Base Station Simulator | Signaling | Smartphone Power Saving

Technology Reports

# Smartphone App Traffic Evaluation System —Toward Smartphone Power Saving and Network Load Reduction—

*The rapid penetration of smartphones in recent years has generated a noticeable increase in signaling (control signals) traffic compared to conventional feature phones. This means high-frequency background communications in applications and the OS thereby increasing the load on the network and increasing power consumption in the user's smartphone. NTT DOCOMO has developed an evaluation system that can easily assess signaling conditions and background communications and can identify areas for improvement at an early stage at the time of an app or OS release.*

Communication Device Development Department

*Noriaki Kono*
*Hiroo Omori*†
*Kazuo Hayashi*

## 1. Introduction

The smartphone has made it possible to provide a variety of new functions and services and the ways in which the smartphone is coming to be used in everyday life are increasing rapidly. On the other hand, many users are voicing their dissatisfaction with power consumption in the standby state that can deplete battery power and make the phone unusable.

One of the reasons for this problem is the increase in power consumption due to background communications performed by applications and the OS unrelated to user operations. Such background communications occur in Push-type*1 data acquisition for achieving real-time transmitting/receiving in smartphones as in the case of Instant Message (IM)*2 processing and in Pull-type*3 data acquisition that is performed frequently to get information that is constantly changing as in the case of weather reports.

Furthermore, in addition to increasing power consumption, background communications increases the load on the network. For example, a smartphone that is initiating communications will transmit and receive control signals in a process called signaling*4 to reserve resources such as radio control equipment and switches. Such a reserved resource will be released if the smartphone does not periodically communicate with it and a released resource will again be reserved the next time that the smartphone communicates with it. As a consequence, discontinuous communications such as that which occurs in background communications will always be accompanied by signaling. Given a smartphone $i$ that generates signaling at frequency $T_i$ as a result of background communications, the signaling load generated continuously on the network by all smartphones can be expressed as $\Sigma T_i$.



† Currently Cellular Phone Division, DOCOMO Technology, Inc.

*1 **Push-type:** A method for delivering necessary information from servers. It requires a communication path called a session between the client and server and the sending of Keep Alive (see *11) messages to maintain the session.

Background communications is therefore a factor in increasing power consumption in the smartphone and traffic load in the network. NTT DOCOMO has been working on measures to save power in smartphones and reduce network load, and this effort has resulted in the development of a smartphone-app traffic evaluation system that makes use of a signaling tester*5 (hereinafter referred to as "base station simulator"). This article describes an overview of the system and our approach to making improvements in smartphone apps.

## 2. System Overview

### 2.1 System Requirements

To analyze power consumption in the smartphone and traffic load on the network due to background communications, it is necessary to analyze not only communication timing and the reason for the communications but also communication-associated power consumption and the occurrence of signaling. This approach uses a technique that performs measurements from various states of connection between the smartphone and the network. In LTE, for example, smartphone/network connection can be divided into three states (hereinafter referred to as "Radio Resource Control (RRC) states"). These are the Connected state in which radio resources*6 are reserved and transmitting/receiving is enabled, the Connected Discontinuous Reception (Connected DRX*7, hereinafter referred to as "CDRX") state in which radio resources are reserved and the smartphone is in standby, and the Idle state in which radio resources have been released and the smartphone is in standby. Transitions among these states occur when data is transferred or when the communication-state monitoring timer expires (**Figure 1**). These states can be ordered as Connected, CDRX, and Idle in terms of power consumption from highest to lowest, so smartphone power consumption may be measured in relation to these states. Furthermore, as signaling occurs at the time of a state transition from Idle to Connected, the amount of signaling may be measured from this RRC state transition.

