Femtocell | Zero Touch PnP | Household Installation

Technology Reports

Femtocell Technologies for Providing New Services at Home

NTT DOCOMO has developed a femtocell system that is attracting attention around the world because it not only can expand coverage areas inside the house and off-load macro cell traffic to femtocells, but can also enable new services by utilizing presence notification and/or in combination with electrical home appliances. For this system, the number of femto BTSs required is far greater compared with that of macro BTSs. Therefore to drastically reduce OPEX for network optimization, ordinary broadband access line connections and zero touch PnP function with autonomous distributed control are introduced. Moreover the platform providing various services to femtocell users is introduced as well.

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1. Introduction

NTT DOCOMO has already developed and put into commercial service femtocell Base Transceiver Station equipment (femto BTS)[*1] [1] in 2007 in order to expand area coverage into places such as SOHO. This time, with the assumption of household installation and for the purpose of further improving "home areas" such as indoor or underground and user service quality, NTT DOCOMO has developed enhanced femtocell system which is capable of providing new services and Closed Subscriber Groups (CSG) function, and enabling zero touch Plug-and-Play (PnP)[*2].

In developing the household installation type femto BTS, we have adopted a system that is compatible with the current FOMA network system and have developed the enhanced femto BTS, its interconnection platform and mobile terminals corresponding to our femtocell system. Furthermore, we have made it possible for users to make use of ordinary broadband access lines which they are subscribing to and to enable zero touch installation using the PnP function. We have also provided a platform to offer new services to femtocell users utilizing presence notification as well as new services in combination with electrical home appliances. The following services are made possible by this system:

1) Services for Femtocell Users

By registering users for each femtocell, it is possible to provide streaming services of large-volume content such as video. It is also possible to offer only registered users special video/audio contents. For instance, in the "My Area" service [2] launched in November 2009, femtocell users can

*1 **Femto BTS**: Ultra-small cellular base station that covers a small area with a radius of several tens of meters, i.e., a femtocell.

*2 **PnP**: Function that enables the start of operation just by connecting the equipment to the broadband access lines at home. Setting and adjusting of various parameters are done automatically taking into account the installed environment.

enjoy streaming services in which they can play the latest music downloading from the Web sites as their exclusive contents (**Figure 1**).

2) Services Utilizing Presence Notification

It is possible to notify pre-determined users of the registered users' presence information or to send messages to registered users using their presence notification as a trigger. For example, with "My Area," a service is available that enables them to check whether their child or elderly person are at home ("Imasu-ka" function) (**Figure 2**).

3) Services Integrating Electrical Home Appliances

It will be possible to control electrical home appliances utilizing registered user's presence notification. Presence notification database can also be used as a trigger.

Moreover we have developed our femtocell system paying attention to interference management and camp-on problem[*3] that are generally considered as issues to be solved for femtocell systems. **Figure 3** shows the configuration of a femtocell connection.

This article describes technologies adopted in our household installation type femtocell system for "My Area" service launched in November 2009.

