Femtocells Technology

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ABSTRACT
Femtocell technology little-known outside the wireless world, which provides a better indoor cellular service. In telecommunication, a Femtocell is a small cellular base station, typically designed for use in a home or small business.[6] It connects to the service provider's network via broadband. Current designs typically support 2 to 4 active mobile phones in a residential setting, and 8 to 16 active mobile phones in enterprise settings. A Femtocell allows service providers to extend service coverage indoors, especially where access would otherwise be limited or unavailable. For a mobile operator, the attractions of a Femtocell are improvements to both coverage and capacity, especially indoors. This can reduce both capital expenditure and operating expense.A Femtocell is typically the size of a residential gateway or smaller, and connects into the end-user's broadband line. Once plugged in, the Femtocell connects to the MNO's mobile network, and provides extra coverage in a range of typically 30 to 50 meters for residential Femtocells. The end-user must declare which mobile phone numbers are allowed to connect to his/her Femtocell, usually via a web interface provided by the MNO. When these mobile phones arrive under coverage of the Femtocell, they switch over from the Macrocell to the Femtocell automatically. Most MNOs provide means for the end-user to know this has happened, for example by having a different network name appear on the mobile phone. All communications will then automatically go through the Femtocell. When the end-user leaves the Femtocell coverage, his phone hands over seamlessly to the macro network. [1]

Keywords
Femtocell, UMTS,WiMAX, Revised System architecture.

1. INTRODUCTION
Femtocells are sold by a Mobile Network Operator (MNO) to its residential or enterprise customers. A femtocell is typically the size of a residential gateway or smaller, and connects to the user's broadband line. Integrated femtocells (which include both a DSL router and femtocell) also exist. Once plugged in, the femtocell connects to the MNO's mobile network, and provides extra coverage. From a user's perspective, it is plug and play, there is no specific installation or technical knowledge required anyone can install a femtocell at home.In most cases the user must then declare which mobile phone numbers are allowed to connect to his/her femtocell, usually via a web interface provided by the MNO.This only needs to be done once. When these mobile phones arrive under coverage of the femtocell, they switch over from the macrocell (outdoor) to the femtocell automatically. Most MNOs provide a way for the user to know this has happened, for example by having a different network name appear on the mobile phone. All communications will then automatically go through the femtocell. When the user leaves the femtocell coverage area, his phone hands over seamlessly to the macro network. Femtocells require specific hardware, so existing WiFi or DSL routers cannot be upgraded to a femtocell.[4] Once installed in a specific location, most femtocells have protection mechanisms so that a location change will be reported to the MNO. Whether the MNO allows femtocells to operate in a different location depends on the MNO's policy. International location change of a femtocell is not permitted because the femtocell transmits licensed frequencies which belong to different network operators in different countries.[5]

2. WORKING OF FEMTOCELLS

In femtocells the main focussed is on the 3G UMTS standard, which evolved from 2G GSM. However, other mobile radio technologies are also adopting femtocells.The femtocell appears to the standard 3G phone as just another cellsite from the host mobile operator, and can be used by almost any 3G phone including roamers visiting from other countries.The mobile operators telephone switch (MSC) and data switch (SGSN) also communicate to 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 controller uses secure IP encryption (IPsec), which avoids interception and there is also authentication of the femtocell itself to ensure it is a valid access point.The figure below illustrates the system architecture and context for femtocell operation. Inside the femtocell are the complete workings of a mobile phone basestation. Additional functions are also included such as some of the RNC (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 operators switching centres.

The key functions are integrated onto a single chip, such as the PC302 from picoChip or the PRC6500 from Percello. These and other chip manufacturers document the different components in more detail in their reference designs. In addition to these highly integrated chips, a radio frontend (such as from Bitwave) and a highly accurate frequency reference crystal oscillator are also required.

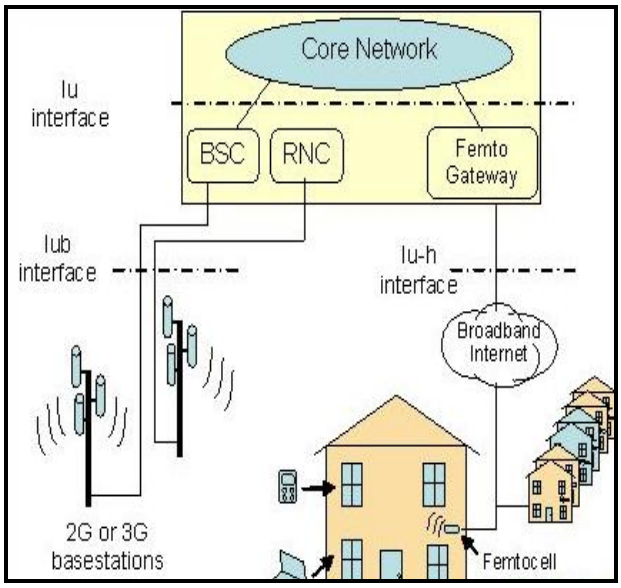

Fig 1 : System architecture and context for femtocell operation[2]

