Femtocells - Interference can be done away with

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Abstract- Femtocells are the new cells of technology of the modern day world. They are used to increase the network coverage of the system by decreasing the data path loss and increasing the connectivity of the system as a whole. They are easy to install and do not require much economic concerns such as land acquisition and installing a traditional base station.

The architecture of this technology is largely based on the UMTS architecture used these days. In most widely used terms, we can also say - on a 3G architecture, the functionality remains the same, only distributed among its components.

The working of femtocells is similar to that of the 3G network. However the main concern in the use of this technology is the interference issues that arise during the interfaces or intersections of the user devices and the power dissipated. The architecture used has to be a stable architecture ensuring scalability. Also the main areas of research in this field are centralized to interference management.

If the interference issue is curbed to a negligible amount, we can have a flawless implementation of technology with potentially high usage.

Index Terms- 3G, 4G, Access mode, Backhaul, CDMA, Cross-tier interference, Femtocells, Femtocell infrastructure, Frequency spectrum, GSM, GPRS, Handoff, HSPA, IMS/SIP protocol, Inter- ference, IP, Location registers, LTE, Mobility, Network coverage, OFDM, RadioLAN, RF frequency emission, RNC, RNS, SINR, UMTS, UTRAN, WiMax.

I. Introduction

The world is shrinking and people are getting closer to one another through the field of telecommunication. The latest innovation that is undergoing changes and evolving is wireless communication.

The traffic in wireless communication is on the high ever since 1980s as radioLANs were introduced. Technologies like bluetooth came into picture. The latest emerging technology is incorporation of femtocells.

Femtocells are like picocells although smaller in size. They are small wireless access points i.e. they connect to a wired network through routers and have data transfer done wirelessly using radio waves at a particular frequency in a specified range. They resemble a repeater as they strengthen signal.

Femtocells are incorporated at the user end and act as base stations. They require a broadband connection or a DSL cable for their working. They send data through the DSL cable over large distances.

The main reason why the concept of femtocells came into picture was because mobile or cellular 3G networks suffer from poor penetration and reception in certain areas. They decrease the quality of the data and slow down speed.

Disadvantages of the 3G networks:

- Poor coverage diminishing the quality.
- Smaller to support high data rates
- Proper infrastructure is needed.

These disadvantages of the 3G networks are then overcome by the installation and incorporation of femtocells at the user end.

The advantages of using a femtocell are:

- Indoor cellular coverage
- Low cost backhauling
- Handle more that 50 % voice calls and 70 % data traffic that arise indoor
- Electricity bill minimized
- Phone calls over wifi
- Incorporate cellular, wifi, DSL in the same box to reduce manufacturing effort.
- Offer better speed and data rate
- Reduce macro base stations to cover an area.

Having so many advantages over 3G networks and an easy implementation gives us a wide range of usage. Thus we can now classify the femtocells according to their deployment and usage patterns[1].

A. Classification of Femtocells

Femtocells can be classified based on the range it gives and the no of simultaneous channels it can support.

Characteristic	Class 1	Class 2	Class 3
Power radiated	>20mW	250mW	>250mW
No of simultaneous voice channels / cell	4/5	16	32
Range	Small	Longer that class 1 lesser than class 3	Longer than class 1 and 2
Access mode		Closed and open	Open
Also called		High power cells	Metrocells
Use	Residential and small enterprises		Buildings, distributed and rural ares

Table 1: Classification based on characteristics.

The applications of femtocells among many more include:

- Forming a sync with all the appliances
- Data sharing that is common to all
- Secure home access

Applications can be classified based on the range given by the femtocells. In the following sections of the article, we will discuss more about femtocells starting from the various standards available to which of these could be incorporated into its infrastructure. We will also list down the working operation of the technology.

Lastly, the main reason of concern of interference management, which is a part of other technical challenges, will be touched with insights on the solutions possible for this problem.

II. STANDARDS FOR FEMTOCELLS

The various standards of femtocells are responsible for providing efficient and consistent architecture for blending over it. The main issues that are supposed to be looked into by them include interference management, authentication, performing handoffs and maintaining the protocols among its layers in the network[2][3].

