



Femtocells – Benefits, Challenges and Deployment Scenarios

Introduction

Traditionally, cellular networks have been designed to provide mobile voice and relatively low bandwidth data services over wide areas, using 2G and 3G outdoor base stations. However, over time, we have learned that large cell deployments serving hundreds of users, all vying for contention of the available network resources, no longer satisfies our requirements for a modern day mobile communications infrastructure:

- It is a well known fact that some 40 to 50 percent of mobile voice and data traffic is now originating from inside buildings and this figure is growing rapidly. Due to signal attenuation through walls, building height and other factors, the 'outside-in' coverage from the outdoor macro network may be poor and unpredictable, rendering the user experience below expectations.
- The emergence of smart phones and tablet PCs, running bandwidth intensive applications such as video streaming, interactive gaming, and mobile TV, represent a massive upsurge in the amounts of data being demanded by the end users. For multiple end users within one large cell the total demand for data may exceed the capacity of that cell.
- The advent of 3G-LTE introduces major increases in capacity and performance which will only serve to exacerbate the in-building and capacity issues highlighted above. High data rates mean greater modulation / symbol rates, and these signals do not travel through walls without considerable disruption.

The solution to these problems is to deploy an in-building wireless system, but which one? The in-building solutions available to us may be classified into two groups, Distributed Antenna Systems (DAS), and Distributed Radios: picocells, femtocells and Wi-Fi access points.

Within Cellular Asset Management we have many years' experience in the design and implementation of in-building wireless systems, including active and passive DAS, Low Power GSM Picocells, and Wi-Fi networks.

The femtocell ecosystem is one of the more recent and potentially disruptive in-building wireless initiatives, comprising one or more small UMTS base stations that can be deployed in homes or small businesses to enhance in-building cellular coverage where the macro signal is insufficient, or, to provide localised capacity for data hungry consumers.

This document presents a high level description of the femtocell from its beginnings as a UMTS base station, through standardisation and widespread adoption, to an LTE femtocell and beyond. Could it be that this disruptive technology could have the potential to change the way we roll out cellular networks?

What is a Femtocell?

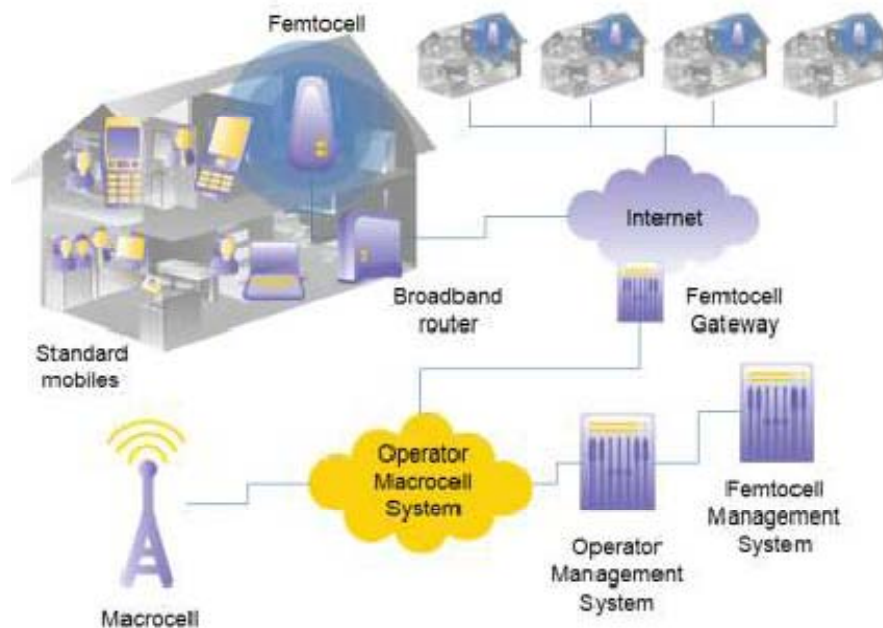
A femtocell is a small 3G base station, designed to be deployed within home or small business premises to provide enhanced coverage for in-building cellular services. The superior coverage and capacity made available by using the 'small cell' approach within the building ensures a better user experience than can be achieved using outdoor macro cells. The enhanced data rates enable new multimedia services which in turn generate new revenue.

