M2M | Efficient Use | Congestion

Technology Reports

Network Functions Geared to Operating Characteristics of M2M Devices

As the M2M market continues to expand, M2M devices are expected to make up an increasing percentage of all mobile contracts. In this environment, mobile phone operators must be able to accommodate a large number of devices efficiently while maintaining high reliability with the aim of providing stable communications quality across the entire network. NTT DOCOMO has developed network functions geared to the characteristics of M2M devices to meet these requirements.

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1. Introduction

A Machine to Machine (M2M) device is a communication device that integrates a mobile-phone radio communications section and a control section for that specific device. In this configuration, the latter section automatically controls the former to exchange information with servers and other communications equipment without human intervention. M2M devices have become smaller, lighter, and inexpensive in recent years and have become capable of using high-speed wireless communications at low cost. These features have been generating increasing interest in M2M devices that use wireless communications. M2M communications is already being used in a variety of industries including automatic vending machines and car sharing and the demand for M2M using wireless communications is rising–the forecast is that the percentage of M2M devices making up all mobile contracts will clearly grow larger. Under these conditions, the growing number of M2M devices must be efficiently accommodated by existing facilities and stable communications quality must be provided. To meet these requirements, NTT DOCOMO developed functions geared to the characteristics of M2M devices in the core network*1 and radio access network.

2. Characteristics of M2M Devices

M2M devices have characteristics that differ from the way in which mobile phones like feature phones and smartphones are used. The discussion in this paper targets devices of this type. **Table 1** provides an overview of M2M device characteristics and corresponding functions.

2.1 Characteristic: Communication Interval and Frequency

M2M devices have a periodic communication interval and a low communication frequency as shown in Table 1, so it is desirable that the radio link be released early after terminating communication with the M2M device using the Preservation*2 function to use radio resources*3 efficiently. To this end, NTT DOCOMO developed an efficient Preservation transition function that shortens the time to Preservation transition

*1 **Core network**: A network consisting of service control nodes and subscriber-information management equipment. Mobile terminals communicate with the core network via the radio access network.

Table 1 M2M device characteristics and corresponding functions

	Communication Interval and Frequency	Frequency of Movement	Operation under Abnormal Conditions	Initiation
Smartphones, etc.	Interval: Non-periodic Frequency: High	High	—	Directly after concluding contract
M2M devices	Interval: Periodic Frequency: Low	Zero	Periodic attempts to access network even though network communications has been disconnected	A certain amount of time after concluding contract
Functions geared to characteristics	Efficient Preservation transition function (newly developed)	Area-limited paging signaling (newly developed)	Device repeated-transmission countermeasure (newly developed)	Automatic circuit activation function (existing)

taking M2M device characteristics into account.

2.2 Characteristic: Frequency of Movement

Implementing the efficient Preservation transition function even for the case of a large number of installed M2M devices prevents sharp increases in the number of users simultaneously connected to the network at any point in time thereby preventing drops in quality due to jumps in system load. On the other hand, a situation in which paging signals are sent out to M2M devices in unison can mean a large amount of paging signals proportional to the number of installed M2M devices. This spike in traffic may exceed the network's radio capacity or increase system load and may even disable the transmission of paging signals as a result. Some type of countermeasure is therefore needed to prevent this from happening.

In the case of low-mobility M2M devices that are fixed and exhibit no geographical movement, it is necessary to limit the area in which paging signals are transmitted so as to make more efficient use of the network's wireless capacity and reduce system load. NTT DOCOMO developed an area-limited paging signaling function for this purpose.

2.3 Characteristic: Operation under Abnormal Conditions

If an M2M device determines that an operator's server has failed and network communications has been disconnected, it can be assumed that the device will not be able to identify the problem location and will continue to access the network periodically in an attempt to restore communications.

Consequently, if a large number of M2M devices belonging to the same operator repeatedly execute retransmissions in unison, radio resources can be inefficiently consumed and excessive load generated on the packet switch. This type of repeated transmission must therefore be suppressed, and to this end, NTT DOCOMO developed a device repeated-transmission countermeasure function.