A. UMTS

It has a similar architecture based on CDMA. They offer higher magnitude then GSM technology. However their performance is dependant on power. There is a near far effect wherein transmission and reception depend on the placement femtocells in the area.

This cannot be used in femtocells because it needs centralized power[1]. There are two possible solutions to this problem:

1) *Open access mode:* Each UE connects to strongest available base station leading to less interference and low power.
2) *Closed access mode:* Use 3G cellular network.

Here open access and close access modes of femtocells are nothing but facilities given. In open access, any unregistered user can access it and use its spectrum. However, that is not the same in the other case where prior authentication is required. There is a high security here. It is also known as 3G. (GSM + CDMA)[3].

B. LTE

Long term evolution (LTE) is also GSM+CDMA. However it is 4G and has high data rate. There is orthogonal frequency division multiplexing (OFDM) meaning there is data modulation over channels that is split over different ranges of frequencies. There is dynamically allotted time and frequency slots[1].

C. GSM

They are the most widely used and called picocells because femtocells can self configure themselves[3].

D. HSPA

High speed packet access (HSPA) is improved version of UMTS with increased radio transmission. [3] It improves performance of existing 3G networks.

It is an amalgamation of mobile protocols mainly HSUPA and HSDPA (uplink and downlink).

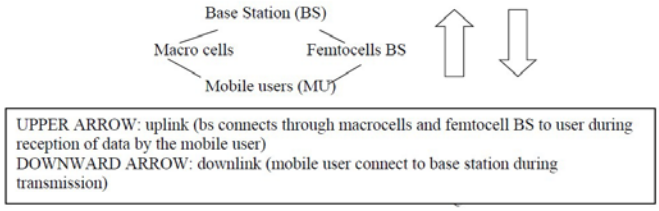

Figure 1: Uplink and downlink decription

E. WiMAX

Worldwide interoperability for microwave access (WiMAX) is used for high-speed data transfer. It also uses OFDM and competes with LTE[3].

III. ARCHITECTURE OF FEMTOCELLS

We can understand this in two parts:

1) UMTS Infrastructure
2) FemtocellInfrastrucure

The UMTS is the general available infrastructure that can be used and this is blended and changes are made to use femtocells. UMTS acts like an abstract.

A. UMTS Infrastructure (3G)

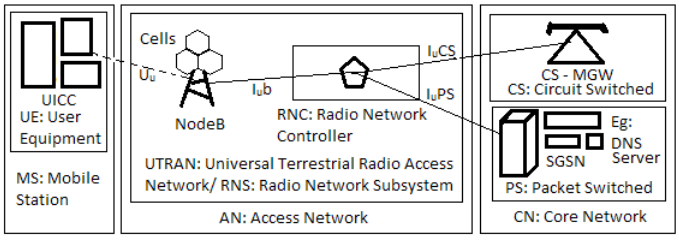

Figure 2: UMTS architecture

It is similar to a GSM. The network is divided into three parts:

1) MS (Mobile station)
2) AN (Access Network)
3) CN (Core network)
   a) Circuit switched (CS)
   b) Packet switched (PS)

1) MS (Mobile Station):

It is an end user device i.e mobile phone (user equipment UE). The US should have a unique USIM and a SIM for its identification.

2) The AN (Access Network):

It includes the antennas(NodeB NB i.e. Base station (BS)) for transmission and reception and a RNC that

controls NB. These two make a connection between AN and the CN as shown in the figure. The combination of RNCs and NBs form the RNS.

Iub is the interface between the base stations. The UTRAN functions include:

- Congestion control
- Encryption and decryption
- Code allocation
- Handover control
- Management

3) CN (Core Network):

It routes the traffic (data packets Voice or SMS etc). There are a lot of elements located in the CN and have a particular task associated with them viz Home Location Register (HLR) which is responsible for user identity , authentication. There is Visitor Location Reg- ister (VLRs) that hold the current location of the user (specific location).