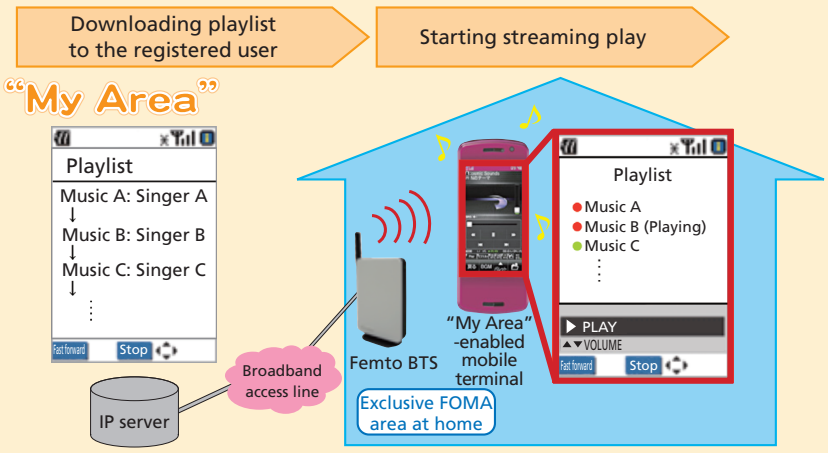


Figure 1 Example of "My Area" service

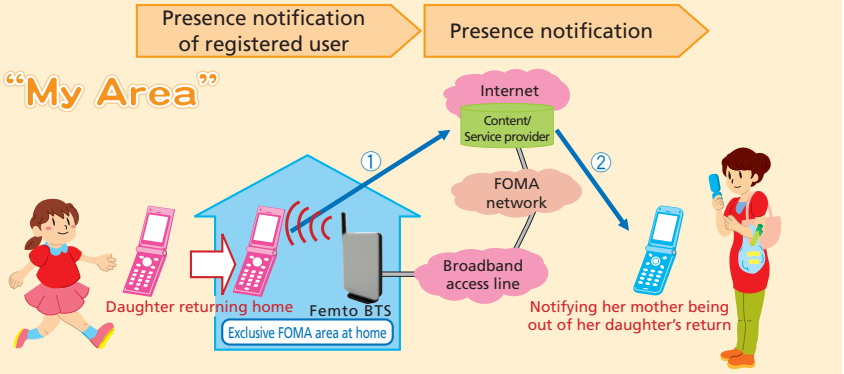
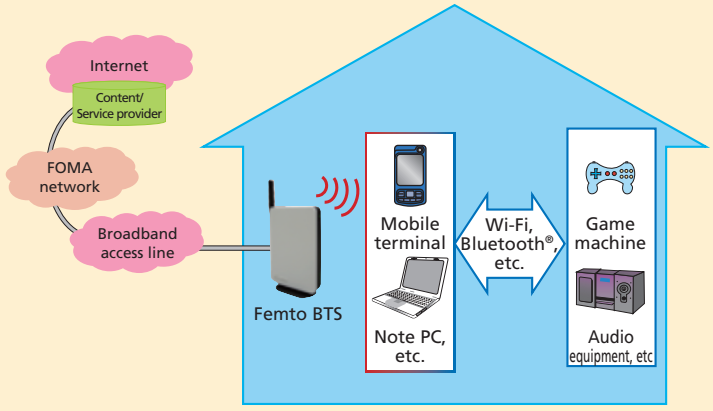


Figure 2 Example of service utilizing presence notification



Bluetooth® : A registered trademark of Bluetooth SIG Inc. in the United States

Figure 3 Overview of femtocell connection configuration

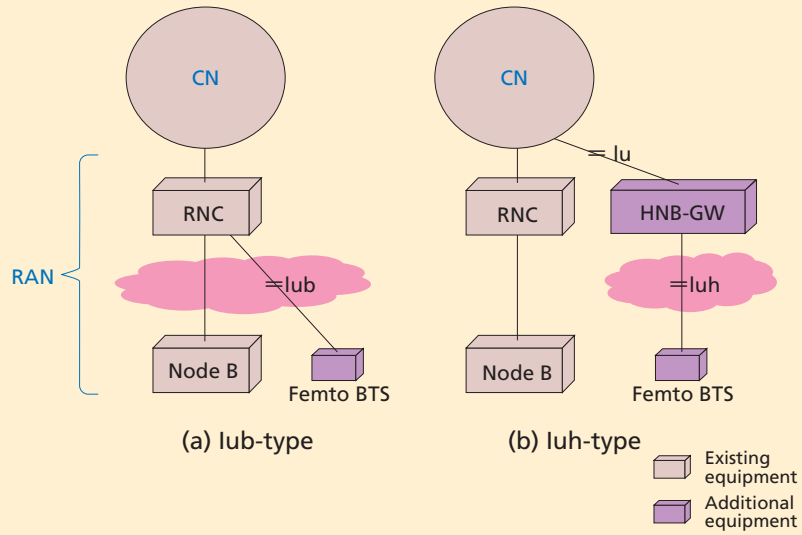
2. Overview of Femtocell System

There are several femtocell system architectures whose examples are shown in **Figure 4**. They are discussed

*3 **Camp-on problem**: Problem caused by inability of a mobile terminal to smoothly camp on a femtocell when more than one frequency is associated with the femtocell.

in 3GPP and other bodies and the discussion is centered around the Iuh-type[*4]. NTT DOCOMO has adopted the Iub-type[*5] in order to make the maximum use of the existing FOMA network and to introduce femtocell system efficiently and economically. By adopting the Iub-type, the addition of new equipments are minimized because mobility control related to femtocells can be taken care of by adding functionalities to the existing Radio Network Controllers (RNCs)[*6].