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. This is a continuous process to adapt to changing radio conditions, for example if the french windows are opened in a room containing the femtocell. Within the operators network, femtocell gateways aggregate large numbers of femtocell connections (typically 100,000 to 300,000) which are first securely connected through high capacity IP security firewalls.Femtocells can enable new services because they have seven *unique traits* that set them apart from all the other devices in the home in terms of service delivery. [2]They are:

- Trait 1. Mobile/Home Network Bridging
- Trait 2. Presence
- Trait 3. Universal Anchor to Home Network
- Trait 4. Managed Service Delivery Platform
- Trait 5. Local Traffic Injection Point
- Trait 6. Transparent Mobile Broadband
- Trait 7. Social Networking Tool

3. STANDARDISED ARCHITECTURES

The standards bodies have published formal specifications for femtocells for the most popular technologies, namely WCDMA, CDMA2000, LTE and WiMAX. [3]These all broadly conform to an architecture with three major elements:

1. The femtocell access points themselves, which embody greater network functionality than found in macrocell basestations, such as the radio resource control functions. This allows much greater autonomy within the femtocell, enabling self-configuration and self-optimisation. Femtocells are connected using broadband IP, such as DSL or cable modems, to the network operator's core switching centres.
2. The femtocell gateway, comprising a security gateway that terminates large numbers of encrypted IP data connections from hundreds of thousands of femtocells, and a signalling gateway which aggregates and validates the signalling traffic, authenticates each femtocell and interfaces with the mobile network core switches using standard protocols, such as Iu.
3. The management and operational system which allows software updates and diagnostic checks to be administered. These typically use the same TR.069 management protocol published by the Broadband Forum and also used for administration of residential modems.

The key interface in these architectures is that between the femtocell access points and the femtocell gateway. Standardisation enables a wider choice of femtocell products to be used with any gateway, increasing competitive pressure and driving costs down. For the common WCDMA femtocells, this is defined as the Iuh interface. In the Iuh architecture, the femtocell gateway sits between the femtocell and the core network and performs the necessary translations to ensure the femtocells appear as a radio network controller to existing MSC's. Each femtocell talks to the femtocell gateway and femtocell gateways talk to the CNE. This model was proposed by 3GPP and the Femto Forum.New protocols (HNBAP and RUA) have been derived; HNBAP is used for the control signaling between the HNB and HNB-GW while RUA is a lightweight mechanism to replace the SCCP and M3UA protocols in the RNC; its primary function is transparent transfer of RANAP messages.The CDMA2000 standard released in March 2010 differs slightly by adopting the SIP protocol to set up a connection between the femtocell and a femtocell convergence server (FCS). Voice calls are routed through the FCS which emulates a Mobile Switching Centre (MSC). SIP is not required or used by the mobile device itself. In the SIP architecture, the femtocell connects to a core network of the mobile operator that is based on the SIP/IMS architecture. This is achieved by having the femtocells behave toward the SIP/IMS network like a SIP/IMS client by converting the circuit-switched 3G signaling to SIP/IMS signaling, and by transporting the voice traffic over RTP as defined in the IETF standards.[3]

3.1 Femtozone Service Components

The figure below illustrates the Femtozone Service Components.

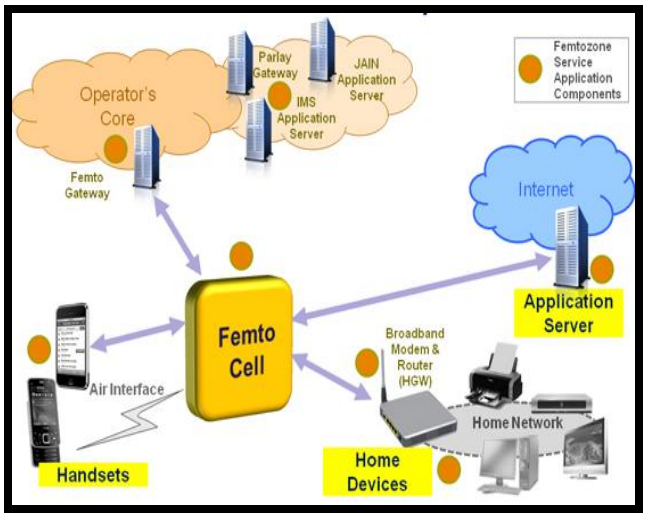

Fig 2 : Femtozone Service Components[7]

Since the femtocell is at the convergence point of the mobile operator's network, the home network, and the Internet, femtozone services may take a wide variety of forms, involving several *components*. The comprehensive reference architecture in the figure above shows all the components that may be involved in delivering a femtozone service. Of course, specific femtozone applications may only need a subset of these components, depending on their required functionality.The comprehensive reference architecture may be rationalized in simpler terms by identifying four possible femtozone service application components (again, a specific service application may only use a subset of the four components). Each service component runs on a corresponding femtozone service node.

