

# Femto Cells- A New Generation Cellular Stations

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**Abstract** This paper provides a cost effective method for cellular telecommunications base stations that can be installed in residential or business environments either as single stand-alone items or in clusters to provide improved cellular coverage within a building. Data transmission, good signal strengths within buildings, increase in system capacity and data rates are some of the issues been discussed in this review work. The increasing demand for higher data rates in cellular networks has resulted in a trend to smaller cell sizes (Femto cells) and Pico-cellular hot spot coverage. As a result the user can have the advantage of better coverage for additional services, cost benefits and also the network operator, the use of Femto cells provides a very cost effective means of improving coverage, along with linking users to the network, and providing additional revenue from the provision of additional services. Femto cells deployed in the macro cell significantly improve the indoor coverage and provide better user experience. This article summarizes about the network architecture of Femto cells and the issues involved with it. Also it describes about the methods to overcome the issues

**Keywords** Femto Cells, 3G, Macro Access Network, Core Network

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## 1. Introduction

Femto cells are cluster of small cells which are used to provide high data rate, capacity and cost effective. The Femto cell includes a base station that looks like a Wi-Fi access point. The Femto cell incorporates RNC (Radio Network Controller; in the case of GSM, BSC) and all the core network elements. Hence only a DSL or cables to the internet are just enough to connect to a mobile operator's core network. The FAP (Femto cell access point) can be divided into two types depending upon the capacity and number of users. They are classified as home FAP which can support 3-5 users and enterprise FAP which can support 8-16 users. This classification is mainly based on the probability of the subscribers who can access the Femto cell, which is why home FAP will have less demand than enterprise FAP. Also according to the cellular technologies

FAP can be classified as UMTS FAP, GSM FAP, Wi-Max FAP, and so on.

A Femto cell provides an improved cellular coverage within a building by using a small internal base station-Femto cell. The user traffic in Femto Base Station is backhauled to the mobile operator core network over IP via the residential broadband wire line connection (DSL, optical network etc.) which is available locally in the site of deployment.

In this way the user can enjoy cost effectiveness and better coverage along with provision of additional services. The network operator with the use of Femto cell can provide better coverage along with linking users to their network.

Femto cells will change the design of wireless networks. To date, the mobile industry has asked subscribers to move to the network-hence you see people walking out into a parking lot to get a 3G signal. With Femto cells, we are bringing the network to the subscriber, which is really a dramatic shift. But Femto cells won't replace the macro network. They will complement it by delivering service in specific targeted areas that the macro network cannot economically reach. Femto cells will evolve into less of a perk and more of a necessity to keep pace with the expanding service expectations [1-3].

The potential of Femto cell deployment in terms of market potential is worth paying attention to. For 2G Femto deployments operators can look for increased revenues from Home Zone type of offerings. With attractive pricing plans and features the home user will communicate more from home, thus redirecting traffic from the traditional landline to the Femto cell radio network. The macro network does not receive any of the traffic over the broadband network directly to the operator's core network. For 3G Femto cell deployments, operators are seeking ways to increase coverage, thus promoting 3G services. Since most 3G network deployments are at higher frequencies than 2G deployments (e.g. 2.1 GHz for UMTS vs. 900 or 1800 MHz for GSM) UMTS deployments require, for the same output power, a denser radio network in order to penetrate walls and indoor environment. 3G Femto cells will address such a problem by providing a dedicated 3G base station at home. Finally, regarding the long term evolution of 3G (LTE), a technology that promises to

deliver over 100 Mbps to the end user in a spectrum bandwidth up to 20 MHz, an LTE Femto cell can address the bandwidth scarcity problem. Such high speeds in the excess of 100 Mbps could be achieved through an LTE Femto cell device.

A Femto cell will offer better data bandwidth/performance, and lower home-zone calling tariffs. With this performance, Femto cells will deliver a better multimedia experience with music, photos and live video to laptops, smartphones and feature phones. Femto cells help UMTS indoors in two ways: first, they provide a strong indoor signal in comparison to macro 3G signals which often have difficulty penetrating building walls. Second, they allow the individual user or family to share the entire available spectrum, rather than sharing among perhaps 100 users on the macro network. This translates into greater capacity for bandwidth-intensive services like IP-TV.

