Femtocell Base Station Out-of-service Areas

Technology Reports

Super-compact Base Station for Femtocells

To improve indoor-area coverage, we have developed a super-compact base station for femtocells which covers a limited range of service areas, such as homes or small stores, that are not easily reached by radio signals from other base stations. The indoor FOMA service area can be expanded into more-confined areas using this new equipment.

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1. Introduction

To improve quality and deal with out-of-service areas within the FOMA service area, NTT DOCOMO is continually increasing the number of outdoor Base Transceiver Stations (BTSs). As of the end of March, 2008, over 42,000 outdoor BTSs were in operation. For indoor areas, NTT DOCOMO has also been expanding its lineup of equipment, such as optical fiber systems and boosters [1][2]. As of the end of March, 2008, over 15,100 indoor systems were in operation. In spite of these efforts, homes, small stores and other areas where the number of users is limited can be very difficult to add to the coverage area compared to places like train stations, underground shopping arcades and large commercial facilities, due to the equipment and operating costs of installing a BTS in the area.

To resolve this issue, NTT DOCOMO has taken a global lead, developing a super-compact BTS for femtocells (hereinafter reffered to as "Femto BTS") (**Photo 1**), to add small areas such as homes and small stores to the FOMA service area.

In this article we describe the application areas for the Femto BTS, and the technology used to reduce its size, weight and cost and to make the operating cost of the transmission line economical.

2. Overview of the Femto BTS

The Femto BTS is a super-compact BTS for covering limited-range service areas (femtocells) of several tens of meters in radius, such as in homes or small stores. On the other hand, regular outdoor BTSs are installed on towers or roof-tops, and cover service areas from several hundreds of meters to several tens of kilometers in radius (macrocells). Therefore the femto prefix (meaning 10^{-15}) is used in naming the equipment to express the fact that the area covered by the Femto BTS is very small compared to a macrocell and the number of users supported is relatively very small.

In order to install outdoor BTSs, large-scale equipment other than the BTS itself is required (tower, outdoor containment box, antenna, etc.), limiting the locations where they can be

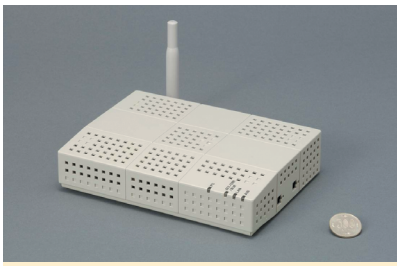

Photo 1 Femto BTS

installed. This makes it difficult to achieve complete service area coverage and the radio signal can be weak in areas such as between buildings, indoors, upper floors of tall buildings and underground. Various indoor systems have been developed to handle these conditions, allowing many out-of-service areas to be added to the service area, but the Femto BTS is making it possible to fill in the coverage area more flexibly, efficiently and economically (**Figure 1**). Also, using outdoor BTSs for data communication, multiple users share the resource of the same BTS, so that transmission speed is affected by other users' communications to a large extent. On the other hand, the number of users occupying a Femto BTS can be limited so that they can use its resources exclusively. Furthermore the propagation environment in an indoor area is much better than that in an outdoor area, so using indoor BTSs can result in improved throughput and easier communication for large-volume data.

3. Application Areas for the Femto BTS

Various equipment has been developed for expanding the FOMA indoor service area effectively, depending on the installation and traffic conditions [3][4] (**Figure 2**).

There are several ways to handle indoor areas using a BTS, including optical feeder systems, which convert electrical signals to optical signals and distribute them to antennas via optical fiber, and coaxial feeder systems, which split the radio signals and distribute them to antennas via coaxial cable. As shown in Fig. 2, an optical feeder system contains a main unit connected to a BTS and up to 256 remote units connected to the main unit by optical fiber for area expansion. This is often used for large-scale buildings. Conversely, a coaxial feeder system simply forwards the radio signal from the BTS and dis-