The femtocell is designed to be installed by the subscriber, with no technical knowledge, i.e. it is a 'plug and play' device. The femtocell uses the consumers' broadband network (DSL or Cable Modem) to backhaul data to the mobile operators' core network.

The femtocell developed from the idea of a 'small UMTS base station' conceived by engineers at Motorola in 2002. During the next few years the idea was taken up by various interested parties, but commercial development was slow due to the lack of a standard. In 2007 The Femto Forum was formed, to promote Femtocell technology and to promote the creation of an open standard.

In 2009 a three way collaboration comprising the Femto Forum, 3GPP and the Broadband Forum announced a Femtocell standard, published by 3GPP. The standard covered four main areas; network architecture, radio and interference aspects, Femtocell management/provisioning and security. The standard was part of 3GPP Release 8 and paved the way for interoperability of Femtocell equipment and the subsequent economies of scale.

The femtocell network architecture is shown in the following picture from the Femto Forum:



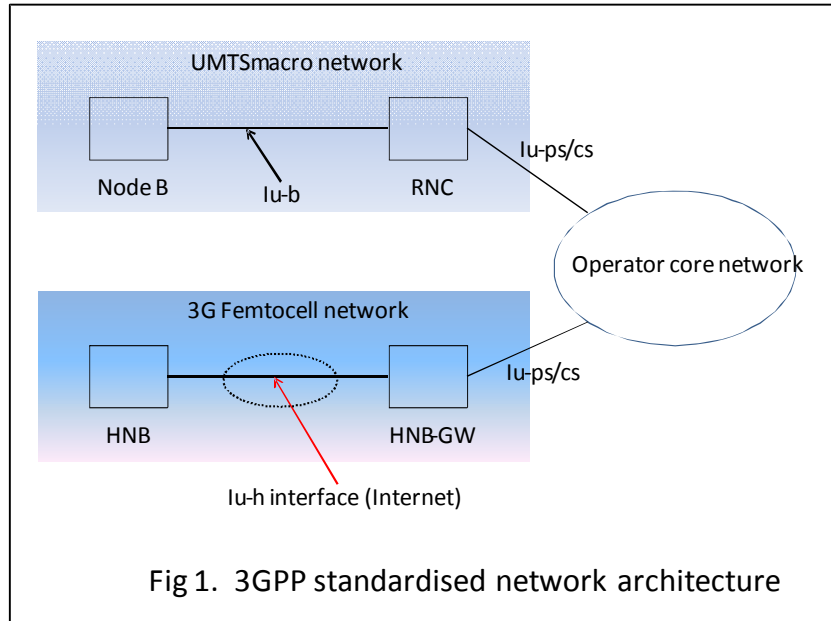
Generic Femto Network Architecture
(Courtesy of the Femto Forum, www.femtoforum.org)

Note: There are two parallel naming conventions used in femtocell documentation. When 3GPP standardised the 'femtocell' architecture, they coined their own names as follows:

- **HomeNodeB (HNB)** is the 3GPP name for a Femtocell
- **Home Node B Gateway (HNB-GW)** is the 3GPP name for a Femtocell gateway

These terms may be used interchangeably throughout this document.

The femtocell network architecture describes three main elements: The Home Node B (HNB) communicates with the Home Node B Gateway (HNB-GW), over the consumer's broadband Internet link, via the Iuh interface as described in the schematic below:



The Home NodeB Gateway (HNB-GW) serves the purpose of an RNC presenting itself to the operator core network as a concentrator of Home NodeB (HNB) connections. Each HNB serves one cell and there is a one-to-many relationship between HNB-GW and HNB's.

Further detail on the femtocell architecture is beyond the scope of this document but CAM is able to provide further information if required.

Challenges in Deploying Femtocells

There are many challenges in deploying a disruptive technology such as femtocells into a pre-existing cellular infrastructure. Interference between femtocells and the macro network; interference between femtocells; restricted access to users (closed user groups); interoperability of femtocells with existing handsets.....

Many of these challenges have been overcome, after all the femtocell ecosystem is up and running; however, a couple of these challenges are still the subject of some scrutiny and are worth expanding upon. They are: backhauling critical voice and data services over a contention based broadband network and the self organising capabilities of a 'plug and play' femtocell.

