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Introduction

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1.1 The Indoor Coverage Challenge

In cellular networks, it is estimated that 2/3 of calls and over 90% of data services occur indoors. Hence, it is extremely important for cellular operators to provide good indoor coverage for not only voice but also video and high speed data services, which are becoming increasingly important. However, some surveys show that 45% of households and 30% of businesses [1] experience poor indoor coverage problem. Good indoor coverage and service quality will generate more revenues for operators, enhance subscriber loyalty and reduce churn. On the other hand, poor indoor coverage will do exactly the opposite. Hence, how to provide good indoor coverage, in particular, for high speed data services, is a big challenge for operators.

A typical approach to providing indoor coverage is to use outdoor macrocells. This approach has a number of drawbacks:

- It is very expensive to provide indoor coverage using an 'outside in' approach. For example, in UMTS, an indoor user will require higher power drain from the base station in order to overcome high penetration loss. This will result in less power to be used by other users and lead to reduced cell throughput. This is because the power used by indoor users is not efficient in terms of generating capacity and in UMTS capacity is linked to power. Hence, the cost per Mb of using 'outside in' approach will become higher and more expensive than using indoor solutions.
- A high capacity network needs a lot of outdoor base station sites, the acquisition of which has become very challenging in densely populated areas.
- It is less likely that a high capacity network using such an approach will be built, due to the interference and higher power drain from base stations to serve indoor users from outdoor macrocells, etc.

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- As the cell sites become denser, the network planning and optimization becomes a big challenge in such networks. For example, in GSM/GPRS/EDGE networks, the frequency planning and in CDMA based networks, the planning of soft handover regions, etc.
- 3G and beyond networks will normally work at 2 GHz or above, the building penetration is a challenge for networks operating above 2 GHz.
- The network performance (e.g., throughput) indoors can not be guaranteed, in particular, in the side not facing the macrocell sites. In order to achieve higher data rates, higher modulation and coding schemes are needed. The higher modulation and coding schemes in HSDPA, WiMAX and LTE require better channel conditions, which can only be met near those windows facing macrocell sites.

Hence, indoor solutions such as DAS (Distributed Antenna Systems) and picocells become an attractive and viable business proposition in hotspots such as large business centres, office buildings and shopping malls. These indoor systems are deployed by operators. The indoor solutions will improve in-building coverage, offload traffic from outdoor macrocells, enhance service quality and facilitate high data rate services due to the improved performance of radio links. With indoor solutions, in UMTS, the orthogonality can be improved, which will result in high throughput. In HSPA/LTE or WiMAX, the better channel conditions will enable high modulation and coding scheme to be used and thus deliver richer services that further drive demand.

Even though the above mentioned indoor solutions are more cost effective than using outdoor macrocells to provide indoor coverage for voice and high speed data services, such solutions are still too expensive to be used in some scenarios such as SOHO (Small Office and Home Office) and home users (for personal communications and entertaining, etc.). The scale of SOHO and home use normally does not represent a viable business proposition for operators. Recently, the development of femtocells provides a good opportunity for low cost indoor solutions for such scenarios. Unlike picocells, femtocells are deployed by users.

1.2 Concepts of Femtocells

1.2.1 What is a Femtocell?

Femtocells, also known as ‘home base station’, are cellular network access points that connect standard mobile devices to a mobile operator’s network using residential DSL, cable broadband connections, optical fibres or wireless last-mile technologies.

1.2.2 A Brief History

The concept of ‘home base station’ was first studied by Bell Labs of Alcatel-Lucent in 1999. In 2002, Motorola announced the first 3G-based home base station product. However, it was not until 2005 that the ‘home base station’ concept started to gain a wider acceptance. In 2006, ‘femtocell’ as a term was coined. In February 2007, a number of companies demonstrated femtocells at the 3GSM World Congress (Barcelona), with operators announcing trials. In July 2007, the Femto Forum [2] was founded to promote femtocell standardization and deployment worldwide. As of December 2008, the forum includes over 100 telecom hardware and software vendors, mobile operators, content providers and start-ups. In 2008. Home NodeB (HNB) and Home eNodeB (HeNB) were first introduced in 3rd Generation Partnership Project (3GPP) *Release 8*, signalling that it had become a mainstream wireless access technology. Large scale femtocell deployment is expected in 2010. It is likely that the roll-out of Long Term Evolution (LTE) networks will include both outdoor macrocells and indoor femtocells from the early stage of network deployment. Femtocells are also very promising for enterprise applications.

