IMT/GSM Dual Mobile Terminal N900iG Supporting International Roaming

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We have developed the IMT/GSM dual mobile terminal N900iG, which is the first FOMA terminal to be equipped with roaming functions.
N900iG can be used not only in Japan but also overseas with its international roaming functions, and i-mode services as same as those available in Japan are also provided in overseas locations.

1. Introduction

DoCoMo positions the use of "multimedia," advancement of the "ubiquitous" networking environment and "globalization" as the three main pillars of our management strategies for business expansion. As part of the advancement of one of these pillars, "globalization," we are promoting development of the international roaming services of Freedom Of Mobile multimedia Access (FOMA).

FOMA's international roaming services were started in June 2003, although at that time it was limited to outbound roaming voice communication only. This service was accessed in an overseas location by inserting a Universal Subscriber Identity Module (USIM) card in a Global System for Mobile communications (GSM) terminal. Following that, FOMA's inbound roaming service was started in May 2004. So far, however, it has not been possible to make FOMA's international roaming services available both in Japan and overseas locations with a single mobile terminal. For this reason, there has been a strong demand for development of FOMA terminals that can be used "anytime, anywhere and with anyone" on a global scale. To meet this demand, we have developed N900iG, a mobile terminal that allows outbound roaming.

The N900iG FOMA terminal is targeted at cosmopolitan users who use their mobile terminals mainly in Japan.

Development Reports

Moreover, N900iG is able to communicate via International Mobile Telecommunications-2000 (IMT-2000) networks as well as via Second-Generation (2G) mobile communication (GSM)/2.5 generation General Packet Radio Service (GPRS) networks, which is the most widespread type of communication network in most countries of the world with a single mobile terminal, thus achieving communication "anytime, anywhere and with anyone" globally. Moreover, i-mode services can now be used in overseas locations in the same way as within Japan.

This article explains the basic functions implemented in N900iG, the outbound roaming service and the new functions incorporated in FOMA terminals to support international roaming, and provides an overview of the plastic roaming-in service.

2. Characteristics of N900iG

2.1 Basic Functions

Photo 1 shows the external appearance of N900iG and **Table 1** shows the main specifications.

In addition to voice communication, the service used every day in Japan, N900iG provides access to Short Message Service (SMS), i-mode services and video telephony services in overseas locations in the same way as in Japan.

In order to provide these services, we have developed several new functions in N900iG. Firstly, we incorporated the GSM/GPRS functions so that the outbound roaming service can be used in a wide area. Secondly, we added a function that allows switching between IMT-2000 communication and GSM/GPRS communication, which can be used when the terminal is in standby mode. The details are explained in Chapter 3. Thirdly, we incorporated a function that notifies the receiving i-mode mails via SMS, which can be used for networks of overseas telecommunications carriers, so that i-mode mails can be received in overseas locations in the same way as in Japan. Fourthly, we implemented a dialing assist function in order to improve operability including operations to make calls in and to overseas locations.

Moreover, since N900iG is also used for inbound roaming rental services, network services required for this purpose, interfaces with USIM and Subscriber Identity Module (SIM) cards have been added as new functions.

2.2 Outbound Roaming Service

Table 2 shows services that are available to N900iG at outbound roaming. There are two types of services, Circuit

Switching (CS) and Packet Switching (PS), and the following services become available depending on the overseas operators network.

Photo 1 N900iG

Table 1 Main specifications of N900iG

Function/characteristics		N900iG
Shape	Design	**Folded**
	Dimensions	**103 × 50 × 28 mm**
	Weight	**132 g**
Time	Continuous voice call time	**105 min./120 min. (FOMA/GSM)**
	Continuous video telephony time	**70 min.**
	Continuous standby time	**3G: 150 hrs./110 hrs. (stationary/in transit)** **2G: 110 hrs.**
Wireless band	3G	**2 GHz**
	2G/2.5G	**900 MHz, 1800 MHz, 1900 MHz**
Main LCD	Size	**App. 2.2 inches**
	Number of dots	**240 × 320 dots 65,536 colors TFT LCD**
Back side LCD	Size	**App. 1.0 inches**
	Number of dots	**120 × 90 dots 65,536 colors TFT LCD**
Camera	Back side camera's effective number of pixels	**App. 1.24 Mpixels (Maicovicon™*)**
	Front side camera's effective number of pixels	**App. 110,000 pixels (CMOS)**

*　Maicovicon™ is a registered trademark of Matsushita Electric Industrial Co., Ltd.