2.4 Characteristic: Initiation

Another characteristic of M2M devices is that a certain period of time is needed from device installation to service commencement. It is therefore desirable that basic charges be applied from the day that the service actually begins.

NTT DOCOMO developed an "automatic circuit activation function" [1] so that basic charges can be applied from the first day of service.

3. Implemented Functions

This section describes the methods used for applying the functions described above.

3.1 Efficient Preservation Transition

The Preservation function was specified in 3rd Generation Partnership Project (3GPP) Technical Specification (TS) 23.606 as a means of releasing only the terminal's radio link when an idle state has continued for a certain period of time after packet communications has been established. In this case, the connection

*2 **Preservation**: A control channel stand-by state in which the communication channel is released.
*3 **Radio resources**: General term for resources needed to allocate radio channels (frequencies).

in the fixed-line core network is still maintained so that only the radio link needs to be reestablished at the time of reconnection. This scheme shortens the time required for connection and makes effective use of radio resources.

In more detail, the Preservation function monitors the duration of an idle state, and if that state continues for a certain period of time, it releases the terminal's radio resources. For M2M devices having a periodic communication interval and a low communication frequency, there is no need to set a radio link with a long duration, so releasing it early makes efficient use of radio resources. In general, however, the idle state monitoring timer uses the same timer setting regardless of device type. If this timer were to be set short for both M2M devices and ordinary devices like smartphones, the latter would end up making frequent retransmissions thereby increasing traffic and generating a load on network facilities.

To deal with this problem and make more effective use of radio resources, an idle state monitoring timer geared to the characteristics of M2M devices must be separated from that of ordinary devices and an appropriate timer setting for M2M use must be established. NTT DOCOMO developed an efficient Preservation transition function for this purpose.

The concept of the efficient Preservation transition function is shown in **Figure 1**. This process begins by storing subscriber information. Then, in the event of a packet transmission from the target M2M device, the function resets the M2M idle state monitoring timer for Preservation transition, and if no packet sending/receiving occurs after that for the time period set, it cuts the radio link and releases radio resources. The M2M idle state monitoring timer is set to a time period shorter than that for ordinary devices like smartphones, which means that the radio link will be released earlier making for more efficient use of radio resources.

3.2 Area-limited Paging Signaling

We first explain the method used to enable ordinary terminals to receive incoming calls in a mobile communications system. To send a paging signal to an ordinary terminal that moves about geographically, the network should always know the location of that terminal. In general, the location of an ordinary terminal is managed in units of mobility management areas*4 each of which usually consists of multiple radio cells. When an ordinary terminal is being called,

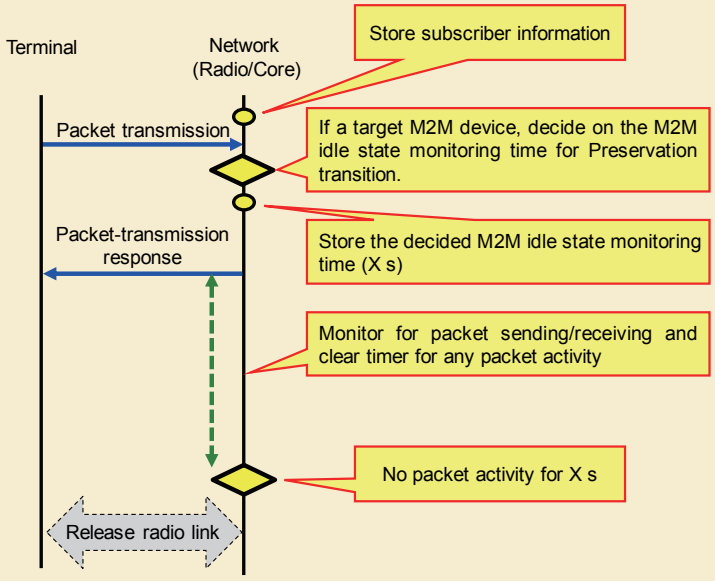

Figure 1 Concept of efficient Preservation transition function

*4 **Mobility management area**: An area in which a mobile terminal can move without registering location.

the network sends a paging signal throughout the mobility management area in which that terminal resides (**Figure 2**). This method, while resulting in many undeliverable paging signals, is effective for a system in which wireless communication devices move about geographically.