1.2.3 What is Included in a Femtocell Access Point?

The femtocell unit incorporates the functionality of a typical base station (Node-B in UMTS). A femtocell unit looks like a WiFi access point, see Figure 1.1. However, it also contains RNC (Radio Network Controller; in the case of GSM, BSC) and all the core network elements. Thus, it does not require a cellular core network, requiring only a data connection to the DSL or cable to the Internet, through which it is then connected to the mobile operator's core network, see Figure 1.1. In this book, we use femtocell access point (FAP) to stand for the femtocell unit that contains base station and core network functionalities, and use femtocell to refer to the service area covered by the FAP. A FAP looks like a WiFi access point (WAP). However, inside, they are fundamentally different. WAP implements WiFi technologies such as IEEE 802.11b, 802.11g, and 802.11n. FAP implements cellular technologies such as GSM/GPRS/EDGE, UMTS/HSPA/LTE and mobile WiMAX (IEEE 802.16e). A comprehensive comparison of WiFi and cellular technologies is beyond the scope of this chapter.

1.2.4 FAP Technologies

The technologies behind femtocell are cellular technologies. As the key driver of femtocell is the demand for higher and higher data rates indoors, UMTS/HSPA FAPs are the current main focus. However, FAPs can also be based on GSM/GPRS/EDGE. 2G/3G based femtocells have been developed by various vendors. The development of WiMAX and LTE based femtocells is also under way.

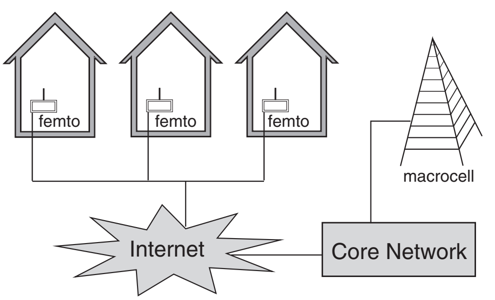

Figure 1.1 Typical femtocell and macrocell scenario

1.2.5 FAP Deployment

Unlike picocells, FAPs are self-deployed by users rather than operators. They should be regarded as consumer electronics. In order to generate minimum interference to outdoor macrocells and neighboring femtocells, a FAP must be able to configure itself automatically. Automatic configuration of FAP can be divided into a sensing phase, in which radio environment will be assessed, and an auto-tuning phase, in which FAP parameters (e.g., downlink Tx power and sub-channel allocation, etc.) will be automatically configured. Automatic configuration of FAP is key to the successful deployment of femtocells. Before FAPs can actually be self-deployed by users, operators must test typical femtocell deployment scenarios by trials and/or simulation. The main purpose of the simulation and trials is to find out the impact of femtocell deployment on the macrocell layer. In addition, how femtocells will affect each other, as well as the performance of both femto- and macro-cell layers will also need to be investigated. A femtocell deployment tool that incorporates system level simulation for various RATs (Radio Access Technologies), accurate radio propagation models (e.g., using 3D ray tracing or FDTD), 3D modelling and visualisation of building structure (for example, to read from AutoCAD .dxf file to generate 3D viewer of building floor structures) and optimization engine will be highly desirable for this purpose because compared with trials, it is much cheaper and convenient. CWiND's industrial partner Ranplan Wireless Network Design Ltd (www.ranplan.co.uk) is developing such a tool and will be ready for commercial offering at the beginning of 2010.

1.2.6 FAP Classification

According to their capacity, FAP can be classified into two categories, namely home FAP, which can support 3–5 simultaneous users, and enterprise FAP, which can support 8–16 users. The key drive of FAP is to provide high data rate services for the residential sector. There is a low probability that all the subscribers will simultaneously use the femtocell, which is why home femtocells supporting more than five simultaneous users would be too useless compared with the real demand. In addition, this is also restricted by the bandwidth limitation of the uplink ADSL. According to the cellular technologies used, FAP can be classified into UMTS FAP, GSM FAP, WiMAX FAP, and so on. There is a trend to combine different air interfaces into one FAP.

1.3 Why is Femtocell Important?

A large deployment of femtocells is expected in 2012 [3] (see Figure 1.2 and Figure 1.3), but why is this small thing important? Femtocell is very important for the following reasons:

- It can provide indoor coverage for places where macrocells cannot.
- It can offload traffic from the macrocell layer and improve macrocell capacity (in the case of using macrocells to provide indoor coverage, more power from the base station will be needed to compensate for high penetration loss, resulting in a decrease in macrocell capacity).