Functions such as femto BTS management, authorized/unauthorized user control and zero touch PnP function were implemented in order to enable household installation of the femtocell system.



Home Node B Gateway (HNB-GW) : Gateway equipment connecting CN to femto BTS which is defined as HNB in 3GPP.
RAN : Radio Access Network

Figure 4 Architectural variants

3. Femto BTS Management

3.1 Area Information Management

Femtocell presence management is necessary in the Core Network (CN) so that guidance can be given to users camped on a femtocell that their calls are originating from a femtocell, and for the charging of calls originating from a femtocell. In our system, we have newly defined area information[*7] for the femtocell in order to enable the utilization of presence/non-presence notification based on cell location registration. If we were to follow the same Location Area Update procedure as that for macro cell[*8], each femtocell would need to have unique location registration area information of its own but this may exhaust each operator's usable area information values. Therefore, we have separately defined the area information to be recognized by mobile terminals and that to be recognized by the CN, and, by maintaining correspondence between the two, we have made it possible to efficiently use area information values for mobile terminals by recycling. Usage of the same area information among the neighboring femtocells is avoided with the help of the PnP function.

Figure 5 shows the process flow for location registration when a mobile terminal moves from a macro cell to a femtocell.

(1) The mobile terminal recognizes that the area information of the femtocell has changed and sends a "Location Area Update Request" to the CN together with the area information of the neighboring BTS it has camped on up to now. At the same time, The RNC sends to the CN an "Initial UE Message" that contains both the area information for the mobile terminal and the corresponding area information for the CN.

(2) The CN gives back to the mobile terminal a "Location Area Update Response" that contains area information for the mobile terminal set in the "Initial UE Message." The mobile terminal remembers the received area information of the new femtocell on which its mobile terminal now camps. The CN manages the location of the mobile terminal using the area information for the CN.

*4 **Iuh-type**: Configuration in which the femto BTS is connected using the Iuh interface that is defined in 3GPP standard specifications as the logical interface between Home Node B and HNB-GW.

*5 **Iub-type**: Configuration in which the femto BTS is connected using the Iub interface that is defined in 3GPP standard specifications as the logical interface between Node B and RNC (see *6).

*6 **RNC**: Equipment in the FOMA network for radio access and mobility control defined in 3GPP specifications.

*7 **Area information**: Area identification codes used in mobile communication systems (LAI: Location Area Identity, RAI: Routing Area Identity).

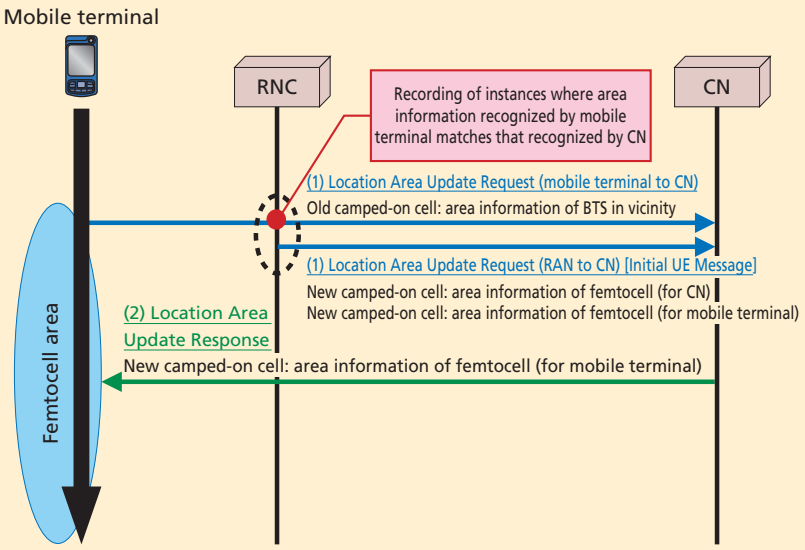


Figure 5 Overview of location registration procedure

3.2 FemtoID Management

At the time of subscription, a unique number, i.e., FemtoID is allocated to each femtocell for call control and as an identifier for management purposes, and this FemtoID is managed in a database. The CN keeps in its mobile terminal subscriber profile a FemtoID list comprising FemtoIDs of femtocells which the terminal is authorized to access and the list is used at the time of location registration for judging whether it is authorized or not.