However, if the same method were to be used to deliver paging signals to M2M devices that are installed at fixed locations and exhibit no geographical movement, the number of undeliverable paging signals would simply escalate. This could have negative effects such as disabling the transmission of paging signals if the network's wireless capacity is exceeded or the load on the system becomes excessive. To prevent this from happening, the following two methods are applied to achieve area-limited paging signaling.

1) Method 1 (M2M Device with Registered Cell Unchanged)

For a permanently installed, geographically stationary M2M device, this method transmits paging signals only to the specific cell in which the device last performed some sort of communications, which has the effect of using radio resources more efficiently and reducing system load. This method is achieved by a configuration consisting of a Serving GPRS Support Node (SGSN)*5 and a Radio Network Controller (RNC)*6 as shown in **Figure 3**.

In more detail, an RNC sends control signals to the SGSN as part of location registration, packet sending/receiving, and other types of communications and attaches information on the radio cells that it manages. It also informs the SGSN of which cell the targeted wireless communication device is currently located. The SGSN, in turn, records the cell in which that device last performed some sort of communications and attaches that cell information to a paging transmission request sent to the RNC for that geographically stationary M2M device. Then, on receiving that paging transmission request with cell information attached, the RNC transmits a paging signal only to that cell.

For the case of a non-moving M2M device, this method makes it possible to call that device using a paging signal sent only to a specific cell thereby

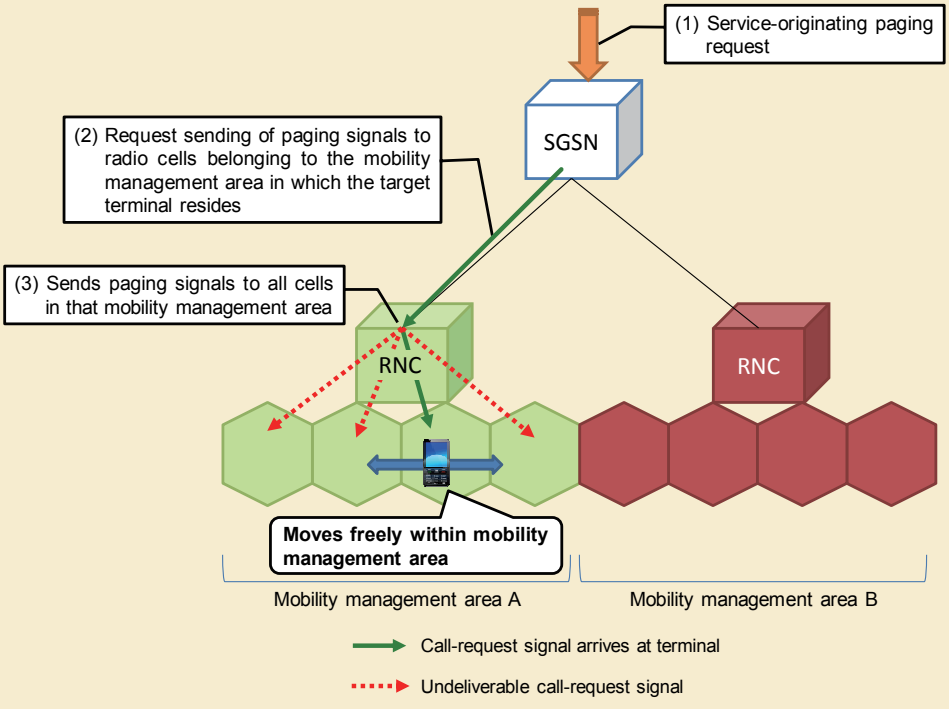

Figure 2 Method of sending a paging signal to a mobile terminal

*5 **SGSN**: Equipment having packet communication functions in a 3G network specified by 3GPP.
*6 **RNC**: A device that performs radio circuit control and migration control in the 3G network defined on 3GPP.