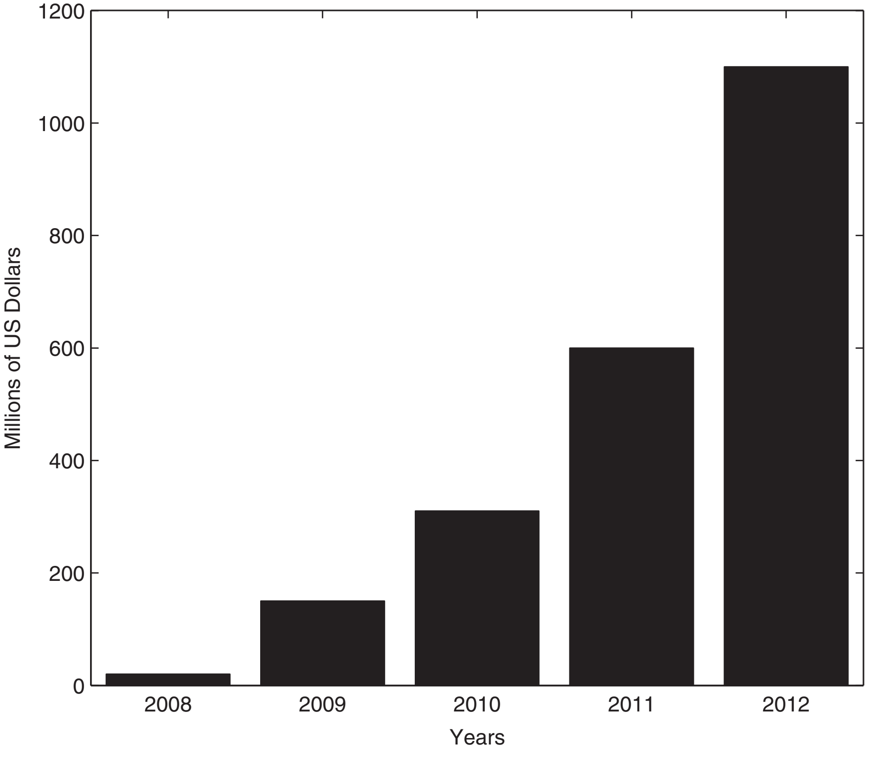

Figure 1.2 Global femto base station infrastructure equipment market forecast (Data from www.wirelessweek.com)

- Assume that good isolation (hence, the signal leakage from indoor to outdoor will be small) can be achieved, the addition of a femtocell layer will significantly improve the total network capacity by reusing radio spectrum indoors.
- There is a growing demand for higher and higher data rates. Due to the high penetration loss, high data rate services can not be provided to indoors apart from those areas near windows that are facing a macrocell site. This is because high data rate requires high performance RF links. High data rate services such as those facilitated by HSDPA are the key drive of femtocells.
- Femtocells can provide significant power saving to UEs. The path loss to indoor FAP is much smaller than that to the outdoor macrocell base station, and so is the required transmitting power from UE to the FAP. Battery life is one of the biggest bottlenecks for providing high speed data services to mobile terminals.
- As FAPs only need to be switched on when the users are at home (for home femtocells) or at work (for enterprise femtocells), the use of femtocell is ‘greener’ than macrocells. The power consumption of base stations accounts for a considerable amount of an operator’s OPEX. In the UK, the power to run base stations is over 3 watts per subscriber. In some developing countries, the power consumption accounts for some $\frac{2}{3}$ of the OPEX. A base station consumes far more power than that is used for transmitting