4. Authorized/ Unauthorized User Control

4.1 Special Number to Guide Mobile Terminal to Access Femtocell

The frequency assigned to the femtocell by the PnP function is not always the same. Therefore, a mobile terminal that was using a different frequency has to switch to this frequency. However, triggering this switch depends on the functions in the mobile terminal as well as the control from the FOMA network and there are cases where the mobile terminal cannot smoothly camp on the femtocell. Thus, in order to guide the mobile terminal to the frequency assigned to the femtocell, a method using a special number has been developed.

The mobile terminal will call the special number and the network will answer with a message indicating that guidance to the femtocell will be initiated and then hangs up. As the network hangs up, it designates one of the frequencies allocated to femtocells and urges the mobile terminal to tune to this frequency. When the mobile terminal has succeeded in registering its location in the femtocell it has been authorized to camp on, the network decides that the guidance is completed. Whether it is authorized or not is judged from the FemtoID that is notified at the time of location registration. Until the location registration is completed, the network continues guidance designating another frequency. Finally, the mobile terminal located in the authorized femtocell area is camped on the femtocell.

4.2 CSG Control

A CSG control function that allows only the authorized mobile terminals to access the femtocell and rejecting unauthorized terminals has been developed in the system. The overview of this function is shown in **Figure 6**. As described above, because location registrations for the femtocell and for the overlaying macro cells are separate, location registration is done when the mobile terminal camps on the femtocell.

The RNC, triggered by the location registration and the sending/receiving of calls in the femtocell, sends the Initial UE Message to the CN that contains such femtocell related information as FemtoID, frequency to be used and area information of overlaying macro cells which are necessary for the above mentioned CN control, i.e., identification of authorized/unauthorized users (Fig. 6(a))

The CN, triggered by call termina-

*8 **Macro cell**: Cellular communication area with a radius of several hundred meters mainly covering outdoors. Usually, antennas are put up on towers or on roofs of buildings.

