is small. In principle, femtocells acts as other base stations and can therefore use existing mobility procedures.
However, femtocell mobility have a number of unique challenges that require special attention. Standards bodies such as 3GPP have devoted considerable attention to the issues concerning mobility. Procedures are also being developed for vertical handovers between femto-cells and non-cellular access technologies such as WiFi.

Self-Organizing Networks
Femtocell networks are unique as they are largely installed by customers or private enterprises Moreover, as the number of femtocells are more in magnitude as compared to macro cells, manual network deployment and maintenance is simply not measurable in a cost effective manner for large femtocell deployment.
Femtocells must support plug-and play operation, with automatic configuration and network adaptation. Due to these features, femtocells are sometimes referred as a self-organizing network (SON). The 3GPP standard body has placed considerable attention on SON features. One aspect of SON that has attracted attention is automatic selection of channel, power adjustment and frequency assignment. Such problems are often formulated as mathematical optimization problems for which a number of algorithms are required.

3. CONCLUSION

Femtocells provide a one-box solution i.e. a small, low-cost, low power unit that can be installed for providing mobile 3G coverage to the home. Femtocells are not simple standalone devices. They must be installed into the mobile operator's network to enable seamless service. The architectures for the UMTS and CDMA solutions are defined by their respective standards bodies.

Both architectures enable a better experience, while ensuring security and scalable solutions for operators. Considering that the majority of ―mobile calls originate in the home and end-users prefer to use a single handset – their mobile, Operators now have focused solutions available to them that overcome the issues of poor in-building coverage. The next logical step for Femtocells in Future is to get your household devices to interact with one another.

In Future, Femtocell application could be to use them in aircrafts, trains. This type of femtocell deployment can use satellite as a backhaul. However, several challenges are yet to be solved. The Potential challenges to the deployment of Femtocells are the reliance on the consumer to support of backhaul capabilities and the possibility of interference caused by the close placement of multiple Femtocell devices.

Some other Problems faced are the security, femtocell spectrum and regulatory issues. Whether or not they live up to move the data avalanche to being a backhaul problem is as yet unclear.

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