Technology Reports

IoT　eDRX　Low-power UIM

Low-power IoT Technology —NTT DOCOMO Provides eDRX Technology and Low-power UIM—

Radio Access Network Development Department Masato Taniguchi

DOCOMO Technology, Inc. Packet Network Division Kazuki Takita Yuichiro Suzuki

Communication Device Development Department Takehiro Ida

In terms of battery life etc., there are demands for IoT communications terminals that consume less power than conventional terminals such as smartphones. In 2017, NTT DOCOMO began providing eDRX technology that reduces power consumption during standby and a low-power UIM to meet these demands.

This article describes the operating principles and characteristics of these technologies.

1. Introduction

Use cases of Internet of Things (IoT)*1 communications terminals could include devices such as environmental sensors or measuring instruments installed in locations where a power supply might not necessarily be secured. In such cases, power can be secured using batteries, although having many terminals installed in dispersed locations etc. will likely lead to cost blowouts due to the difficulty involved with replacing many batteries.

However, some IoT devices communicate less frequently than conventional devices, for example, they only send sensing data once a day [1]. In such communications scenarios, standby power consumption greatly affects terminal battery life.

Considering the above use cases and IoT device characteristics, NTT DOCOMO is developing low-power technologies for IoT to improve on battery life and power efficiency compared to regular LTE terminals such as smartphones. In 2017, DOCOMO developed and began supporting extended Discontinuous Reception (eDRX) low standby power communications technology, and providing a low-power

*1 IoT: A general term for a style of control and communication where various “things” are connected via the Internet or cloud services.

User Identity Module (UIM)*2.

Using sample devices, the results of measurements showed that the combination of the above two technologies can reduce power consumption by approximately 90% [2].

This article describes how these two low-power technologies are achieved on the DOCOMO network and in terminals.

2. eDRX Technology

To achieve lower terminal power consumption, NTT DOCOMO began supporting eDRX during standby (RRC_IDLE*3), as standardized in 3GPP Release 13 [3].

The following describes the eDRX operating principle, and the trade-off between power consumption and reception latency that should be considered in eDRX parameter settings.

2.1 The eDRX Power Saving Mechanism

Firstly, this section describes technology called Discontinuous Reception (DRX) that is used for energy-saving during standby with conventional terminals such as smartphones. When a terminal is on standby for incoming calls, it attempts to receive Paging*4 messages from the network at timed intervals (the DRX cycle). If a message addressed to the terminal is received at this time, the standby status is released, and communications with the network begin. **Figure 1** (a) shows a schematic diagram of the timing that the terminal attempts to receive Paging.

In this DRX operation, radio signal transmission and reception is suspended while no Paging reception is attempted, which reduces power consumption compared to attempting Paging reception continuously.

eDRX technology improves the effectiveness of

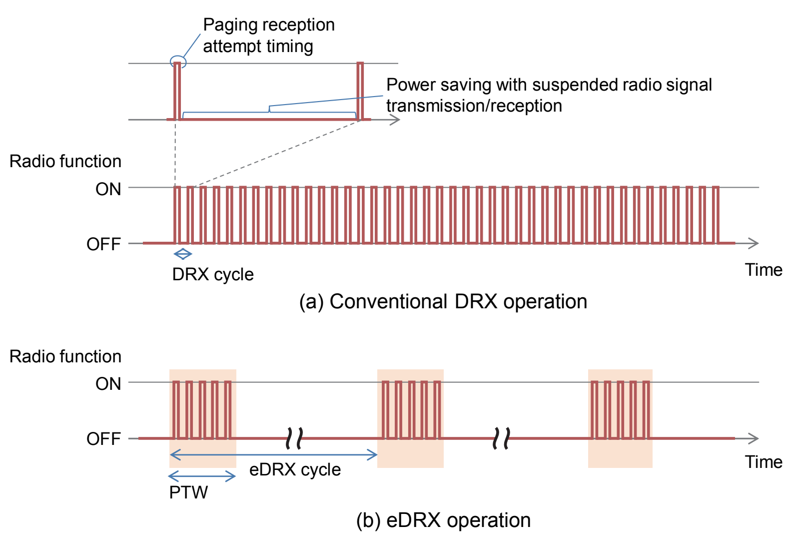


Figure 1 Comparison of DRX and eDRX paging reception timing

*2 UIM: An IC card storing subscriber information including the phone number and the IMSI (see *13), and inserted into the mobile terminal and used to identify the user.

*3 RRC_IDLE: A terminal status in LTE, in which the terminal context is retained in MME (see *5), but not retained in eNB. There are no data communications with RRC_IDLE.