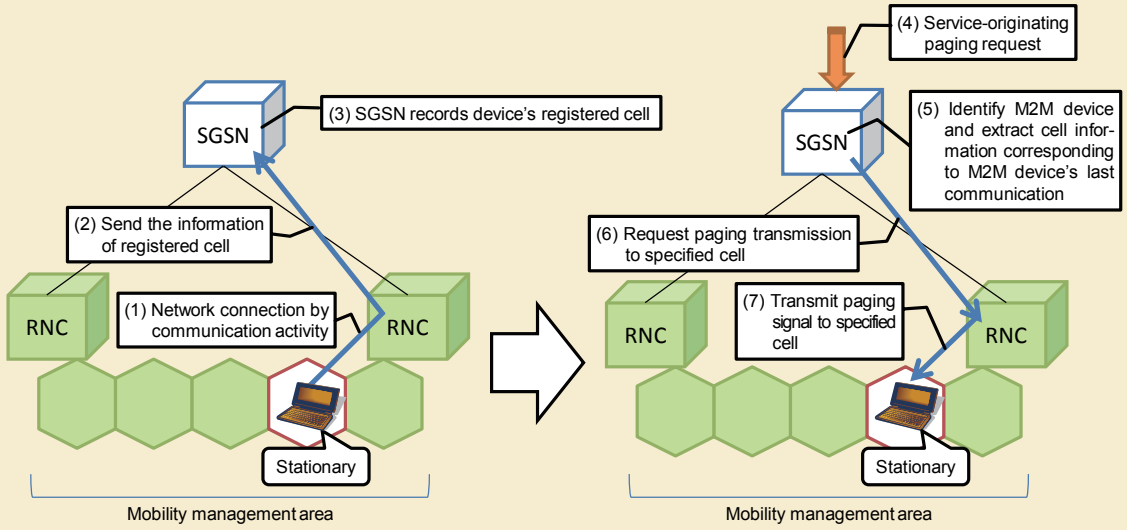

Figure 3 Area-limited paging signaling (registered cell unchanged)

preventing the unnecessary transmission of paging signals to other radio cells.

2) Method 2 (M2M Device with Registered Cell Changed)

It is also possible for the registered cell of even a non-moving M2M device to change. Based on instructions received from the RNC in a system information broadcast*7 during standby, a wireless communication device that includes a M2M device may attempt to change to a registered cell with a stronger and higher quality radio signal if the intensity and quality of signals in the current radio cell have deteriorated. In short, a M2M device's registered cell may change despite the fact that the device may have a fixed position since signal intensity and quality can fluctuate due to changes in the surrounding environment (increase/decrease in interference depending on degree of traffic congestion, presence/absence of moving obstacles like automobiles, etc.)

The method used to achieve area-limited paging signaling for this situation is shown in **Figure 4**. Here, the SGSN detects a no-reply to a paging signal sent only to a specific cell. Consequently, the SGSN decides to send paging signals without specific cell information to the mobility management area. In this way, a paging signal can be delivered even if the M2M device moves.

3.3 Device Repeated-transmission Countermeasure

Mobility Management Backoff (MM-Backoff) has been standardized in 3GPP Rel. 10 as a transmission-suppression function [2]. In the event that the network side cannot accept an attach*8 or location-registration request from a device, this function sets a random timer value in the Reject signal sent from the network switch to the device to instruct the device to suppress retransmissions for the interval set by the timer. Then, on receiving this timer value from the switch, the device refrains from transmitting until this standby interval expires.

It must be pointed out, though, that there is a tendency to use inexpensive M2M devices to keep manufacturing costs down, and as a result, it can be assumed that most M2M devices will not be equipped with the Rel. 10 MM-Backoff function. There is therefore a need to control congestion on the network side.

*7 **System information broadcast**: The broadcasting of system information to each cell including the mobility management area identifier (used to determine whether a terminal requires location registration), neighboring cell information, radio quality information for changing residence to a neighboring cell, and information for controlling outgoing calls.

*8 **Attach**: A procedure, and the status thereof, for registering a terminal on the network when, for example, its power is switched on.