IuCS and IuPS are the interfaces used.

a) Circuit switched (CS):

It is a landline network or PSTN. It routes voice and SMS traffic. Here one user conncets to the other, there is no nulticasting or broadcasting sometimes. So a predefined circuit is booked and the entire transfer is done. Not a lot of load is there so it is applicable.

b) Packet switched (PS):

It is mainly for data traffic (internet). It has a lot of load and multiple simultaneous users can access at the same time. So the best way is to implement it using PS with the best possible route available.

B. Femtocell infrastructure

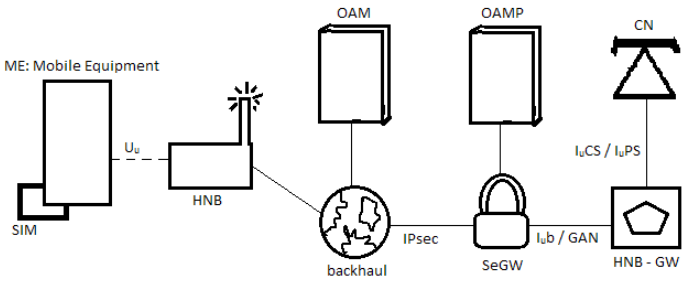

Figure 3: Femtocell infrastructure

The main elements of the infrastructure:

1) HNB (Home NodeB)
2) SeGW (Security Gateway)
3) HNB-GW
4) HMS

1) HNB (Home NodeB):

Femtocell are Base stations (wireless). They are deplyed at home or in home environments therefore are called Home NodeB (HNB). It is a small access point that connects the MS to the CN through RNS. It provides all the functionalities of BS viz Signalling, Radio resource management, IP transportfunctions, QOS management functions, NAT (Network Address Translator), security functions and auto configuration.

2) SeGW (security gateway):

The IPsec traffic (data) is encrypted and goes into CN via SeGW. Accordingly, it mutually authenticates HNB first and eshtablishes further security tunnels. Then sends signals and call related data to the CN. The interface between them is said to be secure.

3) HNB GW:

The Home NodeB sub system is equivalent to RNS in a femtocell.The HNB GW is the communication endpoint for mobile signal orignating HNB (including mobile data traffic).

UMTS Network	Femtocell Network
NBs are controlled by the RNC	HNBs are controlled by the HNB-GWs

Table 2: Analogous terms in UMTS and Femtocell architecture

The HNB is connected with the HNB GW using the Generic Access Network (GAN) protocol (maps 3GPP layer messages from MS and CN to TCP/IP connection i.e user nome broadband connection). The GAN is used for signalling , control telecommunication network and to manage the network. It provides additional function- alities viz Network timing delivery and synchronisation, IP security functions, HNB traffic aggregation, routing and auto configuration functions.

4) HMS:

The HNS includes HMS Management System (HMS) to manage the femtocell. It consists of services monitoring the devices for location verification so that the HNB can connect to Se GW.

Here we can also say that RAN are a part of the UTRAN network. [Many RNCs together form the RNS and they are coupled together to form the RAN which co ordinates with the core network.

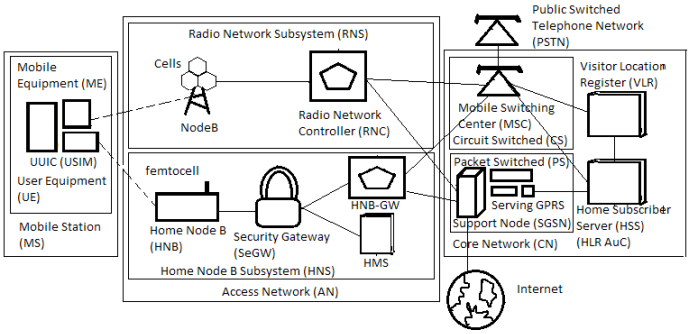

Figure 4: It gives us a simplified version of the architecture of femtocell obtained when blended on the UMTS (3G) architecture.