- Mobile device Application Component, running on the Mobile device;
- Femtocell Application Component, running on the Femtocell;
- Home Device Application Component, running on one or more Home Device attached to the Femtocell via the home network; and
- Network Application Component(s), running on a variety of Application Server(s) in the operator's network or in the Internet.[7]

3.2 Femtozone Service Library

The femtozone service ecosystem is still at a nascent stage. However, several examples of femtozone applications are already available in various forms. A few of these services are starting to be commercially deployed.In the following, we provide short summaries and links to some of the basic femtozone service examples, to give an idea of the type of services enabled by the femtocell.[6]

- **Family Alert Service:** When a family member arrives home or leaves, the femtocell automatically sends an SMS message. For example, a parent at work can be notified that their child has arrived home from school.
- **Virtual Home Number:** A "home" phone number that rings on all the handsets at home when a call comes in to that number.
- **Media Synchronization:** Ability to synchronize music tracks and video clips automatically between a mobile handset and a home PC.
- **Photo Upload:** Ability to upload photos automatically from the handset to a home PC when handset arrives home and display the photos to a digital picture frame.
- **Contact/Calendar Synchronization:** Ability to synchronize handset calendar/contacts with home personal and family calendars/contacts every time the handset arrives home.
- **Remote Control:** Ability of the mobile phone to function as a remote control for home devices (DVR, DVD, TV) when it is in the home.
- **Mobile Video:** Ability to stream videos from DVR/DVD player directly to your mobile phone.
- **Family Tablet:** Ability to enable a group of family communication features on an in-home display to show the geographic locations of household members, display household calendar and reminder messages, access voicemail and text messages, and store and display pictures from the mobile phone.
- **Point-of-Sale promotion:** Femtocells in retail spaces allow merchants to detect customers' presence and provide welcome messages, coupons, and store directory services.
- **Virtual PBX:** In an office setting, the femtocell combined with IP-PBX software on the corporate network can make mobile phones into virtual extensions on the office phone system.[6]

4. AIR INTERFACES

Although much of the commercial focus seems to have been on UMTS, the concept is equally applicable to all air-interfaces. Indeed, the first commercial deployment was the cdma2000 Airave in 2007.Femtocells are also under development or commercially available for GSM, TD-SCDMA, WiMAX and LTE.The H(e)NB functionality and interfaces are basically the same as for regular HSPA or LTE base stations except few additional functions. The differences mostly to support

differences in access control to support closed access for residential deployment or open access for enterprise deployment, as well as handover functionality for active subscribers and cell selection procedures for idle subscribers. For LTE additional functionality was added in 3GPP Release 9 which is summarized in.[5]

5. RADIO TECHNOLOGIES USED FOR FEMTOCELLS

The most commonly used implementation of the femtocell, makes use of the 3G UMTSstandard[8]. However, other radio technologies are also being tested with femtocells and could besuccessfully launched in the near future. The most commonly used radio technologies[8] are as below:

5.1 GSM

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.

5.2UMTS [10]

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.

5.3High Speed Packet Access (HSPA)

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.

5.4Code Division Multiple Access (CDMA)

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.

5.5Long Term Evolution (LTE)

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.

5.6WiMAX [3]

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.

6. BENEFITS OF FEMTOCELLS

6. 1 Femtocell Benefits for the Cable Operator

Femtocells enable operators to provide higher-quality and higher-performance wireless voice and real-time data services to their residential and small home office customers. They will be able to offer subscribers high-quality 3G services at lower costs while they are in their homes. In addition, they enable a lower cost of delivery of wireless traffic in comparison to the macro cell network. Femtocells can be used as part of integrated triple or quad play services, which meet consumer communication needs and increase the operator's competitiveness and ability to retain customers. The integration of broadband and femtocell technologies will allow broadband operators to fend off attacks from competing carriers, create longer-lasting relationships with subscribers, and drive new revenue growth by offering attractive seamless mobility services. Femtocells have an important role to play in driving premium mobile service adoption, finally turning the 3G service vision into a reality by encouraging a culture of usage through low-cost, high-performance mobile data services.

6.2 Femtocell Benefits to the Customer

For consumers, the benefits of femtocells include:

- A seamless communication experience as customers roam from inside to outside their homes.
- Greater convenience via effective fixed-mobile substitution that eliminates the need for separate homephones, offering consumers the flexibility of a single phone for access on the road or at home.
- Reduced in-home call charges.
- Excellent indoor coverage.
- Lower-cost voice calls from within the home.
- Consolidated billing for voice and data services.
- The convenience of using a mobile handset with its personal phonebook and other cool handset features,without the concerns of poor call quality or additional cost.

7. 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[8] 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 (UMA).[9]

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