*4 Paging: A procedure and signal for calling UE while camped in a cell in standby mode at the time of an incoming call.

power consumption reduction by reducing the occasions of Paging reception to even fewer than those of DRX described above. Fig. 1 (b) shows a schematic diagram of standby actions with eDRX.

Terminals operating eDRX only attempt to receive Paging according to the DRX cycle described above during periodic interval called the Paging Time Window (PTW). Setting parameters for the PTW length and cycle (eDRX cycle) determines the frequency of Paging reception actions, and hence determines the level of power saving.

For example, Fig. 1 (b) shows a DRX cycle of 1.28 sec, a PTW length of 6.4 sec (1.28 sec × 5), and an eDRX cycle of 102.4 sec (1.28 sec × 80). In this case, a terminal operating eDRX will attempt to receive Paging 5 times in the PTW during the 102.4 second period. Because regular DRX operations entail 80 receptions in the same period, by comparison, the number of reception operations with eDRX is greatly reduced.

2.2 Overview of eDRX Operations

1) Enabling eDRX and Parameter Settings

eDRX is a network-terminal coordination technology. For this reason, eDRX operating conditions (operation enabled/disabled, settings for eDRX parameters (eDRX cycle, PTW length)) must be established between the network and the terminal when the terminal starts etc. Network-terminal procedures are described below (**Figure 2**).

(1) From the terminal, an eDRX parameter request value is notified to Mobile Management Entity (MME)*5.

Waiting for eDRX to be enabled, the terminal requests operations enabling by setting eDRX parameters to an Attach*6/Tracking Area Update (TAU)*7 Request.

(2) The eDRX parameter values are determined by MME

When MME receives the Attach/TAU Request, it decides the actual setting values to be applied based on the eDRX parameter values notified from the terminal.

(3) eDRX parameter setting values are notified from MME to the terminal

MME notifies the terminal of the setting values determined in step (2) with Attach/TAU Accept, and the terminal applies the notified setting values to enable eDRX.

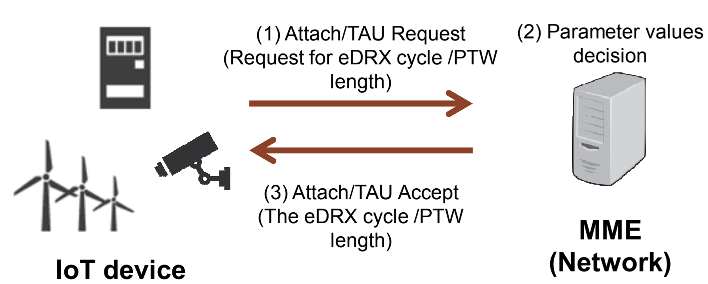


Figure 2 Enabling eDRX and setting parameters

*5 MME: A logical node accommodating a base station (eNB) and providing mobility management and other functions.

*6 Attach: The processing of registering a terminal with a network when terminal power is turned ON, or the state of being registered.

*7 TAU: Processing to update the terminal location registration information.

This procedure can be used to apply eDRX to only the terminals that require eDRX to be enabled, such as IoT devices.

2) Incoming Call Actions during eDRX Standby

Terminals on eDRX standby cannot receive Paging outside of the PTW interval (max. 43 minutes). However, users (e.g., IoT device administrators) or applications that need to communicate with the terminal send data to the terminal regardless of the terminal-side PTW timing.

To compensate for these timing differences, Evolved Packet Core (EPC)*8 uses High Latency Communication (HLCom)*9 technology to control transmission of Paging messages to the terminal with suitable timing, and buffer data for transmission.

Figure 3 shows the HLCom control sequence.

(1) When data packets from the server to the terminal arrive on the network, the arrival is notified to MME while the Serving GateWay (S-GW)*10 buffers the packet.

(2) If the terminal status is outside the PTW, MME derives the time until the terminal can receive the incoming packet in light of the time until the subsequent PTW opens and the Paging message response time etc. Then, MME notifies the packet buffering time (DL Buffering Duration) to S-GW, and S-GW extends packet buffering until the notified time.

(3) MME retains the Paging message transmission until the subsequent PTW open time, and then sends the Paging message to evolved NodeB (eNB)*11 at the PTW open time.

(4) After that, a communications bearer*12 is established between the terminal and the network, and the data packet is sent from S-GW to the terminal.

3) Dispersion of Paging Reception Timing between Terminals

While it's possible to call multiple terminals at the same time with one instance of Paging, the number of terminals that can be called at the same time is limited (a maximum of 16 in standard specifications). If calling to more than the maximum occurs at the same Paging instance, the network postpones Paging transmission. In cases where postponements are not possible due to extremely large amount of Paging conflicts, Paging messages are eventually discarded.