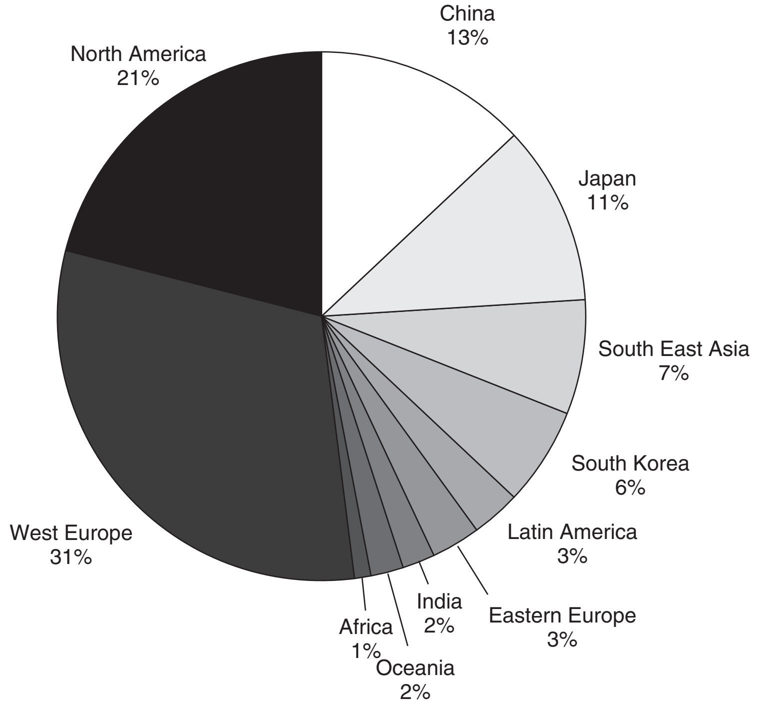

Figure 1.3 Total 3G femtocell deployment market in 2012 (Data from www.fwdconcepts.com/femtocell)

and receiving signals. This is caused by a number of factors: first, the efficiency of the amplifiers is very low (typically 10–15%) as they work at the linear rather than the saturation region as the sophisticated modulation techniques used in 3G and beyond systems require linear amplification; second, a base station requires an air-conditioning system in order to keep running at atmospheric temperature; third, a backup system is also needed to account for loss of power supply. The base station power consumption problem leads to a high demand on the so-called 'green communications systems' or 'green radio'.

- Femtocell provides an ideal solution for FMC (Fixed Mobile Convergence).
- Femtocell plays an important role in mobile broadband and ubiquitous communications.
- Femtocell represents a major paradigm shift. Users will pay to install femtocells. Hence, the first phase of the rollout of high data rate networks such as LTE can start from indoor where high data rates are needed most. As future terminals will support GSM, WCDMA (or other 3G technologies) and LTE, the rollouts of LTE can be very different from the rollouts of GSM and UMTS. This is really an important paradigm shift as far as future mobile communications network rollouts are concerned.

1.4 Deployment of Femtocells

Femtocells can bring a lot of advantages for both operators and subscribers.

1.4.1 Operator's Perspective

As a large amount of traffic (up to 70–80%) can be offloaded from macrocells, which means that fewer outdoor macrocells will be needed. The reduction of macrocell sites will result in a huge CAPEX saving for operators in their radio access networks. The reduction of traffic from macrocell sites will also result in significant saving in the backhauling. This will also lead to associated saving on the OPEX.

The reduction of macrocell sites will simplify the site survey and planning process; it also means less rent will be paid for the usage of base station sites. In the rollout of 3G/4G networks, site acquisition is a big challenge for operators, in particular, in urban areas. It has become increasingly difficult for operators to find base station sites.

Femtocells can help operators cost-effectively to build out network capacity and achieve a more cost-effective evolution plan with reduced risks and financial burdens. This is due to the facts that first, femtocells are low cost solutions for indoor coverage compared with other approaches; second, users will at least share a substantial amount of the installation cost of FAPs and the operation of FAPs will be largely financed by users (operators will also carry out remote maintenance, etc.). In particular, operators can encourage open access for femtocells and further reduce the demand of outdoor macrocells.

Femtocells will improve service quality; hence it will increase customer loyalty and reduce churn, which is a major issue and can cost operators millions of dollars a day. Surveys show that poor service quality is the most important factor for a subscriber leaving a mobile operator.

Femtocells will help mobile operators to drive data usage and provide richer services (for example, through home zone plans and bundled services), which will boost ARPU (Average Revenue Per Unit). Voice alone is no longer enough to future-proof revenue generation.

Compared with picocells and other indoor technologies, femtocells are a low cost solution to increasing indoor coverage and improving service quality.

Femtocells will help operators to deliver a seamless user experience across outdoor and indoor environments, at work, on the move or at home, and provide a basis for next-generation converged services that combine voice, video, and data services to a mobile device.

Even in areas that can be served by macrocells, femtocells can still bring a lot of benefits to operators as they will remove the need to deliver indoor services from macrocells and decrease the overhead incurred by delivering signals indoors.

The reduced demands on macrocells may allow operators to share the outdoor LTE network macrocells.