IV. OPERATION OF FEMTOCELLS

Here we firstly require a broadband connection. This is because it gets a unique IP and backhaul however decreases the pressure on the core network. The femtocell is a secure network because there is encryption and decryption of the data by the femto gateway. Connection between femtocell and its gateway cannot be intercepted due to presence of IPSec. [3]

Here using interfaces there us a connection with the interfaces. The Iu-h connects the home node to the gateway that does the functions mentioned above.

It is same as the security gateway.

The Iu interface (main interface) is used for connection among the core network and its components.

The changes made in Iu give rise to a new interface Iu-b for connection with the base stations.

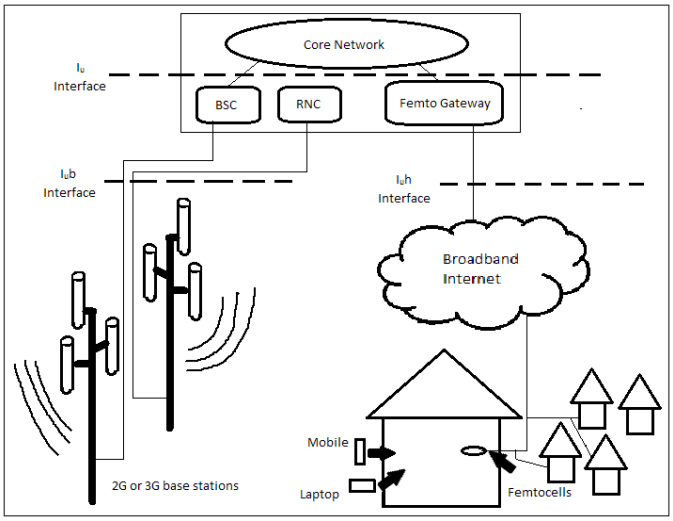

Figure 5: Working of the femtocell

I. TECHNICAL CHALLENGES

There only main difficulties in the femtocell technology are the technical challenges that are faced by it. These could be due to the broadband or the voice packets. They can also be a part of the network infrastructure.

1) Broadband Femtocells
   a) Resource allocation
   b) Timing and synchronization
   c) Backhaul
2) Voice Femtocells
   a) Interference management
   b) Access to femtocells
   c) Handoffs
   d) Mobility
3) Network infrastructure:

The broadband and voice femtocells are present in the physical and MAC layer of the network.

A. Broadband Femtocells

Femtocells need sync to avoid multiple access to network decreasing the interference created. There has to be intra cell orthogonality among macrocell users and mitigate inter cell interference due to fractional frequency reuse[4]. This means that among macrocells there has to be transparency and the interference has to be dissipated so as to lower power levels by frequency division multiplexing. The random location of femtocell will render centralized frequency planning difficult.

B. Voice Femtocells

These mainly concern with the interference issues and its management.

Here we have options to either eliminate cross tier in- terference in same bandwidth. When femtocells are added they create dead zones. This is non-uniform coverage causes interference.

Ideal working of voice(IP) femtocells include:

1) Open mode and closed mode
2) Handoff (Handover)
3) Mobility
4) Self organizing network

1) Open and closed mode:

In this, if we have an open mode femtocell, it is easier for a user to configure itself to the nearest available network instead of the base station when outside, thus decreasing the burden on the core network.

2) Handoff:

Handoff or handover means if there is a shift of network when the user goes out of range. This could be either from macrocell to femtocell or the other way.

3) Mobility:

This depends on handoff. When the user moves in or out of range of the network it should very softly be handed off to the next strongest available network.

It should happen without any loss of data or breakage in the signal.

4) Self configuring networks

These networks should be easy to install and use as the user purchases it implements it. It should not have to wait for a technical person. Also in an open mode, other users must be able to use them.

C. Network infrastructure

This handles the security bridging or connection between interfaces of the network. The main protocol available is the IMS/SIP here. These are the two protocols that are available in the core network. These are a part of the GPRS or the GSM architecture. They provide the core network. They convert subscriber package into IP packet and employ VoIP through SIP that co exists in the macrocell.

The main advantage is that there can be scalability and standardization, which is why we use UMTS architecture widely.