(a) Reception timing determination in DRX operations

To reduce conflicts of Paging with simultaneous timing, standard specifications prescribe dispersion of Paging reception timing for each terminal during the DRX cycle in conventional DRX operations. This dispersion is achieved by determining reception timing from a portion of digits from the terminal International Mobile Subscriber Identity (IMSI)*13, with a Modulo calculation*14 applied [4].

(b) Improving timing dispersion in eDRX operations

In addition to conventional dispersion methods, PTW open points are dispersed for each terminal in the eDRX function. The PTW open points are calculated by applying Cyclic Redundancy Check (CRC)*15 and Modulo calculations to SAE-Temporary Mobile Subscriber Identity (S-TMSI)*16.

In initial 3GPP discussions, extraction of PTW open points from IMSI was considered,

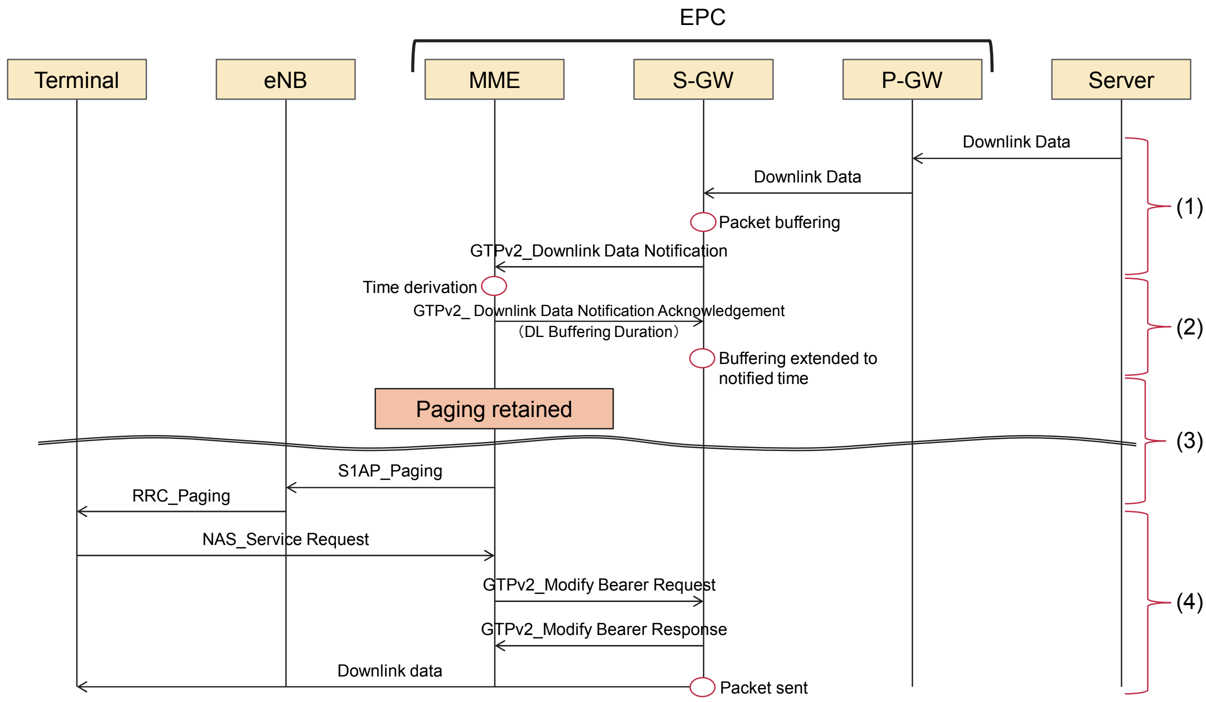
*8 **EPC:** The core network that accommodates radio access networks including LTE.

*9 **HLCom:** A function that controls Paging message transmission and buffers transmission data with appropriate timing for terminals that cannot respond immediately to connection requests using technologies such as eDRX.

*10 **S-GW:** A packet switch on the LTE Network for sending/receiving user data to/from P-GW.

*11 **eNB:** A base station for the LTE radio access system.

*12 **Bearer:** A logical user-data packet transmission path established among P-GW, S-GW, eNB, and UE.



Packet data network GateWay (P-GW): A logical node that has functions to connect terminals with external networks.

Figure 3 HLCom control sequence

however, to improve timing dispersion effectiveness, this was changed to determine PTW open points using S-TMSI instead of the IMSI used with conventional DRX timing.