CMOS : Complementary Metal Oxide Semiconductor
　LCD : Liquid Crystal Display
　TFT : Thin Film Transistor

Table 2 Services of N900iG available at outbound roaming

Service type / Network type	CS service			PS service
	Voice call	Video telephony 64 kbit/s	SMS	i-mode (browser, mail, message R)
In Japan (FOMA network)				
Overseas — IMT-2000 networks				
Overseas — GSM/GPRS networks				
Overseas — GSM networks				

1) IMT-2000 Networks

Voice call, video telephony (transmission speed is 64 kbit/s) and SMS are available as CS services. Overseas IMT-2000 networks do not support 32 kbit/s video telephony and 64 kbit/s unrestricted data communication; corresponding functions are not implemented in N900iG. i-mode services (browser, mail and message R (request)) are provided as PS services, and viewing i-menu, sending/receiving i-mode mails and using i-motion services are made possible.

2) GSM/GPRS Networks

Voice call and SMS are made available as CS services. Moreover, i-mode services (browser, mail and message R) are provided as PS services. The transmission speed of the GPRS network is up to 85.6 kbit/s, although it varies depending on the coding scheme.

3) GSM Networks

Only CS services are provided; voice call and SMS are available.

3. Network Switching Function

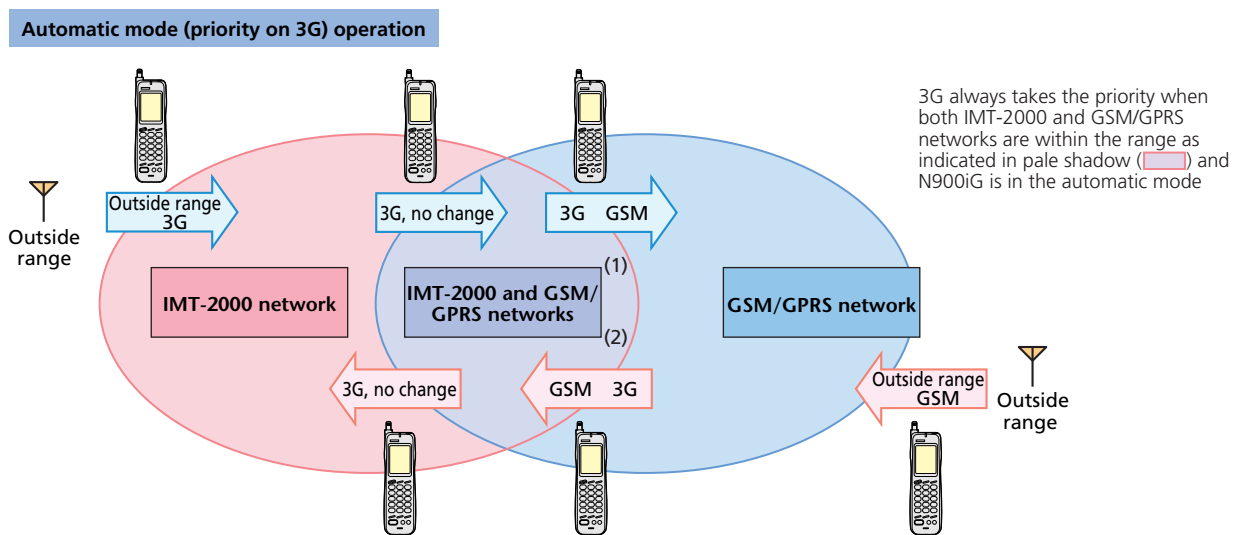This chapter explains the network switching function of N900iG at outbound roaming.

3.1 Network Switching Modes

N900iG can use the following three network switching modes in order to adapt to international network environments.

1) Third-Generation (3G) mode: A mode where communica-

tion is exclusively performed using an IMT-2000 network

2) GSM mode: A mode where communication is only performed using a GSM/GPRS network

3) Automatic mode: A mode where the terminal automatically switches between using an IMT-2000 network and a GSM/GPRS network

N900iG places the highest priority on using an IMT-2000 network. If it is outside the range of an IMT-2000 network and within the range of a GSM/GPRS network, it automatically switches to the GSM/GPRS network (**Figure 1**). It does not switch between the two methods while communicating; the switching functions only in the standby status.