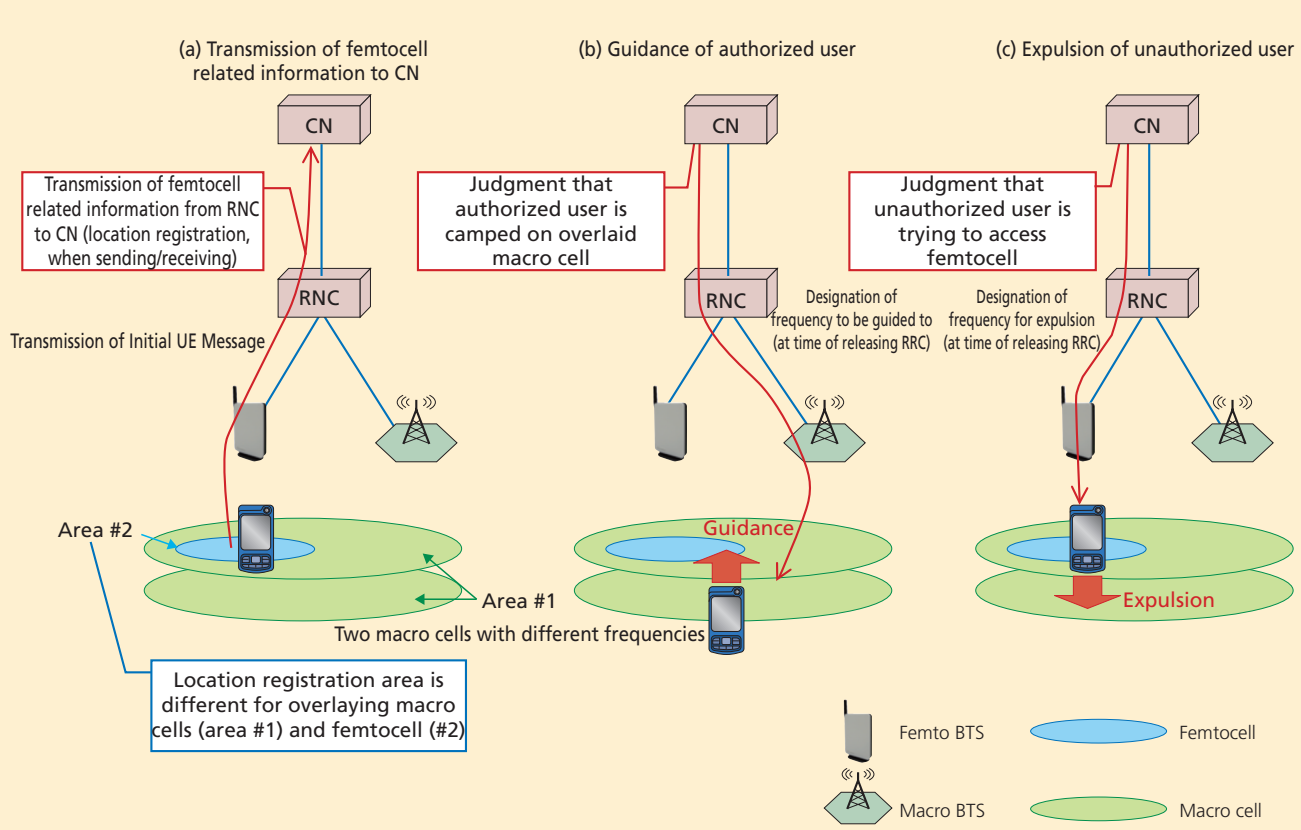


Figure 6 Overview of CSG function

tion and by the fact that the authorized user has registered its location in a macro cell overlaid with the femtocell, instructs the RNC to guide the subject authorized mobile terminal to the frequency of the femtocell. Following instructions, the RNC assigns a frequency as it releases the Radio Resource Control (RRC) connection (Fig. 6(b)).

When the CN finds that an unauthorized mobile terminal is trying to access the femtocell, it rejects registration and at the same time assigns a frequency not used in the femtocell. It is also possible to instruct the femto BTS to temporarily reduce its total output power in order to narrow the femtocell area so that other communicating users in the macro cells will not be affected (Fig. 6(c)).

5. Functions to Enable Simple Installation of Femto BTS

5.1 PnP Function

The overview of the PnP function of the femto BTS is shown in **Figure 7**. When the femto BTS finds that an Ethernet cable is connected to it or that the power is turned on, it connects to the broadband circuit terminating equipment using Point-to-Point Protocol (PPP) and establishes IP security (IPsec)[*9] which is a technology to encrypt communication between femto BTS and the FOMA network so that eavesdropping and falsification of data is prevented in the broadband access lines.

Next, the femto BTS connects to the FOMA network by automatically acquiring information necessary for its operation via the IPsec circuit and setting this information. This includes information concerning the node to be connected to such as RNC.