Depending on the MME implementation, cases where the portions of the S-TMSI digits are close to being fixed can be considered. Thinking of this as a simple example of assignment in order of a series of numbers, the value becomes fixed across longer periods the higher the digits are. To ensure that PTW timing is dispersed appropriately in this case as well, CRC calculation is introduced, where a difference in a small part of the S-TMSI affects the entire part of the computation result used to determine PTW timing.

2.3 The Trade-off between Power Consumption and Incoming Call Latency in the eDRX Cycle

As mentioned, setting a longer eDRX cycle reduces the Paging reception opportunities, and thus

*13 IMSI: A number used in mobile communications that is unique to each user and stored on a UIM card.

*14 Modulo calculation: A calculation for obtaining the remainder when dividing one number with another.

*15 CRC calculation: A calculation which assumes the input bit string as a polynomial and obtains the remainder by division of the polynomial with a particular predetermined polynomial (the generating polynomial). Generally used for detecting errors that occur during data transmission.

*16 S-TMSI: Temporary numbers used for uniquely identifying users on the same network. Issued from MME.

reduces terminal power consumption. However, because it is not possible for a terminal to receive Paging outside the PTW, at maximum, an amount of time equivalent to the eDRX cycle could be required for a downlink incoming call to arrive at the terminal.

Considering the above characteristics, and depending on eDRX-compatible terminal users and system requirements, by setting the value of the eDRX cycle slightly lower than the maximum response latency allowed for incoming calls to the terminal, it's possible to achieve effective reductions in power consumption with eDRX while satisfying target latency requirements.

Moreover, when uplink data occurs to send from a terminal, the standby state is promptly released even if it is outside the PTW, and the uplink data transmission begins. Hence, there is no major impact on uplink data latency with the application of eDRX.

3. Low-power Consumption UIM

3.1 The Role of the UIM in Communications

The UIM operates with the power supplied from the terminal, contains subscriber information granted by the operator, and performs authentication procedures with the network through the terminal with location registration procedures. With these procedures, the subscriber information stored in the UIM is referenced to confirm that the terminal (UIM) is a legitimate user of the operator. In addition, an encryption key is created with the UIM in the authentication procedure to encrypt voice or data for communications with the network (**Figure 4**). Usage requires that the UIM is always

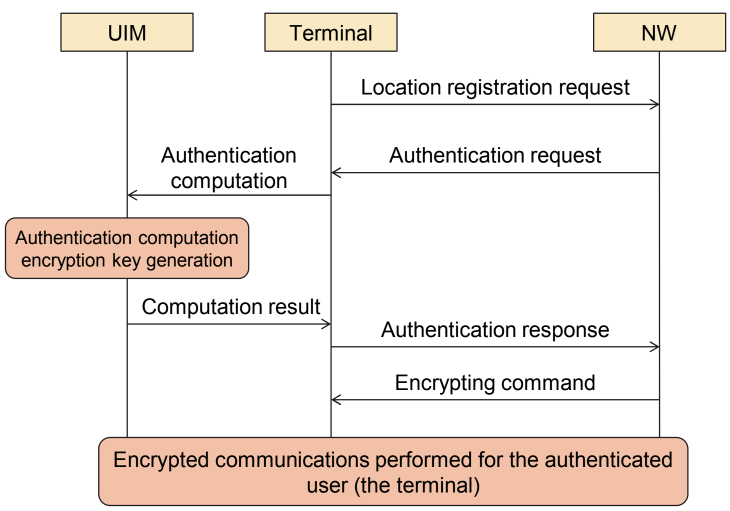


Figure 4 Location registration procedure

inserted into the terminal.

3.2 Power Saving Function

1) Suspension of Universal Integrated Circuit Card (UICC)*17 Presence Detection and Card Application Toolkit (CAT) Polling

As mentioned, because usage requires that the UIM is inserted into the terminal, there is a function called UICC Presence Detection to confirm insertion. With this function, the terminal periodically sends a STATUS command message to the UIM (at least once every 30 seconds in standard specifications), and confirms insertion with the received response. However, in Release 12 and later, this can be omitted to save power if there are no communications with the network. Nevertheless, when communications start, the terminal must send the STATUS command to confirm the presence of the UIM.

Also, to run applications loaded in the UIM, a procedure is periodically run via CAT polling signals from the terminal to confirm the presence of applications waiting to run in the UIM. If there are no applications to run in the UIM, it's possible to suspend polling the UIM in advance.