When N900iG is in the automatic mode and within the range of an IMT-2000 network, it operates in the same way as in the 3G mode. If it is outside the range of an IMT-2000 network and within the range of a GSM/GPRS network, it operates in the same way as in the GSM mode and searches for an IMT-2000 network periodically. If an IMT-2000 network is detected, it attempts to register itself to this network. If it is outside the range of both GSM/GPRS and IMT-2000 networks, it periodically and alternately switches the network to search for.

3.2 Network Search Mode

This function allows the user to select an operator automatically or manually. In the automatic search mode, the terminal detects operators to be registered to according to the priority

Automatic mode (priority on 3G) operation

Outside range

Outside range 3G

IMT-2000 network

3G, no change

3G GSM

IMT-2000 and GSM/GPRS networks

(1)

(2)

GSM/GPRS network

3G, no change

GSM 3G

Outside range GSM

Outside range

3G always takes the priority when both IMT-2000 and GSM/GPRS networks are within the range as indicated in pale shadow (▢) and N900iG is in the automatic mode

(1) N900iG registers itself to a GSM/GPRS network if an IMT-2000 network cannot be detected within range
(2) N900iG regularly searches for an IMT-2000 network and automatically registers itself to the IMT-2000 network if it detects one

Figure 1 Automatic mode (priority on 3G) mode
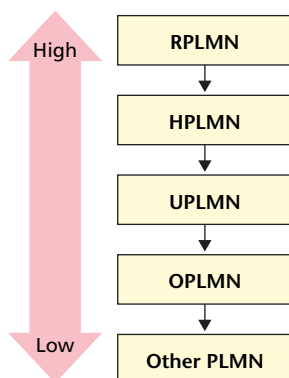
Figure 2 Priority order for network search mode

orders shown in **Figure 2**. In the figure, Home Public Land Mobile Network (HPLMN) refers to the operator of the subscriber, User controlled PLMN (UPLMN) refers to an operator the user prefers, Operator controlled PLMN (OPLMN) refers to an operator the operator providing the USIM prefers, and Other PLMN refers to other operators that can be registered to, which are not among the ones defined above. The operator to which the terminal was registered the last time (Registered PLMN (RPLMN)) takes the highest priority when the power is turned on. The information of RPLMN, HPLMN, UPLMN and OPLMN is stored within the USIM card as data. After registering itself to an operator, N900iG periodically conducts a network search according to the Periodic HPLMN Timer value within the USIM card and registers according to the priority.

With the manual search mode, N900iG displays the list of operators that can currently be registered to on the screen according to the priority order shown in Fig. 2 and the user selects an operator to register to from the list displayed. The manual search mode cannot be used if the network switch function is set to the automatic mode.

Moreover, a "network re-search" function is provided to be used when a user desires to switch from the operator currently used to the other operator in range. If there is another operator that allows roaming, N900iG switches to that operator with this operation.

4. i-mode Functions

N900iG is equipped with functions that allow receiving services equivalent to i-mode services in the FOMA network in both the GPRS network and IMT-2000 network environments.
1) Notification of i-mode Mail Reception at Outbound Roaming
N900iG allows users to receive services equivalent to the services in the FOMA network at outbound roaming, including

contents download and i-mode mail transmission/reception. In addition, it adopts the SMS-based SMS-Push method, which is the method adopted by overseas i-mode operators, to notify the i-mode mail reception to N900iG at outbound roaming at stand-by mode.