Femtocells can offer new mobile operators new alternative approaches to network roll-out. For example, new mobile operators can provide indoor solutions in hotspots using picocells and femtocells, provide femtocells solutions for home users, build macrocell networks where there is real need and reach roaming agreements with some established operators.

So far, we have only discussed the benefits that femtocells can bring to operators. The deployment of femtocells will potentially also cause some problems to operators. One of the drawbacks of femtocells for operators is that interference becomes more random and harder to control. This is particularly problematic for CDMA based networks such as UMTS. In order to improve overall network capacity, it is beneficial for operators for both the macro and femto layers to use the same frequency band to operate. Thus, the randomness of interference from femtocells may cause problems on macrocell operation, for example, causing coverage holes. As CDMA networks are interference limited, macrocell capacity can be affected if the interference from femtocells is not controlled well. Operators will not be able to access subscribers' premises, thus femtocell self-configuration is very important. Remote monitoring and maintenance will also be important for operators.

It needs to be pointed out that UTRAN was developed under the assumption of coordinated network deployment whereas femtocells are typically associated with uncoordinated and large scale deployment [4].

1.4.2 Subscriber's Perspective

For those who experience no or poor indoor coverage at home, femtocells can enable subscribers to use their mobiles at home. With femtocells, in addition to voice service, multimedia, video and high speed data services will also become available. As the indoor performance of the network can be much improved, so can the user experience for both voice and data services. Femtocells will offer users a single address book and one billing account for land line phone, broadband and mobile phone. Users can benefit from home zone plans and bundled services that will be more cost effective than using services from more than one provider. Femtocells can act as the focal point to connect all domestic devices to a home server and act as the gateway for all domestic devices to the Internet. Femtocells will deliver converged services (voice, video and data services) at home and enable users a seamless user experience across both outdoor and indoor environments with personalized converged services for UEs. Femtocells will save UE power. As the distance between the UE and the FAP is much shorter than that between the UE and the macrocell site, transmitting power on the uplink can be much reduced, which will result in power saving on the UE. The battery is one of the biggest bottlenecks in providing high speed data services to mobile devices. As the transmitting power of UE can be greatly reduced, health concerns on using mobile devices can be reduced. It needs to be pointed out that if there are any health concerns arising from using mobile communications, they would mainly come from uplink, as the UE is very close to the users (in particular, the head).

1.5 Important Facts to Attract More Customers

1.5.1 Access Control

There are two possible access methods for femtocells, both of them having some advantages and drawbacks.

Public Access Femtocells

In femtocell networks, an outdoor user could receive a stronger signal from a nearby femtocell than from a distant macrocell. With public access a connection is possible to this femtocell. This method benefits outdoor users, who are able to make use of nearby femtocells, thus reducing the overall use of system resources (power/frequency) and therefore interference. Moreover the situation is identical between neighbouring femtocells. It is possible that in some situations (for example in dense population areas or multi-floored buildings) the signal power of neighbouring femtocells will be higher than the femtocell of the customer. With public access connection to other femtocells would be possible.

Private Access Femtocells

In private access, only a list of registered users can access a femtocell. How the users will enter the list of authorized users has to be defined. Moreover such an approach will increase the interference. For example passing users, if the signal coming from the macrocell is low, will have to increase their power, thus producing more interference with the neighbouring femtocells.

Choice Depending on the Scenarios

The femtocell customers pay for the femtocell themselves, but also for the broadband Internet connection being used for backhaul. That is why access control methods are an important concern for them: should all users passing close to the customer's building have the right to use the femtocells if they do not pay for them? A recent survey [5] shows that customers would prefer femtocells in a private access mode where only a few users are allowed to connect to their femtocells. But in other scenarios like enterprise FAP, many femtocells will have to be used to cover a large area, and also many different passing users can go from offices to offices, which is why the public access will be preferred in nonhome scenarios. Finally there are some concerns to be discussed concerning emergency calls. A FAP is required to provide emergency services, as is the case for VoIP phone providers. That is why in home scenarios, even if private access is preferred, some resources could be released in a public access mode, so that emergency call services can be ensured by everybody.

1.5.2 Standardization

Before the market of femtocells can reach a massive success, a standardization is necessary. It is one of the aims of the Femto Forum to promote this standardization [2]. As a result of the joint work of the Femto Forum, 3GPP and Broadband Forum, which are the three main standards-related organizations for Femto technology, a series of the Femtocell standards has been officially published by 3GPP. The new standard forms part of 3GPP Release 8.

