Femtocell | W-CDMA/LTE Dual Mode | PnP

Technology Reports

W-CDMA/LTE dual-mode Ultra-compact Base Station (Xi Femtocell)

With the rapid increase in mobile traffic, there are pressing demands to quickly and flexibly expand coverage areas for high data rate radio communications.
In November 2012, NTT DOCOMO developed an ultra-compact base station available for both W-CDMA and LTE systems, which the company began operating in December of the same year. The base station enables low-cost and rapid coverage area expansion by employing general-purpose fixed broadband lines and PnP functions to set various operational parameters automatically.

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1. Introduction

In recent years, the spread of smartphones and the expansion of rich multimedia content such as video have led to pressing demands to increase the capacity of mobile networks. To meet these demands, NTT DOCOMO began its "Xi" (crossy) service in December 2010, employing an LTE transmission scheme which offers better frequency usage efficiency[*1] than W-CDMA transmission schemes. There are also strong demands to increase capacity due to the growth of small cell areas and expand coverage areas in more detail. Therefore a more powerful lineup of Base Stations (BSs) had to be developed, in particular more compact and lightweight BSs to provide new coverage in areas that could not be adequately covered by existing BSs. Thus in 2007, NTT DOCOMO developed an ultra-compact base station for small coverage areas (hereinafter referred to as "FOMA Femtocell") and began commercial services with it [1]. FOMA Femtocells are available for the W-CDMA scheme and raise the quality of FOMA services in indoor and underground environments. Then in 2009, NTT DOCOMO developed a new system including a newly designed FOMA Femtocell for residential installations, began new services and improved the quality of FOMA services [2]. In November 2012, NTT DOCOMO then developed a novel base station for indoor small area coverage with both the W-CDMA and LTE schemes (hereinafter referred to as "Xi Femtocell"), which was put into operation in December of the same year. This article describes the applicability, system architecture and specifications of the Xi Femtocell.

2. Overview of Femtocell Base Stations

In contrast to a BS set up on a tower or rooftop (hereinafter referred to as "macrocell BS") with a wide coverage area (macrocell), a femtocell BS is designed for indoor small coverage

*1 **Frequency usage efficiency**: The number of data bits that can be transmitted per unit time over a particular frequency spectrum.

areas such as user residences, small shops and offices. Since the coverage area of the femtocell BS is tiny compared to that of the macrocell BS, the word "Femto," meaning $1/10^{15}$, was chosen as the name of the BS, although this is not a strict definition. For example, other compact BSs installed in large-scale facilities such as shopping malls and stadiums are also called femtocell BSs - small cell BSs can include all of the abovementioned compact BSs and femtocell BSs .

3. Femtocell Base Station Features

3.1 Rapid, Low-cost Expansion of Coverage Areas

Macrocell BSs can only be installed in certain places because they require large constructions such as outdoor housings, towers and antennas in addition to the macrocell BSs themselves. It is also difficult to ensure transmission quality in indoor areas such as upper floors of high-rise buildings and underground areas due to the weak reception levels from outdoor macrocell BSs. It is also difficult to improve the quality of coverage quickly because it takes long time to install a macrocell BS for a local area.

To address these issues, NTT DOCOMO has developed indoor systems to meet various installation conditions and amounts of estimated traffic. For example, there is the In-building Mobile Communication System (IMCS)[*2] that improves transmission quality in indoor areas by transmitting radio waves from BSs to indoor antennas in buildings or underground facilities, as well as optical feeder BSs that provide coverage in buildings and underground facilities outside the coverage areas of macrocell BSs. These systems consist of a Base Unit (BU) and Remote Units (RUs). The former is equipped with digital signal processing, operating and monitoring functions, while the latter are installed inside facilities and function as radio modems connected to the BU via optical fibers.

However, since these systems are large-scale, it isn't always economically feasible to deploy them in small-scale facilities, nor can these systems be deployed quickly due to the comparatively long construction time required. There are low-power radio repeaters available for indoor coverage servicing small numbers of people, but because these repeaters amplify signals from an outdoor macrocell BS to expand its coverage area, received signal strength must be above a certain level or transmission quality in the expanded area cannot be improved.