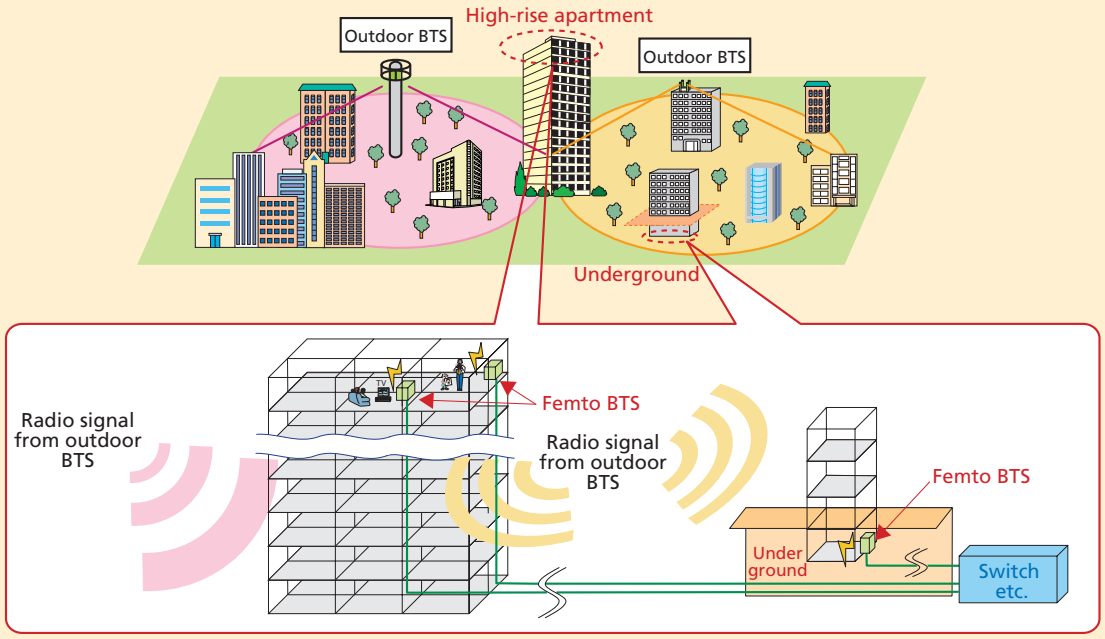

Figure 1 Example Femto BTS application

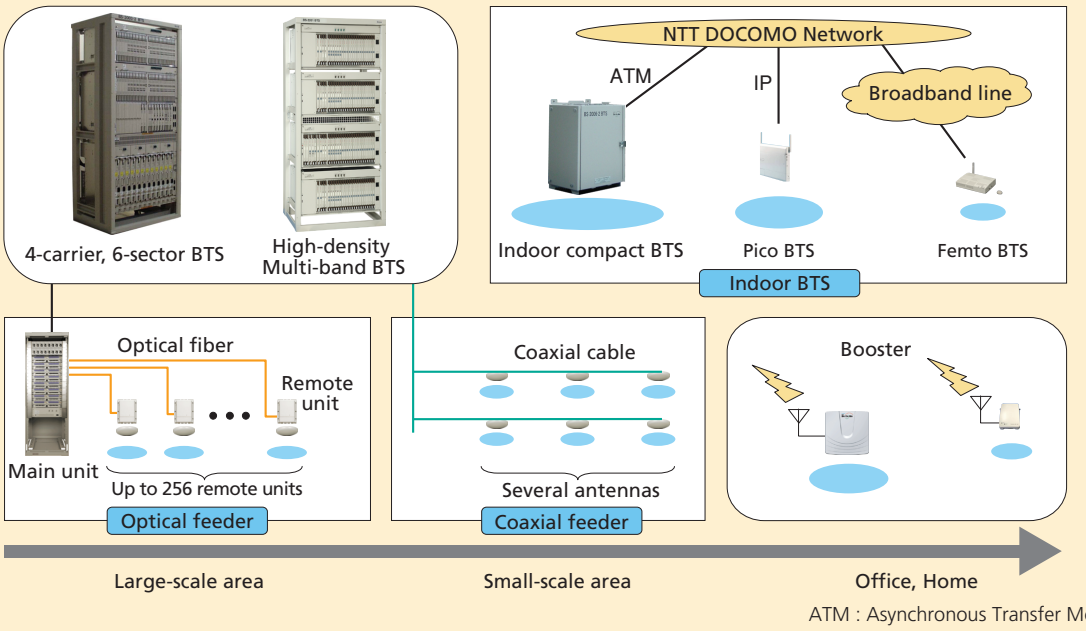

Figure 2 Equipment for covering indoor areas

tributes it using coaxial cables. The number of antennas possible is less than with an optical feeder system due to signal quality deterioration, but it can allow for more economical installation. In either case, however, an expensive BTS must be connected to the system so this makes these approaches infeasible for small-scale areas.