Backhaul over Broadband Networks

Cellular operators have developed the means to manage radio quality and, coupled with the fact that they have access to all points in the subscriber portion of the network, they therefore have the ability to monitor and address voice quality concerns directly. However, in a Femtocell environment cellular operators do not necessarily have access to the broadband connection to the home. To the operator, the broadband connection is an unmanaged link (www.epitiro.com).

Whereas a momentary interruption in a web browsing session would not cause too much consternation, a user will be quick to complain about delays on their phone conversation. It is the nature of broadband that there is a great deal of variance in connection quality from home to home (www.epitiro.com).

There are significant compromises made by ADSL providers in terms of the contention ratios that they employ that would have an adverse impact on the Quality of Service experienced by the end user, which, coupled with factors such as; available bandwidth, ISP traffic management policies, and network load by time of day, may see voice quality deteriorate or result in dropped calls.

If there is any deterioration in voice quality, the user will (quite rightly) blame the mobile operator.

There does not appear to be any mechanism in place whereby the mobile operators can 'close the gap' with the broadband suppliers in terms of SLAs with respect to quality of voice calls.

Self Organising Capabilities

One of the key factors of a femtocell is that it is designed to be purchased and installed by a consumer who has no technical knowledge; it has to be 'plug and play'. This unplanned deployment places significant challenges on the femtocell, in that it must have sufficient intelligence built in to configure itself to the radio environment upon installation, to adapt to any changes in the environment during day-to-day operation, and to adjust to any fault conditions that may occur during operation.

A femtocell must have significant self configuration, self optimisation and fault identification/rectification capabilities to allow zero touch installation and operation. These Self Organising algorithms have been developed and are included in the femtocell software architecture. Self Organising Networks (SON) are currently the subject of research and standardisation within 3GPP.

Note: By contrast to a femtocell, a picocell is a small cellular base station, typically 2G (Low Power GSM), which is installed, owned, and maintained by the operator. Picocells may typically support upwards of 100s of users at a time compared with femtocells which will support 4 – 8 users in a residential configuration and 8 – 32 users in an office type installation. The range of a picocell is ca. 200m or less compared with 10m for a normal femtocell.

Advantages of Femtocells

Some of the advantages have been highlighted earlier in this document; a more complete list may include:

- Assured in-building cellular coverage and higher data rates
- User benefit from better in-building user experience (operator benefit from reduced churn)
- Low cost backhaul over subscribers' broadband network
- Opportunity for new revenue streams
- Low power consumption in mobile device
- Localised services (a dedicated home subnet based around the femtocell)
- Traffic offload from macro network: offload from radio access network to femtocell and offload backhaul to subscriber's broadband connection
- Ability for the operator to place the coverage/capacity exactly where the demand exists i.e. where the revenue is greatest
- Opportunity for LIPA and SIPTO

LTE Femtocells

Ever since the inception of 3G-LTE, with its major increases in capacity and performance, there has been much ado about the role that Femtocells might play in the rollout of this new cellular technology. In this section we take a quick look at the proposals for the LTE femtocell architecture and then consider the deployment scenarios that are open to us, to provide a more efficient, more cost effective and less risky network rollout program than we saw for 3G networks.

LTE Femtocell Architecture

LTE Femtocells are supported within 3GPP as early as Release 8 (2008), and are identified as Home eNodeB's (HeNB). However, unlike the 3G Femtocell, there is currently no defined architectural standard in place.

Fig 3 shows 2 options for LTE Femtocell deployment.

- Option 1 has the HeNB directly interfacing with the MME / Serving GW in the LTE Evolved Packet Core.
- Option 2 has the HeNB interfacing through a HeNB-Gateway as in the 3G Femtocell standard.