The femtocell BS can provide alternative and stand-alone coverage even outside areas covered by existing BSs. Furthermore, no new leased line is required because the femtocell BS can connect to the NTT DOCOMO network via a general-purpose fixed broadband line, enabling quick and low-cost installation, while the Plug and Play (PnP)[*3] functions (described later) automatically acquire and set parameters needed for the femtocell BS to operate where it is installed, together which enable massive installation and operational cost reductions (**Figure 1**).

3.2 Improving the Quality of Communications

Because the data transmission capacity provided by each BS is shared by a number of users, the transmission rate experienced by an individual user is affected by the number of users and the way each user is using the resource. However, since femtocell BSs only cover small areas, they handle comparatively fewer users and the adverse effects of other users are thus mitigated. In addition, the femtocell BS can offer more favorable and stable transmission quality compared to the macrocell BS because of shorter propagation distances and good radio environments, and when installed in areas where there are large amounts of traffic, the femtocell BS can take over some of the macrocell BS traffic (offloading traffic onto the femtocell BS). In this way, femtocell BSs can help to raise the overall processing capability of entire radio network systems (Fig. 1).

4. Overview of Xi Femtocell

4.1 Basic Specifications

Specifications of the Xi Femtocell

*2 **IMCS**: NTT DOCOMO's system that provides communication environments in places such as high-rise buildings, underground areas and other locations where it is difficult or impossible for mobile terminals to make connections.

*3 **PnP**: Functions that enable operations to commence just by connecting the equipment to a home broadband line. Setting and adjusting of various parameters are done automatically to suit the environment where the device is installed.