The new Femtocell standard covers four main areas: Network Architecture, Radio and Interference aspects, Femtocell Management/Provisioning and Security. In terms of network architecture, it re-uses existing 3GPP UMTS protocols and extends them to support the needs of high-volume femtocell deployments, detailed in TS25.469. In Rel-8, 3GPP has specified the basic functionalities for the support of HNB and HeNB. The requirements for these basic functionalities were captured in TS 22.011. From Rel-9 onward, it has been agreed to consolidate all the requirements from Rel-8 and further requirements for HNB and HeNB in the TS22.220. TR23.832 describes an IMS capable HNB SubSystem (the HNB and the HNB Gateway) as an optional capability of HNB that, for example, allows an operator to offload CS traffic to the IMS.

From Rel-8, another important feature called Closed Subscriber Group (CSG) is introduced. A HNB may provide restricted access to only UEs belonging to a Closed Subscriber Group (CSG). One or more of such cells, known as CSG cells, are identified by a unique numeric identifier called CSG Identity. The related description can be found in TS25.367.

The following is a summary.

- TS22.220 : Service requirements for HNB and HeNB
- TR23.830 : Architecture aspects of HNB and HeNB
- TR23.832 : IMS aspects of architecture for HNB
- TS25.467 : UTRAN architecture for 3G HNB
- TS25.367 : Mobility procedures for Home Node B (HNB)
- TS25.469 : UTRAN Iuh interface HNB Application Part (HNBAP) signalling
- TR25.820 : 3G Home Node B (HNB) study item
- TR25.967 : FDD Home Node B (HNB) RF Requirements
- TS32.581 : HNB OAM&P, Concepts and requirements for Type 1 interface HNB to HNB Management System
- TS32.582 : HNB OAM&P, Information model for Type 1 interface HNB to HNB Management System
- TS32.583 : HNB OAM&P, Procedure flows for Type 1 interface HNB to HNB Management System
- TR32.821 : Study of Self-Organizing Networks (SON) related OAM Interfaces for Home HNB
- TR33.820 : Security of HNB/HeNB
- TS25468 : UTRAN Iuh Interface RANAP User Adaptation (RUA) signalling

According to the Femto Forum [2], the new standard has adopted the Broadband Forum TR-069 management protocol which has been extended to incorporate a new data model for Femtocells developed collaboratively by Femto Forum and Broadband Forum members and published by the Broadband Forum as Technical Report 196 (TR-196). TR-069 is already widely used in fixed broadband networks and in set-top boxes, and will allow mobile operators to simplify deployment and enable automated remote provisioning, diagnostics checking and software updates.

Work has already been done to incorporate further Femtocell technology in the 3GPP Release 9 standard, which will address LTE Femtocells and also support more advanced functionality for 3G Femtocells. Femtocell standards are also being developed for additional air interface technologies by other industry bodies.

1.5.3 Business Models

Femto Forum published in February 2009 the research [2] conducted by a US-based wireless telecommunications consultancy – Signals Research Group (SRG). The company used data that had been provided by a group of mobile operators and vendors, and they found that femtocells can generate attractive returns for operators by significantly increasing the expected lifetime value of a subscriber across a range of user scenarios. Subscribers in turn could realize cost savings and other benefits from femtocells. Offloading voice and data traffic from the macro network will become a more important factor in the business case as mobile data traffic continues to grow rapidly around the globe. Value-added services that are made possible by the presence of the femtocell in the home will strengthen the business case. Operators can use femtocells to provide deep in-building mobile broadband coverage in a very cost effective manner:

- to provide 2.5 Mbps broadband at home, it costs 320 dollars using the femto solution.
- to provide 2.5 Mbps broadband at home, it costs 900 dollars using the macro solution.

The study implicitly highlights many benefits of femtocells to the consumer:

- fewer dropped calls,
- better voice quality,
- higher data rates,
- potentially attractive tariffs or voice and data bundles.

However, the business case with femtocells is not simple because it often requires two different entities: the mobile network operators that provide the femtocells and the Internet provider who delivers the broadband backhaul connection.

1.5.4 Applications

The first application of femtocells is phone calls, which will be free or at a low price. Moreover, thanks to femtocells, some new applications can be proposed by the operators. Because the indoor coverage will be maximum, some new data intensive services will be experienced by the customers. As described in [6], the new services can be divided into two kinds of application: Femtozone Services and Connected Home Services.