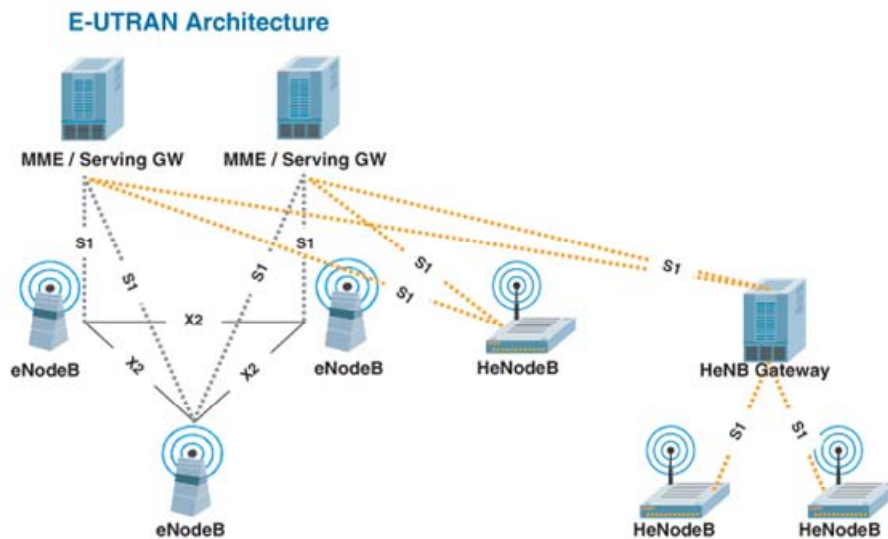


Fig 3: E-UTRAN architecture with Home eNodeB connectivity options
www.continuouscomputing.com

Questions remain open as to the interfaces and protocols to be used for LTE Femtocells, including the methods of self configuration, optimization and fault resolution (SON). Some of the mechanisms developed for 3G Femtocells will no doubt be adapted and re-used for LTE Femtocells.

"The development of the LTE Femtocell standards and designs should be coming to market during the second half of 2011". (Femto Forum).

Potential Deployment Scenarios for LTE Femtocells

Up to now, femtocells have been deployed 'after the fact' to counter the shortcomings of the macro networks in providing adequate in-building coverage and sufficient capacity in localised areas of high data demand, with LTE, we now have the opportunity to employ femtocells from day one.

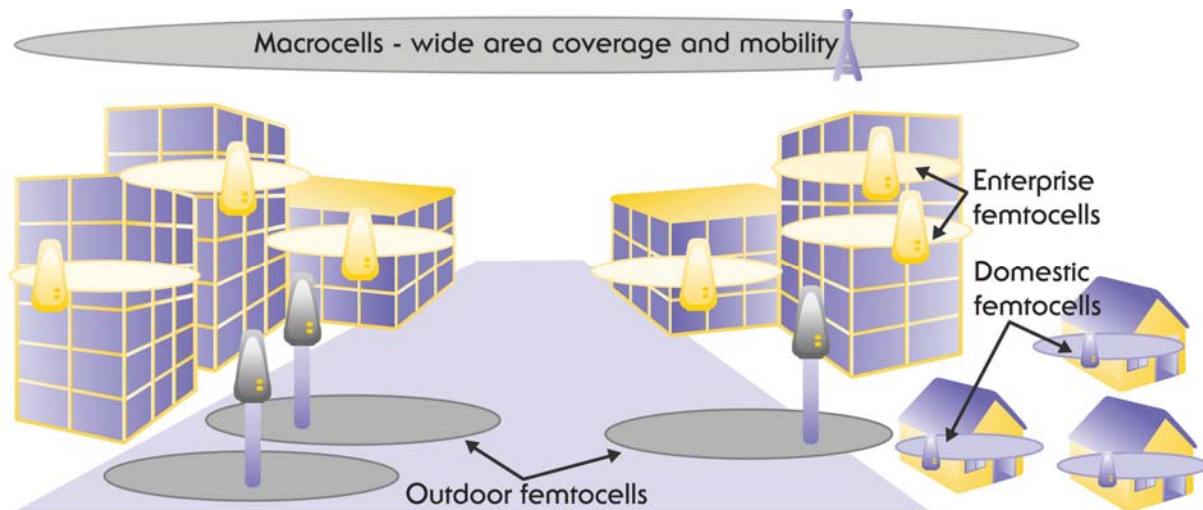
The advent of LTE with its theoretical headline data rates of 100Mbps DL and 50Mbps UL opens up opportunities for new services such as mobile TV, interactive gaming, and so on. However, it is unrealistic to believe we can deliver this kind of broadband capacity with conventional macro networks alone.