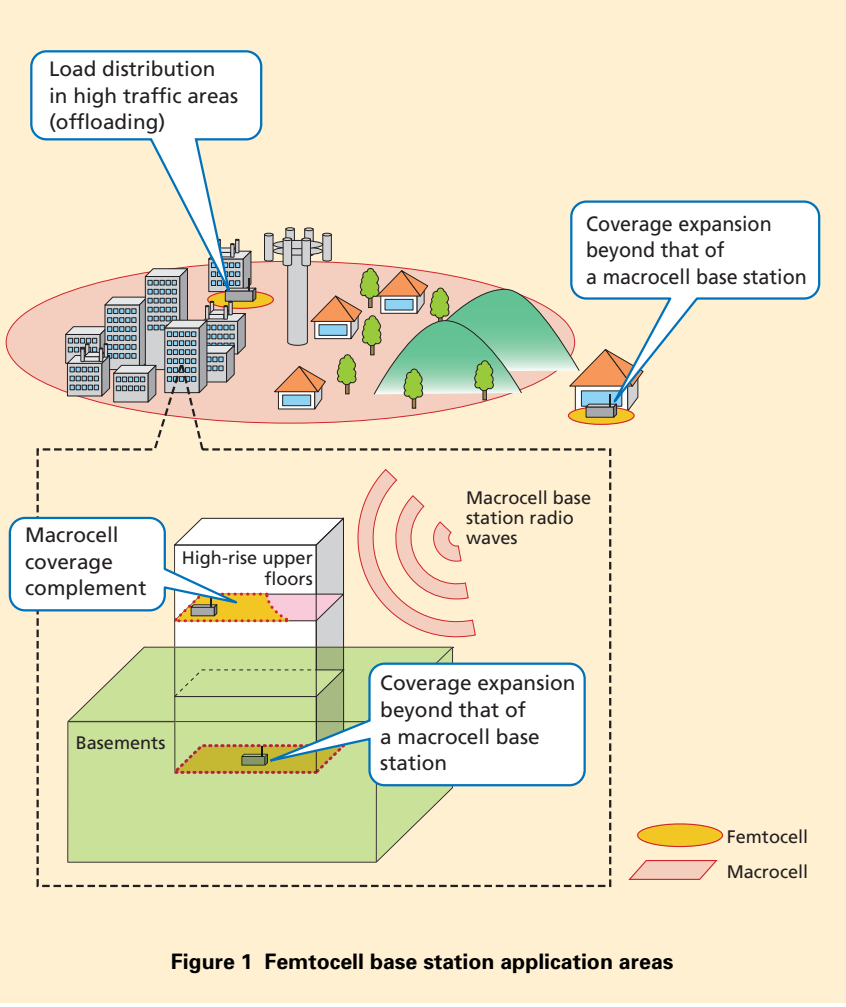

Figure 1 Femtocell base station application areas

are shown in **Table 1**. Specifications for the FOMA Femtocell are also shown as reference in the same table. The Xi Femtocell, designed for indoor areas, can be seen in **Photo 1**. Its most distinctive feature is its ability to simultaneously operate LTE and W-CDMA systems. Enabling optimized, easy-to-use communications, the Xi Femtocell assigns the LTE system for data services such as video and multimedia content and the W-CDMA system for voice services. Users can access either system without any special knowledge or awareness because the Xi femtocell switches systems automatically depending on what services are required.

Both W-CDMA and LTE systems operate with one carrier in the 2 GHz band. LTE offers high-speed data communication at up to 112.5 Mbps downlink and 37.5 Mbps uplink speeds with a maximum bandwidth of 15 MHz.

The use of some of the same com-

Table 1 Xi Femtocell and Femtocell base station specifications

	Xi Femtocell		FOMA Femtocell
Supported systems	LTE	W-CDMA	W-CDMA
Transmission rate (hardware capability)	Downlink: Max. 112.5 Mbps Uplink : Max. 37.5 Mbps	Downlink: Max. 14 Mbps Uplink : Max. 384 Kbps	Downlink: Max. 14 Mbps Uplink : Max. 5.7 Mbps
Frequency band	2 GHz		2 GHz
Bandwidth/ Number of carriers	Max. 15 MHz/one carrier	5 MHz/one carrier	5 MHz/one carrier
Max. transmission power	10 mW/5 MHz/branch	20 mW/5 MHz/branch	20 mW/5 MHz/branch
Number of transmission branches	Two (MIMO-compatible)	one	one
Network interface	10BASE-T/100BASE-TX/1000BASE-T		10BASE-T/100BASE-TX
Size (H x W x D)	Approx. 1.45 L (175 mm x 185 mm x 45 mm)		Approx. 0.85 L (180 mm x 135 mm x 35 mm)
Weight	Approx. 0.7 kg		Approx. 0.4 kg

ponents for both W-CDMA and LTE schemes enables compact size and low power consumption. The unit is naturally cooled, which results in low noise. The internally mounted antennas also help to reduce size and cost. Furthermore, home BS[*4] [3] [4] specifications defined under 3GPP radio characteristics regulations (**Table 2**) are applied to Xi Femtocell under the regulations in Japan. Due to the relaxed specifications regarding frequency stability and reception sensitivity, it is possible to adopt less expensive devices such as crystal oscillators[*5], compared to the macrocell BSs where the stricter wide area base station[*6] 3GPP specifications apply. Additionally, the Xi Femtocell is equipped with a correction function to regularly synchronize internal time with a high-precision external reference clock, and since this is accessible by all Xi Femtocells over the DOCOMO network, less expensive components can be used to further cut costs.

Photo 1 Xi Femtocell

4.2 Network Configuration

An example of network configurations with Xi Femtocell is shown in **Figure 2**.

1) Applicability to General-purpose Fixed Broadband Lines

The Xi Femtocell supports both Point-to-Point Protocol over Ethernet (PPPoE)[*7] and Dynamic Host Configuration Protocol (DHCP)[*8] for acquiring IP addresses to adapt to various installation conditions. In the former, the Xi Femtocell acts as a PPPoE terminal and acquires an IP address from a network terminal device on the fixed broadband line. In the latter, a broadband router on a home LAN acts as the PPPoE terminal and supplies the Xi Femtocell with an IP address via DHCP. The Xi Femtocell also adopts Security Architecture for Internet Protocol (IPsec)[*9] as Internet encryption technology for each Xi and FOMA network link. Setting IPsec for each network link enables Xi and FOMA data identification on a single Ethernet port.