As for the authentication method for establishing the IPsec, the Extensi-

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

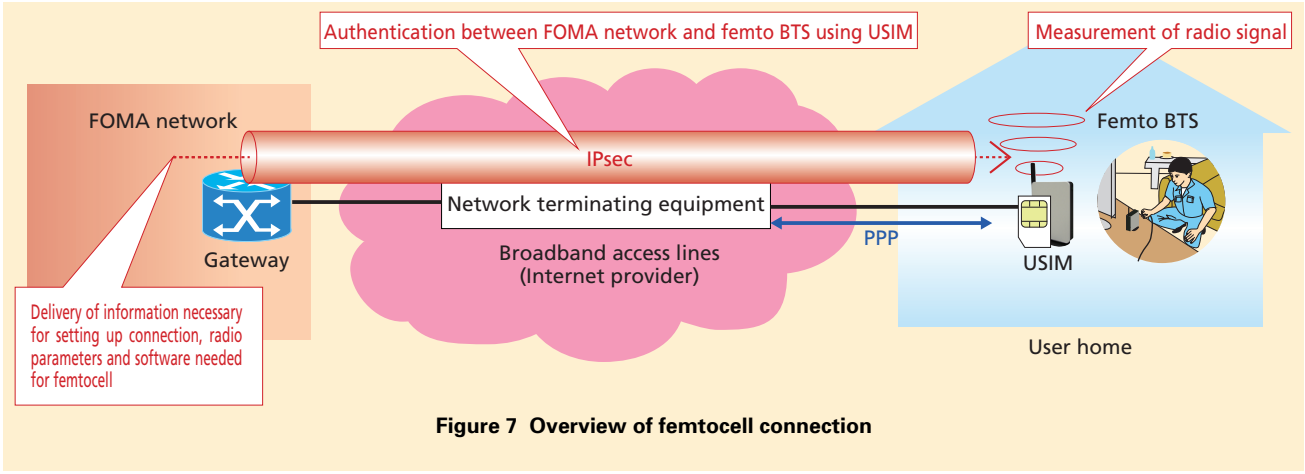


Figure 7 Overview of femtocell connection

ble Authentication Protocol Method for 3rd Generation - Authentication and Key Agreement (EAP-AKA)[*10] already adopted for the Home U Service [3] is used and the authentication is based on the authentication key information contained in the Universal Subscriber Identity Module (USIM)[*11] inserted in the femto BTS.

5.2 Automatic Radio Parameter Adjustment Function

A femto BTS monitors radio signal conditions at its installed site not only at the initial connection but periodically and reports the results to the network. Based on the monitored radio signal condition, the network together with the femto BTS selects the optimum radio parameters (frequency, output power, code, etc.) using the PnP function taking into account its impact on the overlaying macro cells and the neighboring femtocells. This will enable the femto BTS to operate with the optimum performance in the installed environment.

In order to enable emergency communications from the femtocell, legitimacy of the installed location has to be checked. This system has the function of authenticating the installed location based on the report sent from the femto BTS.

5.3 Automatic File Updating Function

A new function has been developed whereby the femto BTS, after starting its operation in the home, periodically checks whether its software is the latest one or not, and if not, automatically downloads the latest software from the network and incorporates the new system functions.

6. Enhanced Femto BTS

Compared with current femto BTS, the enhanced femto BTS supporting this system has realized high-speed packet access as well as the PnP function (**Photo 1**).

Photo 1 Enhanced femto BTS

Regarding data transmission capability, the uplink has increased by four times and the downlink has increased by 15 times with the adoption of High Speed Packet Access (HSPA)[*12] technology. Size and power consumption remain the same as with current femto BTS by adopting Large Scale Integration (LSI) technology (**Table 1**). Thanks to these improvements users can enjoy large volumes of content such as video and music at home in a better communication environment.

*10 **EAP-AKA**: An authentication and key-sharing system for third-generation mobile communications standardized by Internet Engineering Task Force (IETF).

*11 **USIM**: IC card that contains user's contract information with the mobile operator. Mobile communication subscriber identification module for W-CDMA in 3GPP.

*12 **HSPA**: Standard that enables the high speed packet data transmission in W-CDMA; collective term for High Speed Downlink Packet Access (HSDPA) that speeds up the downlink (from base station to mobile terminal) and High Speed Uplink Packet Access (HSUPA) that speeds up uplink (from mobile terminal to base station).

7. Overview of "My Area" -capable Mobile Terminals

This system assumes that dedicated services are provided only to mobile terminals that are camped on the femtocell. Therefore, we have developed functions to let the mobile terminal securely camp on the femtocell as well as to let the user know that the terminal is camped on the femtocell, and we have incorporated these functions into the mobile terminals to be launched as winter/spring 2009 models (F - 01B, SH - 01B, P - 01B, N - 01B, etc.).

1) Function for Assisting Camping on Femtocell

In order for the user to camp on the femtocell, apart from the femtocell guidance function using the special number, a function where the terminal camps on the femtocell spontaneously and with priority has been developed.

In this function the terminal remembers in the form of a list the frequencies and the scrambling codes[*13] associated with the femtocells which it has camped on at least once in the past, and during standby the terminal periodically searches the cells in the list and camps on spontaneously if it finds any femtocell contained in the list (**Figure 8**).