In contrast, the Pico BTS[*1], Femto BTS and boosters, allow independent coverage of an area, and can be applied to a small office of several tens of people, or a home or a small store with several individuals. The Pico BTS is designed for small-scale offices, while the Femto BTS is designed to target homes and small stores. Boosters can also be used in homes to amplify the radio signals from BTSs and expand the coverage area, but a radio signal from an outdoor BTS that are strong-enough must be available, requiring additional construction work to install equipment, cables and antennas. The Pico BTS and Femto BTS use an IP transmission line and, particularly for the Femto BTS, a typical broadband line used for broadband Internet service at home can be used. By making it possible to use a broadband line instead of a conventional IP leased line, the operating costs of the transmission line are greatly reduced. With the Femto BTS, areas where the FOMA signal does not reach can be added to the FOMA service area using a broadband line. Installation requires only the broadband-line connection and an AC adaptor connection, making it easy to expand the FOMA area economically.

4. Features of the Femto BTS

4.1 Basic Specifications

The basic specifications of the Femto BTS and Pico BTS are shown in **Table 1**. Both are BTSs for indoor areas with a single carrier in the 2 GHz band. The Pico BTS can cover a cell of radius from several tens of meters to several hundreds of meters, and the Femto BTS can cover a cell of radius up to several tens of meters. As the cell radius is reduced the maximum transmission power required also decreases, so power consumption can be further reduced. Also, as a result of activity of the domestic standardization body, it has become possible to apply the Local

*1 **Pico BTS**: A small FOMA BTS designed for small offices and allowing up to 32 simultaneous connections. Also supporting IP transport and used for "OFFICEED", a flat-rate communication service among groups of people pre-registered to an area.

Area Base Station (BS)[*2] standards, radio characteristics specified by the 3rd Generation Partnership Project (3GPP) (**Table 2**) for indoor BTS equipment [5]. Therefore NTT DOCOMO has applied the standard to the Femto BTS as a first among NTT DOCOMO's indoor BTSs. Because the requirements for reference sensitivity and frequency stability are somewhat relaxed for the Local Area BS standard, internal devices such as crystal oscillators that are low-cost compared to those for Wide Area BS[*3] standard can be used. Also, by optimizing specifications for home use, such as limiting simultaneous connections to four users, the scale of the circuits can be reduced. Based on this optimization, the Femto BTS was implemented approximately one third smaller, one fifth lighter, consuming one eighth less power, and costing approximately on sixth less than the Pico BTS.

Table 1 Basic specifications for Femto BTS and Pico BTS

	Femto BTS	Pico BTS
Frequency band	2 GHz band	
Number of carriers	1 Carrier	
Transmission power	20 mW	100 mW
Number of users	4 Users	32 Users
Size	W135×H184×D40 mm	W320×H240×D45 mm
Weight	Approx. 0.6 kg	Approx. 3.0 kg
Power consumption	12 W or less	100 W or less

Table 2 Comparison of Local Area BS and Wide Area BS specifications

	Classification	Local Area BS	Wide Area BS
Transmitter	Maximum transmission power	+24 dBm or less	No regulation
	Frequency stability	Within ±0.1 ppm	Within ±0.05 ppm
Receiver	Reference sensitivity	–106.3 dBm	–120.3 dBm
	Adjacent channel selectivity	–38 dBm	–52 dBm
	Spurious response	–30 dBm	–40 dBm
	Intermodulation characteristic	–38 dBm	–48 dBm

4.2 Network Configuration

An example of the network configuration for the Femto BTS is shown in **Figure 3**. The network configuration for the Pico BTS required a leased line such as FlatEther[*4] or dark fiber[*5], but the Femto BTS has been implemented using Point-to-Point Protocol over Ethernet (PPPoE)[*6] and Dynamic Host Configuration Protocol (DHCP)[*7], so in addition to dedicated-line connections,