To maintain levels of capacity and ensure a good 'user experience' we need to adopt a 'small cell' approach. Using smaller cells, closer to the users, with less contention, results in greater available capacity. Shorter distances between the femtocell and the user means RF power levels can be much lower, reducing interference and increased battery life in the mobile terminal.

Instead of rolling out 'large cell' networks with the traditional approach of 'build it and they will come', a different strategy could be adopted whereby LTE Femtocells could be located in strategically targeted areas, providing coverage and capacity where it is needed most (hence where the revenue is greatest).

The wide area coverage would be provided in the conventional manner by the 2G/3G network. This type of rollout strategy would allow networks to be deployed more efficiently and cost effectively whilst drastically reducing upfront costs and risks that are commonly associated with rolling out 3G macro networks.

The diagram below shows this approach, with LTE being rolled out in 'pockets', with seamless handover to the macro 2G/3G networks (via the Evolved Packet Core (EPC)).



Courtesy of the Femto Forum
www.femtoforum.org

The level of interest from operators is driving the femtocell ecosystem forward at a pace. Enterprise femtocells are now in the pipeline, supporting femto-to-femto handover. Outdoor femtocells are on the way, targeting markets such as theme parks, business parks and so on.

Traffic Offload

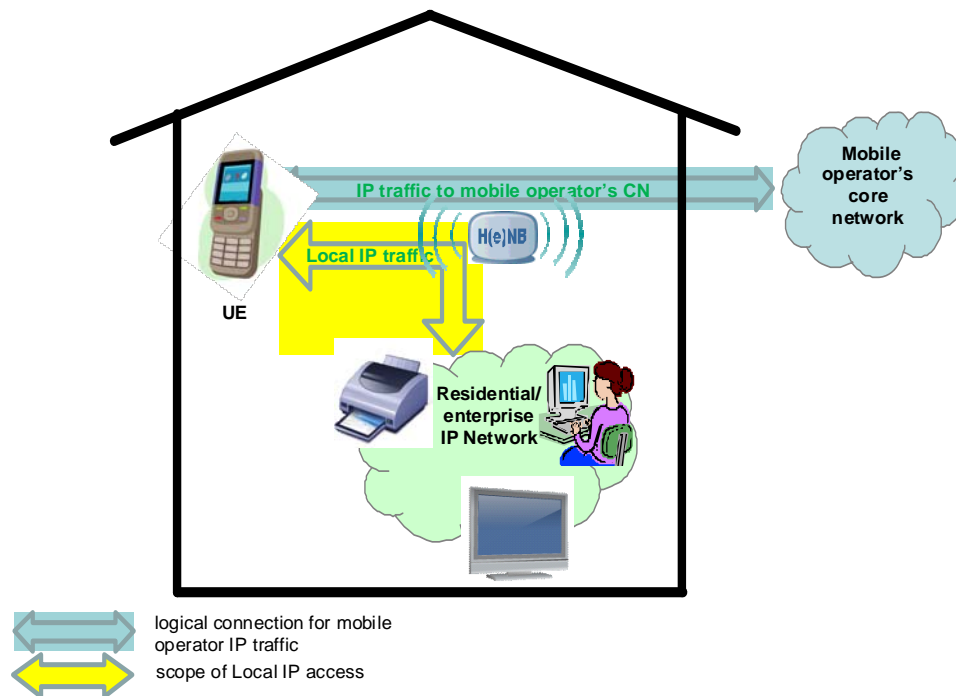
One of the advantages of femtocells mentioned earlier in this document is the ability to offload traffic from the macro network, both in radio access (cellular re-use,) and in RAN backhaul across the subscriber’s broadband internet link.

Within 3GPP there are two recent initiatives in Release 10, each centred around the Home(e)NodeB, that enable traffic offload in the access network: Local IP access (LIPA) and Selected IP Traffic Offload (SIPTO).

Local IP Access LIPA

LIPA is a 3GPP initiative that allows the subscriber to access a residential or corporate subnet via the Home(e)NodeB. The terminal, whilst connected to the mobile operator’s core network will also have simultaneous access to devices on the local IP subnet.

The LIPA facility may be advertised by the Home(e)Node and will be accessible by subscription. Roaming access to LIPA in a visited network is also an option, subject to roaming agreements between operators. Further details are available in 3GPP Release 10.