Femto cells are being designed to cover a radius of 50-100 meters, which would cover even a fairly large house. They will also have built-in intelligence to increase or decrease transmit power so as not to interfere with other signals in the area. The range of the Femto cell will be affected by the RF (radio frequencies) environment due to both the macro cell and other Femto cells. The Femto cell system will attempt to adjust the Femto cell power while still maintaining a quality experience for both macro cell users and users of other Femto cells. A Femto cell is like a Wi-Fi access point for mobile 3G; it uses a low-power integrated antenna to transmit voice and data cellular signals within a home or small office. It connects to the mobile operator's network through a broadband internet connection.

## 2. Femto Cell Self-Organization Requirements

Femto cells are required to be able to completely self-organize themselves so that there is no intervention from the user. This can be split into three main areas [8]:

**A. Femto cell Self-Configuration-** This element of Femto cell installation requires the Femto cell to be able to select the initial parameters required for operation to commence. These will include the channel, neighbor list, power, etc.

**B. Femto cell Self-Optimization-** Once operational, the Femto cell will need to monitor the environment to ensure that it takes account of any changes required including the channel and resources required.

**C. Femto cell Self-Healing-** As problems may occur after set-up, the Femto cell will need to be able to resolve any problems that may occur.

**D. Secure and Self-Managing-** Small cells encrypt all voice and data sent and received, ensuring a high level of protection from sniffing or snooping. In order to reduce operational and installation costs, these units are self-installing and use a variety of clever tricks to sense

which frequency to transmit on and power level to use. Unlike large outdoor mobile phone base stations (masts), Femto cells don't require specialist RF planning engineers to design, calibrate or configure themselves - minimizing the ongoing cost of maintaining them. They do have remote management from the network operator, who can upgrade the configuration and software as required.

## 3. Femto Cell Architecture

Femto cells present mobile operators with an opportunity to reduce the total cost of ownership of their voice and data services while improving customer loyalty and unlocking new revenue opportunities. The cost benefits include reducing macro RAN expansion needs for voice and 3G data capacity and lowering backhaul costs by using the subscriber broadband connection. At the same time, mobile operators will improve indoor radio coverage at the subscriber home or business and could enhance their average revenue per user (ARPU) and profitability with new tariffs, pricing plans or Femto zone services. Applicable to CDMA, GSM/UMTS, LTE and Wi MAX, Femto cells can leverage existing mobile switching centers or Session Initiation Protocol (SIP) core networks, including IP Multimedia Subsystem (IMS) networks. All Femto cell architectures use IPsec tunnels to deliver voice, messaging and packet data services to 2G, 3G or 4G handsets connected via a fixed broadband access connection to the Internet or a managed IP network. The figure 1 shows about the general backhaul connection of Femto cell network where the voice/data traffic is routed to the internet.

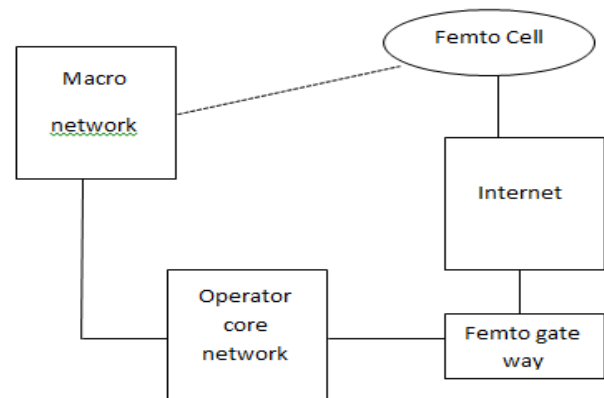


Figure 1. 3GFemto cell general Network Architecture

### A. Common Elements and Interfaces of the Femto Cell Network Architecture [11]

**Home NodeB (HNB) -** A common terminology for HNB is Femto cell Access Point (FAP). HNB are low-power access point installed in user premises (Home or office) and it involves the function of base station and base station controller, which gives the secure access to the operator's network via internet. A standalone HNB can be easily

installed just like a plug-and-play device. Technologies like 3G, 4G or WiMax can have a better access to the network and this in turn increases the coverage area.

The authorized user get a dedicated coverage over this HNB in a licensed spectrum, this leads to a good QoS and enriches the end-user service experience. Furthermore, HNB uses the standard 3GPP Uu over-the-air interface to communicate with the mobile devices.