Accordingly, the system must be capable of measuring the following three elements:

(1) Communications timing: Must be able to measure when background communications occur

(2) Reason of communications: Must be able to determine why background communications occur

(3) RRC states: Must be able to measure power consumption and signaling occurrence due to background communications

### 2.2 Comparison of Evaluation Techniques

We can consider a number of techniques as means of enabling the above three elements to be measured (**Table 1**). These techniques may use emulators*8

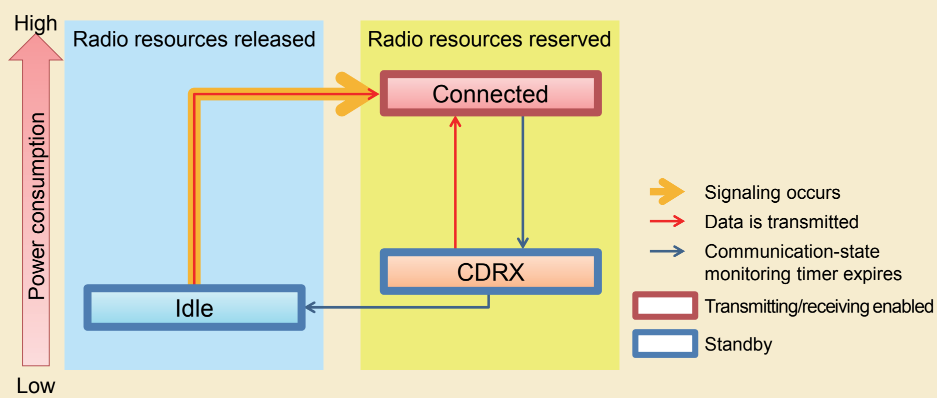


**Figure 1 RRC state transitions (LTE) versus power consumption and signaling**

*2 **IM:** A function for sending and receiving messages over the Internet and other networks, frequently achieved by dedicated applications.

*3 **Pull-type:** A method for getting necessary information from servers. To keep data on a smartphone updated, a server must be periodically checked for updated data.

*4 **Signaling:** The transmission of control signals by a smartphone to enable communications with radio control equipment and switches.

*5 **Signaling tester:** Pseudo base station equipment for use in communications protocol testing with smartphones. It features high reproducibility of operations between smartphones and the network and can simulate an environment that approximates an actual network.

to create a virtual smartphone/network setup or evaluation facilities that employ network equipment as used in actual operations. In addition, the measurement point may be on the smartphone side or the network side. We rate each of these techniques in terms of three key features: “validity of results,” “ease of measurement and analysis,” and “flexibility in changing parameters” according to the type of evaluation desired.

1) Smartphone Emulator

As shown in **Figure 2**, this is a technique that can realize the IP layer and higher by software on a computer and that enables measurement results to be analyzed directly on the same computer. This technique therefore ranks high in “ease of measurement and analysis.” For an emulator, however, it is difficult to accurately reproduce the state transitions of a smartphone, which means that operations between the smartphone and network cannot be faithfully reproduced. This means a low score in “validity of results,” i.e., results cannot be guaranteed. Finally, in terms of “flexibility in changing parameters,” the parameters that can be set are generally limited to those related to RRC states, so it may not always be possible to construct the test environment needed.

2) Data Measurement Smartphone App

This technique runs data measurement software on the smartphone itself and evaluates the smartphone while it is connected to an actual network. It is a good technique in terms of “ease of measurement and analysis” since only a smartphone is needed to make measurements and results can be easily obtained. On the other hand, this technique requires that the measurement software run continuously, which can affect smartphone operation. As a consequence, some results cannot be guaranteed, which detracts from “validity of results.” As for “flexibility in changing parameters,” there is concern that changing parameters can affect other users since the smartphone is connected to an actual network, and

**Table 1　Comparison of app-traffic evaluation techniques**

| Technique | Overview | Validity of results | Ease of measurement and analysis | Flexibility in changing parameters |
|---|---|---|---|---|
| Smartphone emulator | Software running on a computer | × | ◎ | △ |
| Data measurement smartphone app | Data measurement software running on the smartphone<br>Evaluation can be performed on an actual network | ○ | ○ | × |
| Base station simulator | Measuring equipment that simulates an actual network | ◎ | ○ | ◎ |
| Laboratory evaluation with actual equipment | Evaluation facilities using equipment the same as that in an actual network | ◎ | △ | ○ |

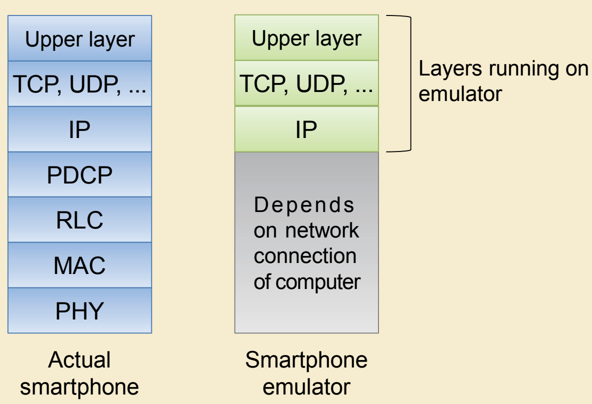


**Figure 2　User-data protocol stack in an actual smartphone and smartphone emulator**

*6　**Radio resources:** General term for radio-communication resources (radio transmission power, allocated frequency, etc.).