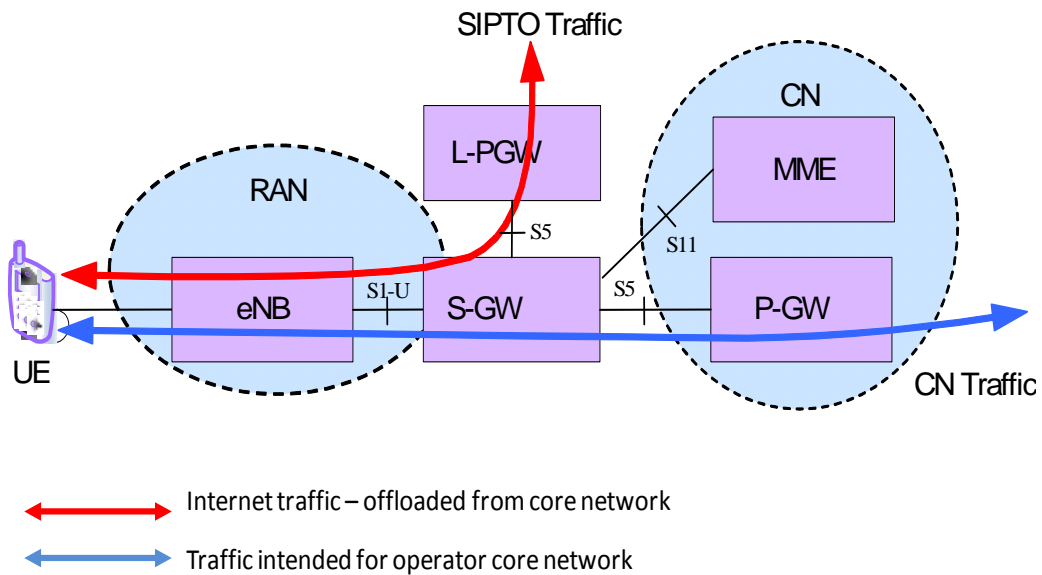


Local IP Access LIPA 3GPP Release 10 – Courtesy 3GPP

Selected IP Traffic Offload: SIPTO

SIPTO refers to the ability to selectively route different types of traffic, originating from the terminal, to different destinations, dependent on some predefined operator policy. Traffic can be routed directly to the Internet therefore bypassing (offloading) the operators' core network.

There are two flavours of SIPTO, Home Network SIPTO, for traffic originating from the Home(e)NodeB and Macro Network SIPTO, for traffic originating from the eNodeB. The principle is clearly shown in the diagram below.



Selective offloading of Internet traffic away from operators core network : SIPTO

Courtesy 3GPP

Whereas LIPA is for the benefit of the end user, SIPTO is for the benefit of the operator and is transparent to the end user.

Commercial Considerations and Opportunities Going Forward

Sprint was the first company to market femtocells in the United States, closely followed by Verizon Wireless and AT&T. Vodafone have launched femtocell product throughout Europe and now offer services in the UK, Spain and Greece. As of November 2010 there are 17 major operators deploying femtocells throughout the world. The 3G femtocell market is currently enjoying sustained growth (Femto Forum – May 2010).

Despite all this activity by the operators, the actual take up of femtocells by the consumer is surprisingly low (according to Cisco Systems - 2010). Although the consumer wants the user experience that a femtocell may offer, they do not want to pay for it. From the consumer's point of view it is up to the services provider to provide good coverage in the first place.

In response to this reaction, the business proposition to the consumer seems to be changing for the better; service providers have been offering deals with up to 70% off the price of the femtocell; some service providers offering to pay for the subscribers DSL backhaul link, and other such offers. Time will tell if the uptake on 3G femtocells improves.

The move to LTE femtocells has not entered a commercial phase yet; however, if the aspirations of the Femto Forum et al are correct and the small cell evolution is sufficiently disruptive as to alter the way in which future cellular networks are deployed, then the commercial implications will be enormous.

The femtocell ecosystem and its accompanying technologies are in a stage of continual development, with vendors, operators, the Femto Forum, 3GPP and others, all striving for new levels of performance, efficiency and cost savings. Engineers at Cellular Asset Management are continually monitoring the state of the art and will be happy to discuss matters in more detail if required.