V. INTERFERENCE MANAGEMENT

This is the main concern of the femtocell technology. If this issue is minimized, we will have an efficient and consistent use of technology. Interferenece happens because femtocells and macrocells operate on the same frequency spectrum[3]. Also, femtocells are installed in an ad hoc manner without taking into account topology.

Interference Depends largely on power radiated or intercepted.

This section for basic understanding can be divided into two parts:

1) Types of interference
2) Reason for occurrence
3) Solution

A. Types of interference

1) Femtocells interfering with base stations on the same frequency.
2) Base stations interfering with femtocells on the same frequency
3) Femtocells interfering with each other
4) Cell phone signal received by both femtocell and macro- cell because the macrocell signal is strong.

The most logically possible solution to this problem might be to use a 3G architecture (UMTS) because it gives us 2 separate licensed frequencies to use. So interference might be decreased. However if we have femtocells operating in one frequency band and macrocells in the other, there are chances of interferences between two femtocells. This problem could be overcome by sharing of spectrum using time and frequency hopping techniques (multiplexing).

Alternative solutions could be to increase the capacity of the femtocell network so that it can accommodate a larger data frequency.

B. Reason for occurrence

The main reason for interference is its direct association to the power levels sent during transmission and received during reception. However we can mathematically look at the problem and device a solution by readjusting the parameters that affect it.

The capacity potential of femtocells is verified by Shannons Law that gives SINR (Signal to interference plus noise ratio), which is a function of transmission power and path loss[4].

Here Path loss is given by

$Ad-\alpha$ (1)

where A=fixed loss,

D= distance between transmitter and receiver and

α=path loss exponont

Thus, by decreasing the distance between the transmitter and receiver capacity can be increased. Also power transmitted can be reduced by

$10(\alpha - \beta)logL + 5\beta logN$ (2)

Here

L=area covered,

N=No of femtocells in that area.

α, β =path loss components (indoor and outdoor resp).

C. Solutions

The other possible solutions to this problem could be [4]:

1) Frequency and time hopping:

This is use of multiplexing techniques to send data over the network.

2) Use of directional antennas and multiple antennas: Femtocell can avoid radio interference within antenna sector. Antennas associate to spatial use of the channel.
3) Adaptive power control:

Depending on the location of the femtocell, receive power vary. Using the automatic adaptive protocol it adjusts the transmit power. Increasing the distance from the macro base station reduces this power.

4) Mobile phone uplink power capping:

This places a limit on max power output. There is handover without increase in transmission power[3].

II. CONCLUSION

The femtocell technology has the potential to improvise itself and emerge a flawless and efficient technology with minimized cons. Femtocells have helped put off data traffic burden from the macrocell base station network. All the functionalities: cellular as well as data are handled efficiently well.

The only main concern is the interference problem. Using a UMTS architecture that offers two separate frequency bands, use of multiplexing and an automatic power transmission control protocol for automatic adjustment of power, can solve this problem.

Keeping the radiated power in limits avoids interference. We know that the UMTS infrastructure cannot be dependable because there is a near far effect that can be seen during dissipation of power.

But we still prefer using a UMTS architecture because it can handle scalabilty issues very well and in its operation we know that it offers two separate frequency spectrum. Femtocells are installed in an ad hoc manner and that is why scalabilty is an important feature that cannot be negotiable.

Keeping in mind various issues, the only important solution to the other problem is implementation of an adaptive power control protocol. This will help decrease the interference as signal strength does not reach neighboring femtocell antennas. Proper utilization of resources will help curb interference.

VI. SUGGESTIONS AND FUTURE SCOPE

The future scope of this technology is wide region of connectivity covered to every nook and corner of the world. the only logical next step will be to implement a more stable network like 2G that offers data speed and connectivity like the 3G. These are termed as 4G networks.

What I think should be the logical step is to use 3G networks because it gives us two licensed frequency spectrum and that we can use adaptive power control techniques along with frequency division multiplexing to avoid interference between two femtocells.

Another concern that isn't discussed, however as the rate of RF frequency emission. If we decrease power, RF frequency emission decreases leading to less damage at heath because femtocells are always in our range.

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