If an i-mode mail is sent to an N900iG at outbound roaming, a reception notification is sent from the treasure Casket of i-mode service, high Reliability platform for CUStomer (CiRCUS) server to an appropriate Wireless Protocol Conversion Gateway (WPCG). Then, the reception notification is sent from the WPCG to a Gateway Mobile Multimedia switching System (GMMS) node. The GMMS, upon receiving the notice from the WPCG, confirms the network to which the N900iG is registered with the New Mobile Service Control Point (NMSCP). If the N900iG to which the reception notification is addressed is outbound roaming, the GMMS creates an SMS that includes information necessary to be determined as the reception notice and sends it as a mail reception notice to the roaming N900iG (**Figure 3**). Upon receiving the SMS-Push, the N900iG sends an Activate Packet Data Protocol (PDP) Context Request (PacKeT (PKT) connection request) from the visited network to the GMMS. The N900iG receives the i-mode mail if a signal control (Control-Plane (C-Plane)) link can be established between the terminal at the outbound roaming location and the WPCG in the FOMA network, a Transmission Control Protocol (TCP) connection is established and the PKT communication is conducted. The SMS the N900iG receives as a reception notification is not stored; it is deleted at the terminal before the mail reception sequence is commenced. Moreover, if the N900iG is performing PKT communication, reception notification is performed in the same way as reception notification in the FOMA network, even during outbound roaming: a User-Plane (U-Plane) reception notice is sent and the i-mode mail is received.
2) SMS-Push Security Check
Although SMS-Push is used for reception notification using SMS, there is a possibility that false SMSs may be sent to mobile terminals, and data may be tampered with. In order to avoid obtaining mails by receiving such false SMS-Push messages, multiple security checks are conducted inside the mobile terminal after receiving an SMS-Push message, and if the message is judged false, it is immediately discarded within. This approach ensures that only mails whose SMS-Push message is valid are received.
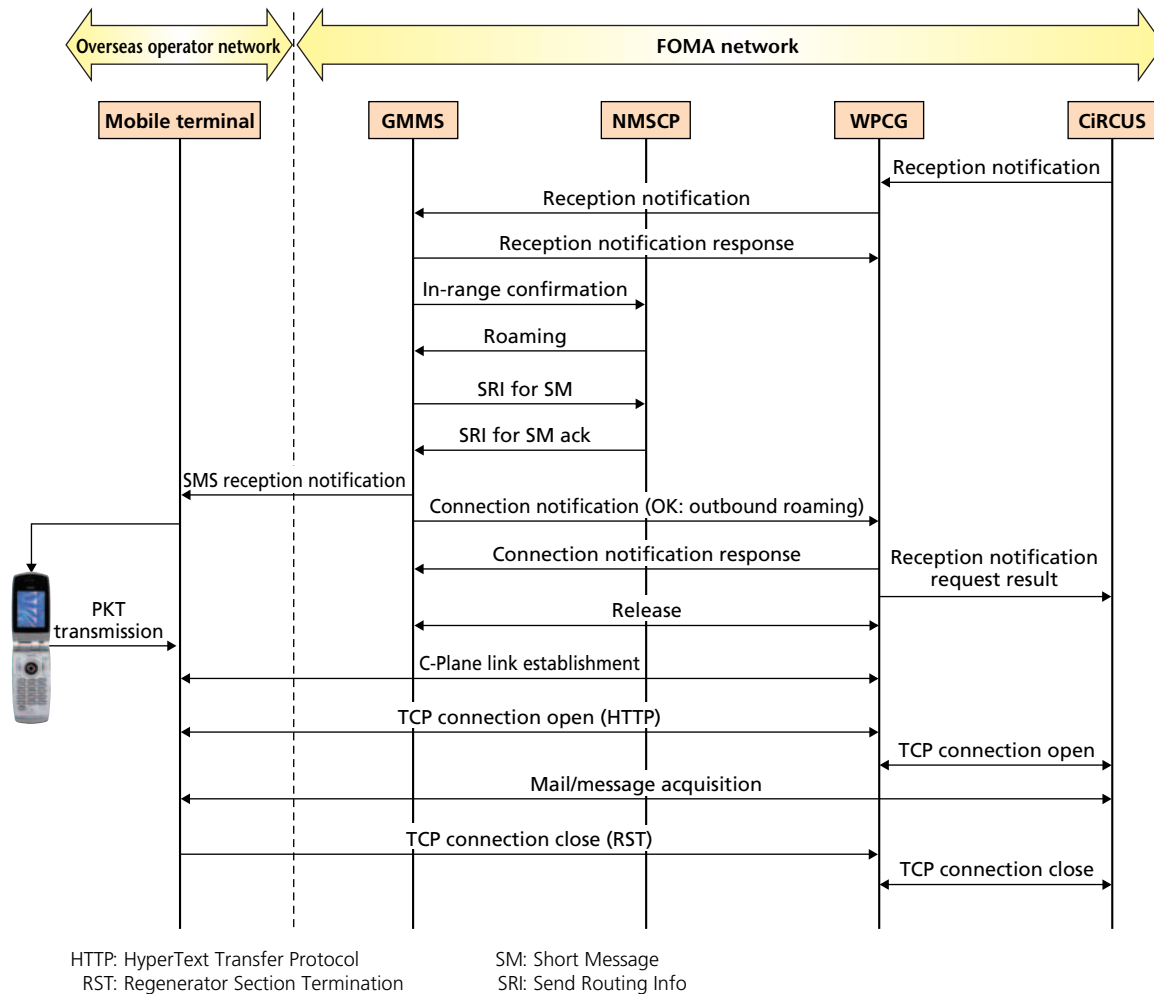
HTTP: HyperText Transfer Protocol   SM: Short Message
RST: Regenerator Section Termination   SRI: Send Routing Info