*7　**DRX:** Discontinuous reception control used to reduce power consumption in UE.

*8　**Emulator:** An environment for simulating the hardware and software operations of a mobile smartphone on a computer to make application software running on the emulator run the same as on a mobile smartphone.

for this reason, changing parameters to suit evaluation objectives is not easy with this technique.

3) Base Station Simulator

This technique uses a base station simulator that enables interactive responses the same as in an actual network. It differs from base station simulators that perform previously specified operations for radio communications protocol testing. This technique uses specialized hardware that makes it easy to make measurements and obtain results, so it scores well in terms of "ease of measurement and analysis," and since it enables operations between the smartphone and network to be reproduced, it can obtain reliable results, which means a high score for "validity of results." This technique also scores high in "flexibility in changing parameters" since it makes it easy to vary parameters.

4) Laboratory Evaluation with Actual Equipment

This technique uses evaluation facilities consisting of network equipment used in actual operations, which means high reliability and a high score in "validity of results." However, it requires a relatively large amount of space to set up the equipment and a certain amount of time to make preparations for measurements. It also requires a high degree of specialized knowledge to analyze the data collected by each piece of equipment. For these reasons, the technique ranks low in "ease of measurement and analysis." Furthermore, while various types of parameters may be varied, specific procedures and tasks are needed to do so, so this technique is somewhat lacking in the "flexibility in changing parameters" category.

Based on the results of the comparison described above, we made a comprehensive assessment and decided to adopt the base station simulator technique that ranks high in "validity of results" and "flexibility in changing parameters" and that makes it relatively easy to make measurements and perform analysis.

### 2.3 System Configuration

The configuration of our evaluation system using a base station simulator is shown in **Figure 3**. The base station

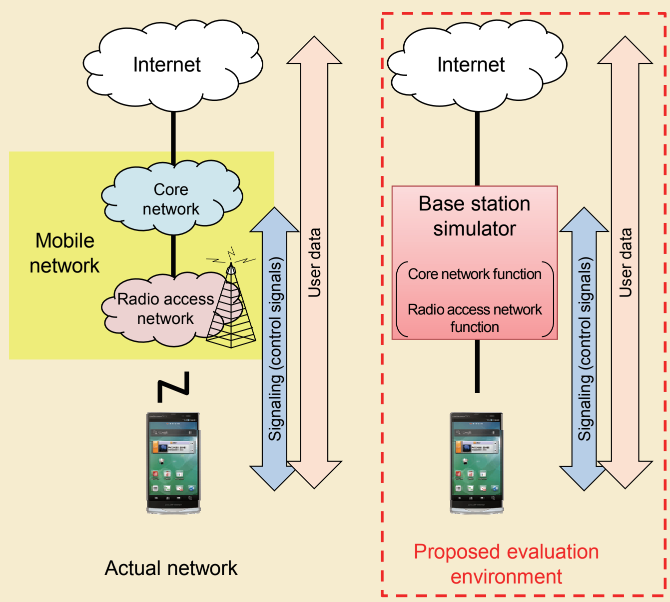


**Figure 3 Configuration of evaluation system using a base station simulator**

simulator features a radio access network*9 function and a core network*10 function making it possible to replace an actual network with one piece of equipment. In this evaluation environment, the core network connects to the Internet and the radio access network connects to the smartphone as in an actual network.

## 3. Evaluation Results and Areas of Improvement

An example of traffic volumes and RRC state transitions as obtained by our evaluation system is shown in **Figure 4**. These results were obtained for actual signals generated during basic operations in a certain app. The first signals to be generated are those resulting from user app operations (interval A). Then, after the completion of these operations, a small volume of traffic is periodically generated with short gaps for a short time (interval B). Then, with the passage of time, a small volume of traffic is again periodically generated but this time with relatively long gaps (interval C). The following presents the results of analyzing each of these intervals.