**HNB GateWay (HNB GW)** – The functionality given by HNB GW includes link security, control, and aggregation. HNB supports radio management while HNB GW maintains the core network functionality. They both work together to perform some operations like paging. HNB and HNB GW need each other cooperation. Security of the femto cell network architecture can be improved by including the functions like Authentication, Authorization and Accounting (AAA) functions in HNB GW.

**Security GateWay (SeGW)** – Security gateway provides the secured internet connection between femto cell users and the core network. It uses the standard Internet security protocols such as IPSec to authenticate and authorize femto cells and provide encryption support for all signaling and user traffic. The secured data access is provided with the help of GPRS Tunneling Protocol (GTP) over the Iu-PS interface and it runs inside the IPSec connection.

**HNB Management System (HMS)** - The TR-069 family of standards specifies about the functionality of HMS. This protocol is widely seen in DSL modem and residential gateway deployments and by using web based architecture it can support millions of devices. The Automatic Network Planner application and the Device Manager application are the two primary elements of HMS. The Automatic Network Planner adds RF planning algorithms, RF configuration and a northbound interface to Operational Support Systems (OSS). The Device Manager implements functions such as remote configuration, remote diagnostics, software upgrade, fault management, performance data collection and device authentication.

**Iu-h Interface** - The Iu-h interface is used to provide the link or interface that connects the HNB with the HNB-GW. The Iu-h interface includes a new HNB Application Protocol, HNBAP that provides the high level of scalability required for the HNB deployment that will occur in a rather ad-hoc fashion.

**Iu-b Over IP** - Existing RNCs connect to Femto cells through standard Iu-CS (circuit-switched) and Iu-PS (packet-switched) interfaces present in macro cell networks. The advantage is that the capital expenditure is comparatively low insofar as the operator can leverage existing RNCs. The shortcomings are the lack of scalability and that the interface is not yet standardized.

This Femto cell network is then connected to macro access network via core network.

## B. General Working Principle of Femto Cell Network

In the 3G Femto cell network architecture, User Equipment (UE) or Mobile Equipment (ME) is connected to the HNB over the Uu interface. This interface is the standard WCDMA radio interface between the UE and HNB.

HNB(s) that are installed in user premises provides better coverage, and it connects the user to the HNB GW through the Iu-h interface. The Iu-h is a new interface which is used to link the HNB and HNB GW. The Iu-h Interface provides control and user plane functionalities, along with the basic set of functions for the user plane, such as, Radio Access Bearer management, Radio Resource Management, Mobility management and security, etc.

As described earlier, the functionality of the Home NodeB Management System (HMS) is based on the TR-069 family of standards. The functions of HMS include the discovery of the HNB GW, location verification of the HNB and the assignment of serving elements to the serving network. The use of the HNB GW enables the better mobility and Operation Administration and Maintenance (OAM) function for UEs.

The HNB GW connects the large number of HNBs with the Iu interface to the core network. The functionality of the Iu interface is in turn divided two interfaces, the Iu-PS for Packet Switching network, that is to GPRS Server (SGSN) and Iu-CS for Circuit Switching networks, that is for MSC.

The Security Gateway (SeGW) in 3G Femto cell architecture is a separate logical entity that is used to manage and terminate secure IPSec tunnels between the HNB and Core Network (CN). The function of SeGW is to provide protection against potential security threats and network attacks that may occur when mobile traffic is exposed to the public access network. Sometimes the SeGW is integrated within the HNB GW.