Figure 3 SMS-Push sequence

3) Preservation Function in Overseas Networks

In an overseas IMT-2000 network where a packet connection has been established, but no communication is performed for a specified period of time, the mobile terminal releases only the radio link and shifts to the status where the packet connection is logically maintained between the core network and mobile terminal. This function conforms to the Preservation specification of the 3rd Generation Partnership Project (3GPP). N900iG is equipped with this function for outbound roaming.

At outbound roaming, a fixed fee is charged for each packet connection session, but with this Preservation function, it is possible to reduce the number of packet connection sessions. For example, if a radio link is released when moving outside the service area of the network during i-mode communication, the Preservation function maintains the packet connection logically. For this reason, it is possible to continue the i-mode communication without starting a new packet connection session after returning to the service area, as far as the packet connection sta-

tus is not released via user operation or from the network side.

5. User Interface for Roaming

N900iG is equipped with new user interface functions for outbound roaming and plastic roaming-in.

Figure 4 shows an example of an N900iG screen display.

The Radio Access Technology (RAT) identification icon changes depending on the type of network the mobile terminal is registered to. Specifically, either FOMA, 3G or GSM/GPRS is displayed on the standby screen. The FOMA icon is always displayed if the mobile terminal is in the FOMA network coverage.

Remote clock display is a function that displays the time in a remote location on the standby screen by specifying a time zone, city name and summer time. The remote clock is displayed at the same time as the local clock.

Operator name display is a function that displays the name of the network the mobile terminal is currently registered to. If a
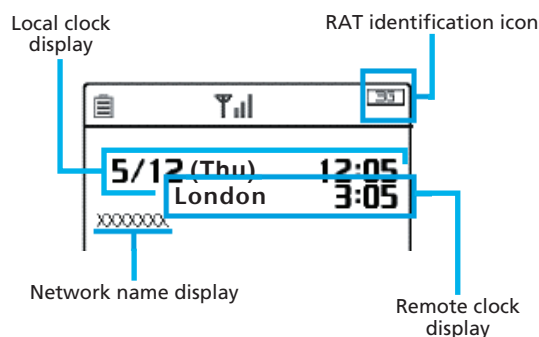
Local clock display — RAT identification icon

5/12 (Thu) 12:05
London 3:05
XXXXXXX

Network name display — Remote clock display

Figure 4 Screen display example

FOMA card is inserted in the mobile terminal and the terminal is in the FOMA network coverage, no network name is displayed.

Network switch provides a function to specify one of the following modes: fixed to 3G, fixed to GSM and automatic (priority is on 3G).

Network search mode provides the option to select a network either manually according to the user's selection or automatically, which is effective in case several networks that can be connected to are detected at the same time in an overseas location. It also provides the option to search for more preferable networks than currently registered one again according to the current network search mode.

PLMN setting is a function for setting a network of high priority for the user in advance. There are three ways of designating a network: "direct designation by entering the country code and operator code," "selection from a list of operators in the mobile terminal" and "designation of the currently registered network." The designated priority information is stored in the USIM/SIM card.

The functions related to plastic roaming-in can be executed if a USIM/SIM card of another operator is inserted in the mobile terminal particularly configured for a plastic roaming-in user. The "supplementary service menus defined in the 3GPP standard specification" and the " Call Barrings menu" are exam-

ples of this function.