Table 2 Comparison of home BS and wide area BS 3GPP standards

Standard		Home BS		Wide Area BS	
Communication system		W-CDMA	LTE	W-CDMA	LTE
Transmission system	Max. transmission power	+20 dBm		Not defined	
	Frequency stability	less than +/– (0.25 ppm+12 Hz)		less than +/– (0.05 ppm+12 Hz)	
Reception system	Receiver sensitivity	–106.3 dBm	–92.8 dBm/5 MHz	–120.3 dBm	–100.8 dBm/5 MHz
	Adjacent channel selectivity	–38 dBm	–28 dBm	–52 dBm	–52 dBm
	Spurious response	–30 dBm	–27 dBm	–40 dBm	–43 dBm
	Intermodulation characteristics	–38 dBm	–36 dBm	–48 dBm	–52 dBm

*4 **Home BS**: A base station classification for residential and indoor base stations. Defined under 3GPP.
*5 **Crystal oscillator**: An oscillator that uses the Piezo electric effect of crystals to produce highly precise frequencies.
*6 **Wide area base station**: A base station classification for outdoor base stations. Defined under 3GPP.
*7 **PPPoE**: A protocol for using PPP functions over Ethernet. PPP provides functions for automatically allocating an IP address and performing user authentication.
*8 **DHCP**: A protocol used for automatically allocating information (e.g., IP addresses) to devices connected to networks.

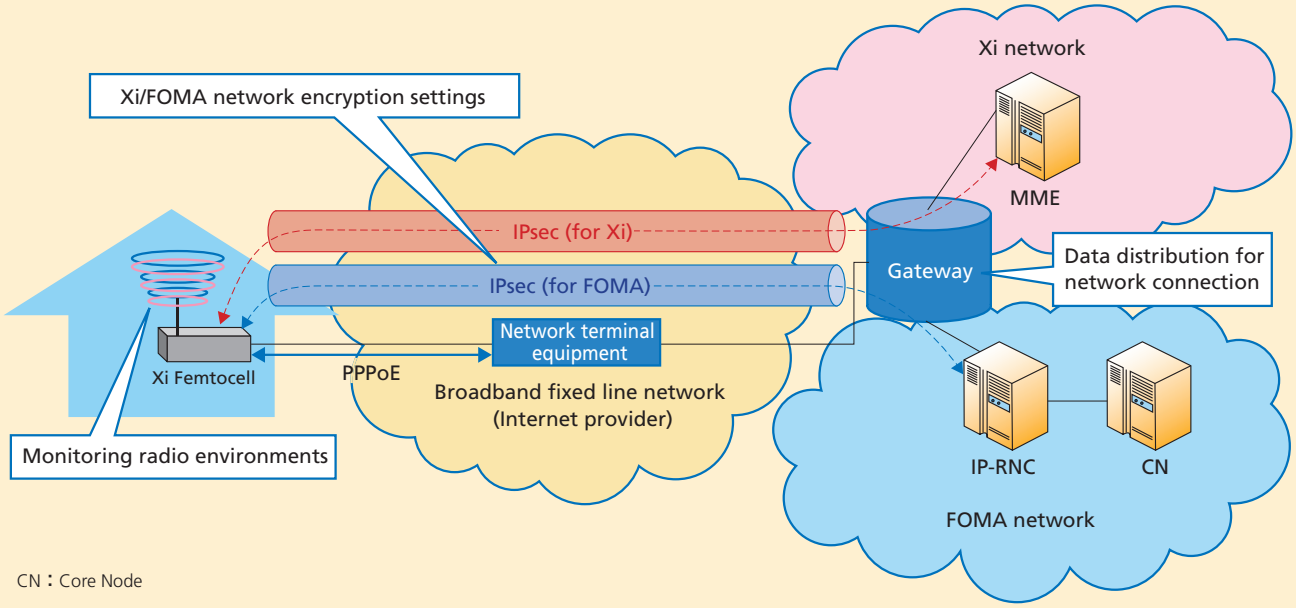

Figure 2 Network configuration example with Xi Femtocell (PPPoE termination)

2) PnP Capabilities

(1) Wired PnP capabilities

The Xi Femtocell automatically connects to Xi and FOMA networks by acquiring and setting data required to connect to the Mobility Management Entity (MME)[*10]/IP-Radio Network Controller (IP-RNC)[*11] over IPsec lines. Furthermore, when IPsec lines are established, Extensible Authentication Protocol method for 3rd generation-Authentication and Key Agreement (EAP-AKA)[*12] [5] is adopted as the authentication method for the authentication key data in the Universal Subscriber Identity Module (USIM)[*13] in the Xi Femtocell.