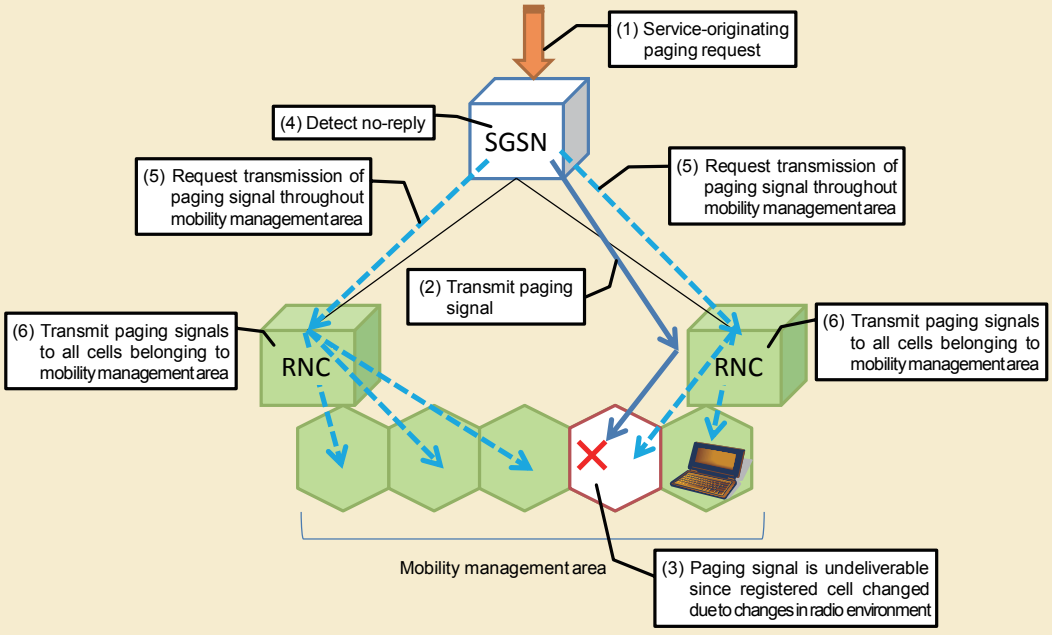

Figure 4 Area-limited paging signaling (registered cell changed)

For this reason, the approach adopted by the network is to identify which M2M devices are making repeated transmissions when an operator's server fails so that it can suppress attach or call requests from those devices. This scheme achieves access control that prevents a load from being applied on the network by excessive reconnection attempts.

3.4 Automatic Circuit Activation Function

Operation of an M2M device must be checked before providing actual M2M services. This requires a function that can test the transmission of the M2M device in a state prior to applying basic use charges.

NTT DOCOMO has developed an "automatic circuit activation function" that combines a function for differentiating between test use and service use in a M2M device and a function for automatically opening the device's circuit at initiation [1].

3.5 Function Application

The functions introduced in this paper were developed so that they could each be applied in a flexible manner. For example, the efficient Preservation transition function can be applied to M2M devices like meter readers characterized by a periodic communication interval and a low communication frequency, and area-limited paging signaling can be applied to M2M devices like automatic vending machines that do not move. Subscriber information or terminal information such as International Mobile Subscriber Identity (IMSI)*9 can be used here to judge function applicability.

4. Conclusion

We described the development of functions for making efficient use of radio resources taking into account the characteristics of M2M devices. These functions constitute the first step toward improving the level of user satisfaction in an environment in which the M2M market is surging and M2M devices are making up an increasing percentage of all mobile contracts. They have made it possible to efficiently accommodate an ever-increasing number of M2M devices with existing facilities and to provide

*9 **IMSI**: A number for uniquely identifying a subscriber, stored in a User Identity Module (UIM) when concluding the contract.

stable communications quality throughout the network.

In addition to NTT DOCOMO, 3GPP has also been conducting technical studies from 2010 to the present with the aim of expanding the M2M market even further and improving network reliability.

At NTT DOCOMO, we plan to continue our work in expanding and enhancing network infrastructure functions while keeping a close watch on standardization trends at 3GPP and other standardization bodies.

References

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[2] K. Sasada et al.: "Core Network Infrastructure and Congestion Control Technology for M2M Communications," NTT DOCOMO Technical Journal, Vol. 15, No. 2, pp. 31–36, Oct. 2013.