Dialing assist is a function that assists the user in making international calls from Japan or overseas locations. Here, the function for DoCoMo's outbound roaming users, "+country codes automatic addition function," is chosen and elaborated. If this function is activated, the applicable one of the "+country codes" registered in advance is added as necessary at the beginning of the telephone number when a user is making a voice/video telephony call from an overseas location using the telephone book or redial/ dialed call history/received call history for which the names have already been checked against the telephone book (**Figure 5**). This function allows users to make an international call easily from an overseas location to a person registered in the telephone book as the local telephone number.

Supplementary services for outbound roaming are "call barring of incoming call at roaming," "roaming guidance," "voice mail (Int.)," "call forwarding (Int.)" and "roaming guidance (Int.)." These are implemented as menu items.

6. Interoperability Tests of Mobile Terminals

The issues of interoperability of mobile terminals can largely be classified into interoperability between a mobile terminal and a network and interoperability between a mobile terminal and a USIM/SIM card.

6.1 Interoperability with Overseas Networks

In order to provide outbound roaming services, N900iG is required to secure connectivity with not only the DoCoMo network, but also overseas networks. The tests for securing connectivity between a mobile terminal and each network are generally referred to as InterOperability Tests (IOT). The general method for conducting IOTs between a GSM terminal and a network is explained below.

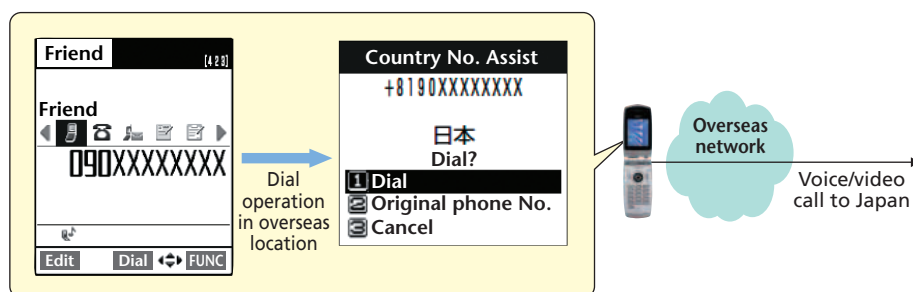An international organization called the Global Certification Forum (GCF) has been founded in order to guarantee interoperability among mobile terminals and GSM networks. Mobile terminal vendors secure connectivity with each network by obtaining GCF certification. GCF is expanding its activities in the IMT field as well.

Figure 5 +Country codes automatic addition function

As shown in **Figure 6**, the general steps involved in a GSM terminal's obtaining a GCF certification are largely classified in to two: tests related to IOT and tests related to GCF.

IOTs include Network Vendor-InterOperability Tests (NV-IOT), which are tests of connectivity with vendors manufacturing network devices, and Network Operator-InterOperability Tests (NO-IOT), which are tests of connectivity with operators running networks. Interoperability with multiple network vendors is secured with NV-IOT and interoperability with actually operating networks with NO-IOT.

Moreover, in order to obtain GCF certificates, it is necessary to pass two tests. One is a Conformance Test (CT) that checks conformation to the specifications via simulation and the other is a Field Trial (FT) that checks whether a mobile terminal can connect on an end-to-end basis. Operators to be tested are selected by a vendor. The vendor applies for the certification to the GCF based on the result of FT, and the GCF registers the application. It is required to perform FT with at least five operators. NV-IOT shall be performed first and then NO-IOT is performed to obtain a GCF certificate.

The interoperability of N900iG was secured by going through the same procedure as above. We chose the popular overseas destinations among Japanese people when selecting the overseas locations to be used for FT.

6.2 Interoperability between USIM/SIM and Mobile Terminals

Since international roaming is a basic feature in the IMT-2000 system, all products conforming to the 3GPP specification and similar must be logically interoperable with USIM and SIM cards in any combinations of vendors, mobile terminals and networks.