1) Interval A

In this interval, traffic is generated by app operations performed by the user, so the RRC state is maintained at Connected, which means that a state of high power consumption continues throughout. Since this traffic is generated by user operations, this interval is generally excluded as a target for making improvements.

However, if this interval should include traffic not caused by user operations but rather, for example, by data updates, it should be possible to reduce that traffic or consolidate communication timing, which would have the effect of shortening Connected time and reducing power consumption.

2) Interval B

This interval follows the completion of user app operations, and because it features a small volume of traffic periodically generated with short gaps, the RRC state is maintained at Connected rather than making a transition to CDRX. As a result, power consumption remains high despite the fact that this interval includes no user operations.

Here, it would be possible to shorten Connected time and reduce power consumption by broadening the communication gap. However, if this gap is made larger than the total time required for making a transition from Connected to CDRX and from CDRX to Idle (hereinafter referred to as "Idle transition time"), the system will again move to the Connected state after the transition to Idle, which could have the unwanted effect of increasing signaling. There is therefore a need here to improve communication timing while taking Idle transition time into account.

3) Interval C

This interval features the periodic generation of a small volume of traffic with a fixed gap, which means that a transition to the Connected state is made and power consumption jumps with each occurrence of traffic generation and that

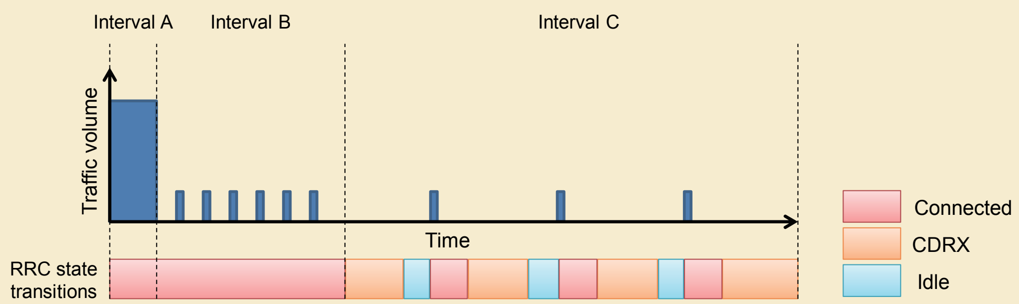


**Figure 4 Traffic volume and RRC state transitions**

*9 **Radio access network:** A network positioned between the core network (see *10) and mobile smartphones consisting of radio base stations and radio-resource control equipment.

*10 **Core network:** A network consisting of switches, subscriber information management systems and other equipment. Mobile smartphones communicate with the core network through the radio access network.

signaling occurs every time a transition is made from Idle to Connected. In this case, broadening the communication gap can reduce power consumption and signaling. Such a small volume of periodically generated traffic is frequently used as a Keep Alive*11 function to maintain a TCP session*12. If the communication gap is made overly wide, the session will be released, so improvements here must be made in accordance with network and server settings.

Reducing the volume of communications or adjusting communication timing in the above ways can reduce Connected time and the number of Idle-Connected transitions and can therefore make improvements in power consumption and signaling generation.

## 4. Conclusion

This article described a smartphone-app traffic evaluation system for saving smartphone power and reducing network load by supporting the optimization of background communications.

In addition to apps developed by NTT DOCOMO, traffic evaluation by this system is also being used for proposing improvements in a number of apps developed by external vendors pointing out to them that such improvements can help save smartphone power. However, evaluating all of the huge number of existing apps would be difficult to say the least, and at present, we are focusing our attention on highly popular apps. In future work, we plan to make the evaluation technique more efficient to enable an even greater number of apps to be evaluated and to enhance the "App Creation Guidelines" [1] released to application developers with the aim of saving smartphone power and reducing network load.

### Reference

[1] NTT DOCOMO: "Android™ App Creation Guidelines—Toward Efficient Communications Control—" (in Japanese).
https://www.nttdocomo.co.jp/service/developer/smart_phone/etc/index.html

*11 **Keep Alive:** A short message that is transmitted usually at fixed intervals to prevent a session from being released due to inactivity.

*12 **TCP session:** A communication path established by TCP protocol.