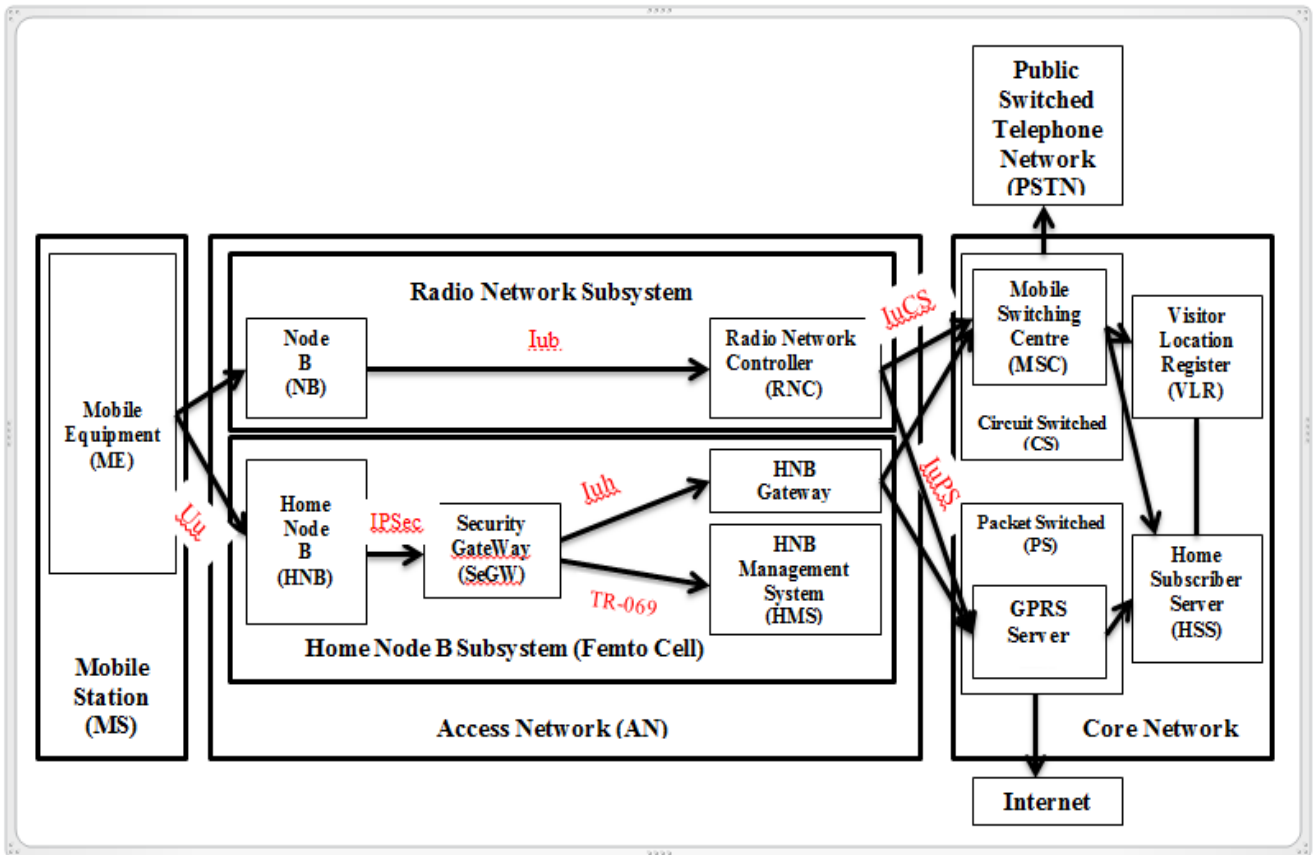


Figure 2. 3GFemto cell Network Architecture [2]

### C. Network Infrastructure

In a Femto cell environment the operator will need to provide a secure and scalable interface over the Internet at a reasonable cost. Traditional radio network controllers (RNCs) are equipped to handle tens to hundreds of macro cells.

Four network interfaces have been proposed, of which the IP multimedia subsystem (IMS)/Session Initiation Protocol (SIP) and unlicensed mobile access (UMA)-based interfaces appear to be the architectures of choice.

**I. Iu-b over IP:** Existing RNCs connect to Femto cells through standard Iu-CS (circuit-switched) and Iu-PS (packet-switched) interfaces presenting macro cell networks. The advantage is that the capital expenditure is comparatively low in so far as the operator can leverage existing RNCs. The shortcomings are the lack of scalability and that the interface is not yet standardized. [1]

**II. Concentrator:** A concentrator will be placed before the traffic is diverted to RNC hence current RNCs can handle thousands of Home NodeBs. This approach allows for a partition differently between Home NodeB and RNC, thus enabling to have a large number of Home NodeBs. But this technology did not go any further after 3GPP started standardizing architecture for Femto cell access networks. [1]

**III. IMS/SIP:** The IMS/SIP interface provides a core network residing between the Femto cell and the operator.

The 3 GPP multimedia subsystems (IMS) interface converts subscriber traffic into IP packets and employs voiceover IP (VoIP) using session initiated protocol (SIP), and coexists with the macro cell network. The main advantages are scalability and rapid standardization. Disadvantages include the capital expenditure for upgrade, and the operating expenditure in maintaining two separate core networks for the macro cell and Femto cell respectively. [1]