Femtozone Service

These services are web/voice services that are activated when the phone comes to the range of the FAP. Some examples include:

- Receive an SMS to indicate when someone enters or leaves the home.
- A virtual number to reach all the people currently in the home.

Connected Home Services

In these kinds of service, the phone accesses the LAN via the femtocell, in order to control a range of networked services, for example:

- upload some musics from the mobile phone to the PC,
- use the mobile phone to control other devices (TV, HiFi).

Table 1.1 UMA/FAP air interfaces

	At home	Outdoor
Unlicensed Mobile Access (UMA)	WiFi	GSM/CDMA
FAP	GSM/CDMA	GSM/CDMA

The development of new applications will be very important in the future, if femtocells are to succeed and attract more customers.

1.5.5 Femtocells vs Unlicensed Mobile Access (UMA)

Unlicensed Mobile Access extends voice and data applications over IP access networks. The most common approach is the successful dual-mode handset, where the customer can roam and handover between the GSM/UMTS and their WiFi network (see Table 1.1). UMA and femtocells are both efficient solutions to providing Fixed Mobile Convergence. However it is important to note that femtocells have the following advantages:

- Femtocells do not require the use of special dual mode handsets. Every mobile phone can use femtocells.
- Femtocells save the battery compared with dual mode handsets where GSM/UMTS and WiFi interfaces have to coexist, largely increasing the battery consumption.
- With femtocells, thanks to the handover with the outdoor network, users can smoothly use their mobile when they enter or leave their house.
- As detailed before, femtocells are a more interesting solution for operators, because they increase at a low cost their indoor radio coverage, allowing them to provide new services and get more revenues.

In reality, UMA and femtocells are not competitors, but are more complementary, which is why operators are interested by both approaches, which will have to coexist.

1.6 The Structure of the Book

This book is organized as follows.

In Chapter 2 an overview of the different indoor coverage techniques is given. The evolution from macrocell to femtocells is presented and the different methods are compared. Advantages and drawbacks of the different techniques, like Distributed Antenna System (DAS), repeaters, and picocells are given and the main challenges related to femtocells are introduced.

Different possible approaches have been proposed to include a femtocell network within a mobile operator network. Therefore the different femtocell architectures will be presented in Chapter 3, where the different options for ensuring the connectivity of the femtocell to the core network will be described.

The different possible air interfaces for femtocells are presented in Chapter 4: first Global System for Mobile communication (GSM), which is still the main wireless interface in many locations, will be presented. The first deployments will be more focused on Universal Mobile Telecommunication System (UMTS) and High Speed Downlink Packet Access (HSDPA), and in the future, Orthogonal Frequency Division Multiplexing (OFDM) based femtocells like Wireless Interoperability for Microwave Access (WiMAX) and LTE are expected to be produced.

In Chapter 5, the problem of how to simulate femtocells is detailed. The development of a femtocell simulation tool is presented, from radio coverage level, to system level. This chapter considers the different technologies (Code Division Multiple Access (CDMA) or Orthogonal Frequency Division Multiple Access (OFDMA)). This tool will be used in the next chapters to provide some interesting results.

Chapter 6 analyses the important problem of interference due to femtocells. The two main kinds of interference are described and discussed: interference between femtocell and macrocell called *cross-layer*, and interference between neighbouring femtocells called *co-layer*. Some interference cancellation and avoidance techniques will be presented.

In femtocell networks, it is important to manage correctly the mobility of the users, so that they can hand over from the macro to the femto network. The high density of femtocells will require the operators carefully to take into consideration the problem of mobility, such as, for example, how to manage the neighbouring cell lists. That is why the topic of mobility management will be investigated in Chapter 7.

To reduce the negative impact of the femtocells on the network due to interference, the femtocells should be able to configure their main parameters. It is important that the configuration is done by the femtocell device itself, and so in Chapter 8 self-organization is presented.

In Chapter 9, some other important challenges that have to be solved will be presented, such as the solutions to ensuring the timing accuracy, security and the location of the femtocell devices. Finally some other more commercial issues related to access methods, applications and health will be investigated.

In this book, the term FAP is used to denote the femtocell device, while the term *femtocell* makes reference to the coverage area of an FAP. Similarly, Macrocell Base Station (MBS) refers to the hardware that creates a macrocell, while *macrocell* denotes the area of coverage created by the MBS.

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