During the eDRX period, because the terminal is not communicating with the network, these two types of periodic communications between the terminal and the UIM can be suppressed.

2) UIM Deactivate Function

The UIM is constantly supplied power from the terminal so that it can respond to a request from the terminal at any time. However, if there are no communications (including location registration) with the network, the aforementioned UICC Presence Detection and CAT polling can be suspended so that communications between the terminal and the UIM do not occur. This method makes it possible to cut off the power supply to the UIM, reducing its power consumption to 0. Release 13 enables confirmation of whether suspension of the power supply to the UIM during communications is supported by UIM readout, so that the terminal can deactivate the UIM (suspend its operations) as required and cut off the power supply to it. However, because a UIM activate procedure and reading of several files in the UIM are required to start communications, which uses power, this technique is beneficial if a certain level of hibernation or above is expected.

According to the example in standardization documentation (3GPP TR31.970 Table2: Comparison of power consumption [5]) the current flowing to the UIM while the UIM and the terminal are not communicating is low at approximately 15 μA, although this adds up to around 0.36 mAh consumed per day. On the other hand, one activation (start of operations) of the UIM consumes approximately 0.06 mAh. For this reason, usage conditions with low frequencies of communications with the network (including location registrations) such as those of less than several times per day can be expected to be effective.

Combining these technologies enables suppression of power consumed by the UIM (**Figure 5**).

4. Conclusion

This article has described the operating principles and characteristics of the eDRX function and low-power UIM to achieve power saving with IoT terminals.

*17 UICC: An IC card used to record subscriber information such as telephone number and IMSI. UIM and SIM cards are used synonymously.

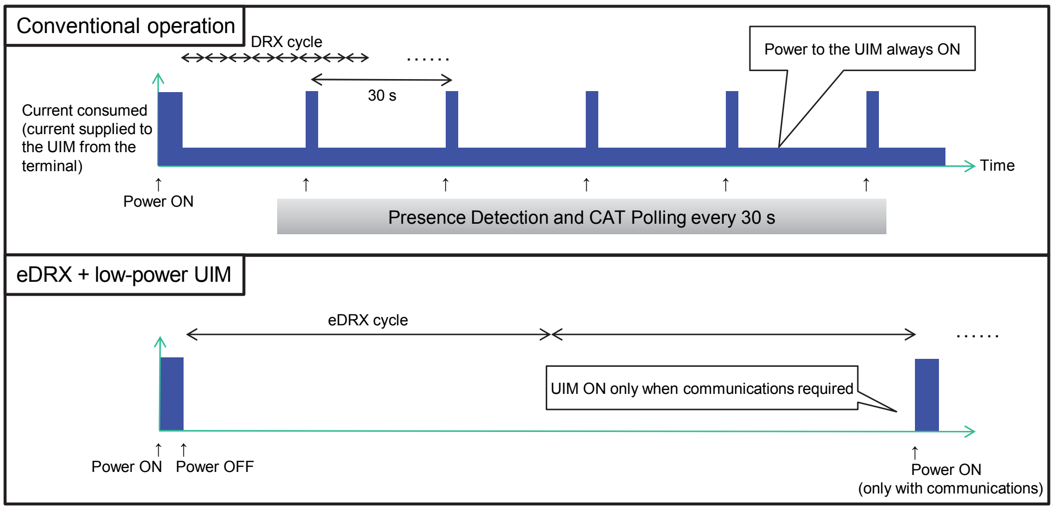


Figure 5 UIM operation and current consumption during standby

Going forward, NTT DOCOMO plans to realize optimized IoT communications environments through commercialization of communications technologies such as UE Category M1 (LTE-M) and UE Category NB1 (NB-IoT) [3].

REFERENCES

[1] 3GPP TR 23.887 V12.0.0: "Study on Machine-Type Communications (MTC) and other mobile data applications communications enhancements," Dec. 2013.

[2] NTT DOCOMO Press Release: "(Notice) NTT DOCOMO begins providing eDRX technology to reduce IoT communications device power consumption to approximately 1/5," Sep. 2017 (In Japanese).
https://www.nttdocomo.co.jp/info/news_release/2017/09/26_01.html

[3] K. Takeda et al.: "New Technologies for Achieving IoT in LTE Release 13," NTT DOCOMO Technical Journal, Vol.18, No.2, pp.39-51, Oct. 2016.

[4] 3GPP TS 36.304 V13.8.0: "Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) procedures in idle mode," Dec. 2017.

[5] 3GPP TR31.970 V14.0.0: "Universal Mobile Telecommunications System (UMTS); LTE UICC power optimisation for Machine-Type Communication," Jun. 2017.