**IV. Generic Access Network (GAN)-Based RAN Gateway:** A radio access network (RAN) gateway exists between the IP and operator networks, aggregating traffic from Femto cells. This gateway is connected to the operator network using a standard Iu-PS/CS interface. Between the Femto cell and the RAN gateway, the UMA protocol makes use of secure IP tunneling for transporting the Femto cell signals over the Internet. Current UMA-enabled services such as T-Mobile's Hot spot@ Home require dual-mode handsets for switching between in-home Wi-Fi and outdoor cellular access. Integrating the UMA client inside Femto cells rather than the mobile would enable future deployments support use of legacy handsets. [1]

## 4. Generic Access Network

The Access Network (AN) consists of multiple Radio Network Subsystems (RNSs). An RNS accommodates base stations called NodeBs (NBs) and a Radio Network

Controller (RNC) managing them. The RNC acts as the gateway towards the CN and forwards all traffic originating from MSs that passes through the NBs. Both the original GSM and current 3G architectures trust the base stations: although the phones use link-encryption to communicate with the base station and the base stations could use link-encryption to communicate with the operator's back-end network, there is no end-to-end confidentiality or integrity between the user's phone and the carrier's network.

#### **Core Network Communication: Generic Access Network Protocol**

Integration of Femto cells into the existing telecommunication network over the public Internet is a challenge for operators and vendors. The 3GPP defines the following three approaches to connect these devices to the core network over the so-called Iuh interface: Iub over IP, SIP/IMS, and Radio Access Network (RAN) gateway based. While these protocols differ in details, the architecture and supported features are all similar. We concentrate on the third approach based on a RAN gateway as our device uses this protocol. This technique utilizes the 3GPP Generic Access Network (GAN) protocol as the interface between the Femto cell and the gateway. The GAN protocol, formerly known as Unlicensed Mobile Access (UMA), was originally designed to allow mobile communication over Wi-Fi access points, enabling the phone to connect to the operator network over an IP network. This protocol was first standardized by MNOs in 2004 and led to the GAN specification in 2005. The protocol transparently encapsulates all traffic generated by the phone and forwards it to the HNB-GW. This gateway is referred to as GAN Controller (GANC). Similar to the RNC in traditional 3G networks, it is linked to the operator's CN using the IuCS/IuPS interface. For compatibility with the HNB architecture, the GAN protocol has been slightly extended. The HNB acts as a gateway between the MS and the GANC.

The RAN Gateway approach is based on a new, purpose built, network controller (RAN Gateway) that resides between an operator's existing core network and the IP access network, akin to an RNC. On its Internet side, the RAN Gateway aggregates traffic from a large number of Femto cells over the new Iu-over-IP interface. The RAN Gateway then integrates the traffic into the existing mobile core network through standard Iu-CS and Iu-PS interfaces on the core network side.

As in a classical 3G network, mobile phones connect to cells (in this case the HNB) via the Uu interface. Therefore, the presence of GAN is transparent to the subscriber's phone. Our Femto cell device supports this protocol to enable mobile telecommunication via the customer's broadband connection. The GAN protocol implementation running on the HNB maps all 3GPP Layer 3 (L3) radio signaling to TCP/IP based GAN messages and passes them to the GANC. This enables the HNB to perform signaling tasks by sending encapsulated L3 messages to the GANC.

Details of these GAN messages are as follows. To map radio signaling from a specific subscriber to GAN messages, the Femto cell maintains a TCP connection with the GANC for each individual subscriber. The connection management is based on Generic Access Resource Control (GA-RC) messages. The CS traffic is encapsulated in Generic Access Circuit Switched Resource (GA CSR) messages, while PS traffic is covered by Generic Access Packet Switched Resource (GA-PSR) messages. Additionally, GAN supports MAP based signaling to control the telecommunication circuit and to manage the network. This provides the necessary protocol functions for all Mobile Terminated (MT) as well as Mobile Originated (MO) services and thus supports full 3G functionality.

## **5. Femto cell Issues**

There are a number of issues that needed to be resolved in terms of the basic system design and set-up [8].