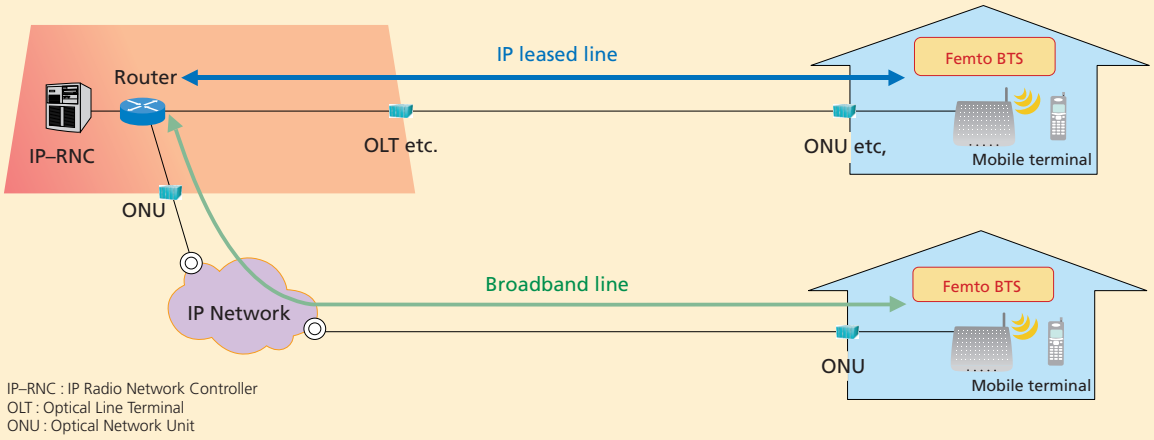

Figure 3 Example Femto BTS network configuration

*2 **Local Area BS**: A BTS classification setting standards for radio characteristics on indoor BTS. Defined by the 3GPP.
*3 **Wide Area BS**: A BTS classification setting standards for radio characteristics on outdoor BTS. Defined by the 3GPP.
*4 **FlatEther**: A wide-area Ethernet service provided by NTT East Corp. and NTT West Corp.
*5 **Dark fiber**: Optical fiber installed but not yet used by telecommunications carriers such as NTT East Corp. or NTT West Corp., and lent to another telecommunications carriers.
*6 **PPPoE**: A protocol for using PPP functions over Ethernet. PPP provides functions for automatically allocating an IP address and performing user authentication.

network configurations using broadband lines can also be used. When using a broadband line, a PPPoE function is necessary to obtain an IP address, but the Femto BTS supports various configurations, terminating PPPoE, or connecting to a router which terminates PPPoE in a DHCP-configured home LAN environment. The Femto BTS will be used with broadband lines in addition to leased lines, so security measures are required to prevent interception or falsification of data. Security architecture for the Internet Protocol (IPSec)[*8] encryption technology is used between the Femto BTS and the NTT DOCOMO network.

4.3 Other Features

Regular AC power is generally the easiest source of power in households, but depending on the situation, Power over Ethernet (PoE)[*9] is another available option for the Femto BTS. By using a device which supports PoE, the Femto BTS can also be used in locations where regular AC power is not available, making installation even more flexible.

5. Conclusion

We have developed the Femto BTS, which can be used to add homes and small stores to the FOMA coverage area.

In this article, we have described the technology used to reduce the equipment costs and make operating costs economical for areas where the number of users is limited. In the future, we will continue to study ways to increase transmission speeds and further improve the performance of the Femto BTS.

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[5] 3GPP TS25.141 V6.19.0 (2008-03): "Base Station (BS) conformance testing (FDD)."

*7 **DHCP**: An Internet application protocol over User Datagram Protocol (UDP) used to dynamically allocate network informations such as IP address to a network client.

*8 **IPSec**: A protocol for high-security communications that performs authentication and encrypts IP packets.

*9 **PoE**: Technology to transmit electrical power, to other LAN devices using Category 5 or above LAN cables (Unshielded Twist Pair (UTP) cables). Being standardized by IEEE802.3ef.