(2) Radio PnP capabilities

Xi Femtocells monitor surrounding radio environments at initial start-up and at regular intervals to automatically set radio parameters (frequency, transmission power, codes and so forth) to suit their local radio environment, and thus provide optimized radio coverage across entire networks that include Xi Femtocells.

4.3 Other Features

Xi Femtocells simultaneously operate Xi and FOMA services. However, if the FOMA service becomes unavailable due to equipment or fixed line malfunction, it may be impossible to switch to the Xi service as an alternative. In this case, when the Xi femtocell is installed in an area covered by a macrocell BS, its operation is suspended and all its users handed over to the macrocell BS to minimize adverse effects on communication services (**Figure 3** (a)). In contrast, in environments where the Xi Femtocell is installed outside a macrocell BS coverage area, the Xi service can be continued even if the FOMA service is unavailable (Fig. 3 (b)).

In local environments, Xi Femtocells monitor Xi and FOMA operations to determine whether one service can be continued if the other is unavailable.

5. Conclusion

This article has described an overview of the W-CDMA/LTE dual-

*9 **IPsec**: A protocol for high-security communications that performs authentication and encrypts IP packets.
*10 **MME**: A logical node that accommodates a base station (eNodeB) and provides mobility management and other functions.
*11 **IP-RNC**: 3G nodes that perform functions such as radio resource control. Developed based on IP technologies, these nodes have IP and ATM interfaces.
*12 **EAP-AKA**: An authentication and key-sharing system for third-generation mobile communications standardized by the Internet Engineering Task Force (IETF).
*13 **USIM**: An IC card that contains data for the user's subscription with the mobile operator. A mobile communication subscriber identification module for W-CDMA under 3GPP.

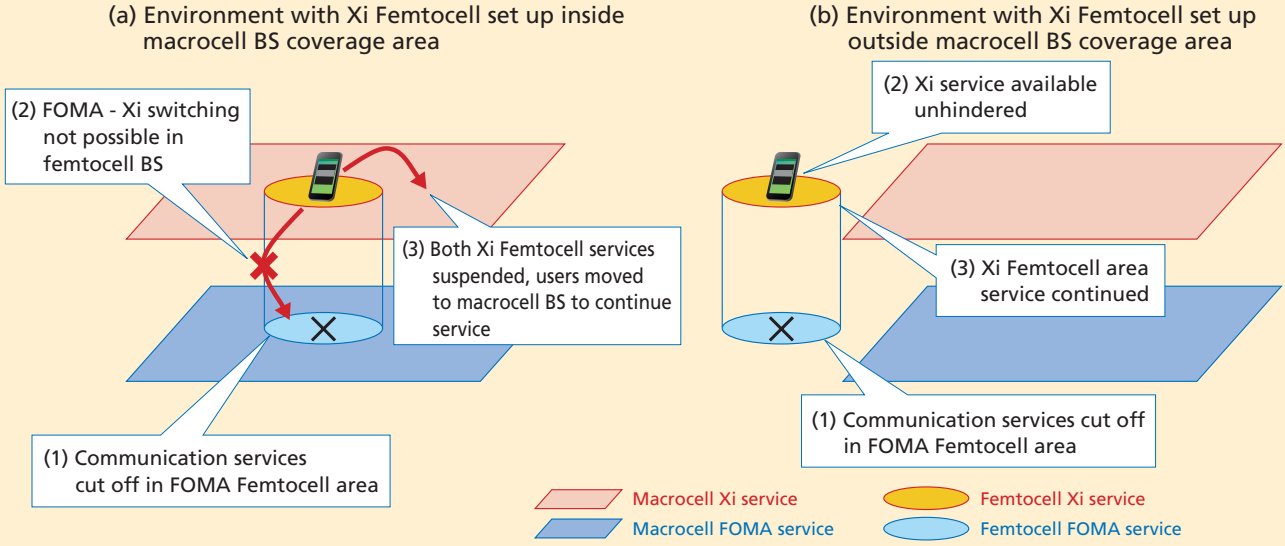

Figure 3 Example of determining service continuation

mode Xi Femtocell developed in November 2012. In the future we plan to further study even higher functionality and expand the range of applications for this technology.

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