- Femto cell interference issues: One key issue associated with Femto cells is that of interference. There is only limited spectrum on which the cellular systems can run. Some 3G operators for example may only have one channel in some places. Therefore it is necessary that Femto cells are able to operate within the normal spectrum shared with many other cellular base stations. There are a number of ways in which this can be achieved: the use of cognitive radio technology; the use of systems that are tolerant to interference (3G and 4G are able to tolerate interference and single channel working); spectrum planning where possible.
- Femto cell spectrum issues: Radio spectrum is a particularly scarce resource, especially when large amounts of data are required. Planning the available spectrum so that it can be used with the possible huge numbers of Femto cells can require careful attention, although in some instances single channel operation with main base stations may be required.
- Femto cell regulatory issues: Femto cells operate in licensed or regulated spectrum. Unlike Wi-Fi which operates in unlicensed spectrum, Femto cells need regulatory approval. The spectrum and radio regulations vary from one country to the next and therefore regulations may need to be changed in each country. International agreement may also be required, because private individuals may take Femto cells from one country to the next.
- Femto cells and health issues: With a large public awareness of the possible dangers of RF radiation, one key issue has been that of health and safety. As a Femto cell is a cellular base station, there could be public concern regarding the levels of RF radiation received. However the power levels emitted by Femto cells are small - no greater than most Wi-Fi access points which are common in very many homes. As a result it is not believed by the industry in general that there are any health issues that should cause any concern.
- Handling Interference: Interference is expected to be a

significant issue for Femto cell deployments based on wideband technologies such as WCDMA. This is either because initial operator deployments will use the same frequency for both the Femto cell or the macro networks or due to the proximity of Femto cell base stations in dense urban areas. Two interference scenarios are anticipated. Femto-to-Femto interference and Femto-to-macro interference. The study of Femto-to-macro interference from a recent study has shown the existence of macro cell "dead zones" caused by the downlink interference from the Femto cell which prevents visiting user equipment access in the dead-zone. To complicate the issue further, the size of the dead zone in relation to the Home-NodeB coverage area will depend on the proximity of the Femto cell site to the macro site.

Three solutions to combat interference have been proposed:

- A The use of different frequencies for macro and Femto networks if available
- B A decreased Femto cell power to reduce the effect of dead zones
- C Implementing 2G as a fall back in dead zones to mitigate interference

## 6. Synchronization [8]

Femto cells, like any other cellular technology, require synchronization. In general, three types of synchronization might be required, namely, frequency, time and phase. For example, for UMTS 3G/HSPA FDD type of deployments, frequency type of synchronization is required. Femto cells will be deployed with a packet type of backhauling interface (typically Ethernet/IP). Synchronization methods for Ethernet/IP networks are either the well-known NTP protocol or the newly standardized IEEE 1588 standard.

## 7. Comparisons of Femto Cell with Other Technologies

Femto cell Vs. Wi fi

Femto cell	Wi-Fi
Enable cellular carriers to compete with VoIP, Wi-Fi and UMA	VoIP pricing on calls within the home
No need for expensive dual mode handsets	Single phone for indoor/outdoor calls
Improves 3G coverage indoors and encourages use of data services	Provides indoor coverage via Wi-Fi(or Bluetooth)
Improves capacity	Use dual mode phones in Wi-Fi hot spots
Works in licensed spectrum	Works in unlicensed spectrum

Femto cell Vs. Macro cell

	Femto cell	Macro cell
Air interface	Telecommunication standard	Telecommunication Standard
Backhaul	Broadband Internet	Telephony network
Cost*	\$200/year	\$60,000/year
Cell phone Power consumption	Low	High
Radio Range	10-50 meters	300-2000 meters

\*Analysis, [Http://research.analysis.com](http://research.analysis.com)

Femto cell VS WLAN

	Femto cell	WLAN (AP)
Spectrum	Licensed	Unlicensed
MAC layer	Conflict-free	Contention-based
Backhaul	Cable/DSL	Cable/DSL
Air interface	Cellular standard	802.11a/b/g/n
Range	10-50m	35-70m
Service	Primarily voice	Primarily data
Current Cost	\$200-\$250	\$50-\$100

## 8. Conclusions

Femto cells have the potential to provide high quality network access to indoor users at low cost, while simultaneously reducing the burden on the whole system. The increasing demand for higher data rates in cellular networks has resulted in a trend to smaller cell sizes (Femto cells) and pico-cellular hot spot coverage. As a result the user can have the advantage of better coverage for additional services, cost benefits and also the network operator, the use of Femto cells provides a very cost effective means of improving coverage, along with linking users to the network, and providing additional revenue from the provision of additional services. Femto cells deployed in the macro cell significantly improve the indoor coverage and provide better user experience. This work summarizes about the network architecture of Femto cells and the issues involved with it. Also it describes about the methods to overcome the issues.

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