2) Display Showing That the Terminal is Camped on a Femtocell

A function has been developed for displaying on the screen with an icon that this mobile terminal is camped on a

Table 1 Hardware specification for enhanced femto BTS

Equipment name	Current femto BTS	Enhanced femto BTS
Transmission power	20 mW	20 mW
Max. number of simultaneous connection users	4	4
Data transmission capability[*1] (Hardware capability)	Downlink: up to 3.6 Mbit/s (HSDPA) Uplink: up to 384 kbit/s	Downlink: up to 14 Mbit/s (HSDPA) Uplink: up to 5.7 Mbit/s (HSUPA)[*2]
Transmission interface	IP (10BASE-T/100BASE-TX)	IP (10BASE-T/100BASE-TX)
Size (mm) (H×W×D)	184×135×40	180×135×35
Weight	Approx. 0.6 kg	Approx. 0.6 kg
Power consumption	Less than 12 W	Less than 12 W

*1 Data transmission capability is the peak data rates and does not represent actual speeds. Actual transmission is based on best efforts and the speeds vary depending on terminal specifications, communication environment and network congestion.
*2 Although the equipment is fully compatible with HSUPA technology, the launch of a corresponding HSUPA service has not been fixed yet.

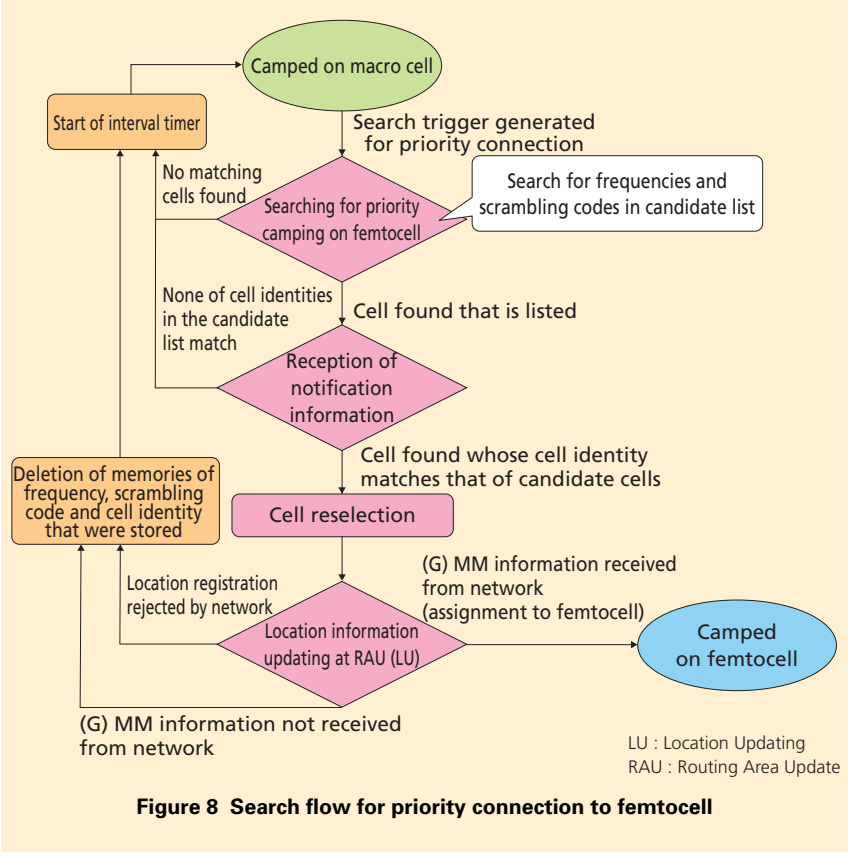


Figure 8 Search flow for priority connection to femtocell

*13 **Scrambling code**: Code used in W-CDMA system for the spreading process, assigned on a per-cell-basis in the downlink (base station to mobile terminal) to distinguish cells.

femtocell when it is indeed camped on a femtocell by using the (General Packet Radio Service) Mobility Management information ((G) MM information)[*14].

8. Conclusion

This article described the technologies developed for the household femtocell system in the FOMA service that was launched as "My Area" in November 2009.

We will examine expanding the femtocell system as well as developing an enhanced femtocell system taking LTE femto BTS into consideration.

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[3] B. Yamauchi et. al: "Home U Service System," NTT DOCOMO Technical Journal, Vol.10, No.3, pp.4-11, Dec.2008.

*14 **(G) MM information**: Name of mobility management message in W-CDMA system sent from CN to mobile terminal when registering location of mobile terminal etc.