7. Plastic Roaming-in Function

7.1 Plastic Roaming-in Function of N900iG

USIM and SIM cards are used as User Identity Modules (UIM) when connecting to IMT-2000 and GSM networks, respectively.
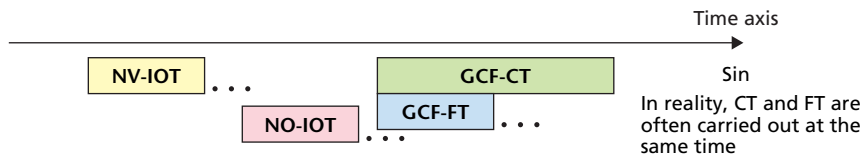
N900iG is the first FOMA terminal that supports plastic roaming-in and accommodates both USIM and SIM cards. N900iG adopts a design that guarantees interoperability with USIM and SIM cards other than FOMA cards. N900iG implements a plastic roaming-in function where a person traveling from an overseas location to Japan can receive services in Japan as well using the same numbers by inserting a USIM or SIM card in an N900iG terminal. The plastic roaming-in services were started with A835, a rental terminal available to inbound roaming users, from May 2004.

7.2 IOT between N900iG and Overseas USIM and SIM Cards

We conducted two types of testing as IOT to guarantee N900iG's inbound roaming function.

In the USIM/SIM simulator testing, we confirmed that there were no problems with the operation of N900iG by simulating various patterns of configurations and operations assumed to be implemented in USIM/SIM cards supplied by overseas card vendors and operators, among those conforming to the 3GPP specification.

In the testing with exist-

| | IOT | | GCF | |
	NV-IOT	NO-IOT	GCF-CT	GCF-FT
Positioning	• Guaranteeing interoperability with network vendors	• Guaranteeing interoperability with operators specified by an operator to which terminals are shipped (FT can be conducted immediately if the operator does not require NO-IOT)	• Confirmation of conformation to specifications • Confirmation of differences in interpretation of test specifications	• Confirmation that a mobile terminal that went through CT can actually connect end-to-end
Test description	• System registration, mobility tests, tests for different call types, etc.	• System registration, mobility tests, tests for different call types, etc.	• RF tests, signaling tests, audio tests, USIM test, etc.	• System registration, mobility tests, tests for different call types, additional service tests, etc.
Test item	• Determined after due consultation with mobile terminal vendors	• Determined after due consultation with a mobile terminal vendor and operators	• Specified as GCF-CC at GCF	• A mobile terminal vendor determines the actual test items by referencing the FT guidelines (TW.11) by GSMA

GCF-CC: GCF-Certification Criteria
GSMA: GSM Association
RF: Radio Frequency

Figure 6 General procedure for obtaining GCF certification for GSM terminals

ing USIM and SIM cards, we confirmed that N900iG operated normally by inserting already commercialized USIM/SIM cards in an N900iG terminal; this test was carried out because N900iG is the first FOMA mobile terminal that supports plastic roaming-in.

8. Conclusion

We have developed the IMT/GSM dual mobile terminal N900iG that allows to use i-mode services in overseas locations in the same way as in Japan, targeted for cosmopolitan users who mainly use their terminals in Japan. This article explained new functions and new services (outbound roaming service and plastic roaming-in service) implemented in N900iG. These new functions developed for N900iG have the important role of forming the foundation of future mobile terminals supporting international roaming.

In the future, we will further enrich the functions related to international roaming and promote development of new mobile terminals supporting international roaming by implementing basic specifications such as improvement of standby time and size/weight reduction, as well as multimedia functions for standard FOMA terminals.

ABBREVIATIONS

3GPP: 3rd Generation Partnership Project
CiRCUS: treasure Casket of i-mode service, high Reliability platform for CUStomer
CMOS: Complementary Metal Oxide Semiconductor
C-Plane: Control-Plane
CS: Circuit Switching
CT: Conformance Test
FOMA: Freedom Of Mobile multimedia Access
FT: Field Trial
GCF: Global Certification Forum
GCF-CC: GCF-Certification Criteria
GMMS: Gateway Mobile Multimedia switching System
GPRS: General Packet Radio Service
GSM: Global System for Mobile communications
GSMA: GSM Association
HPLMN: Home Public Land Mobile Network
HTTP: HyperText Transfer Protocol
IMT-2000: International Mobile Telecommunications-2000
IOT: InterOperability Test
LCD: Liquid Crystal Display
NMSCP: New Mobile Service Control Point

NO-IOT: Network Operator-InterOperability Test
NV-IOT: Network Vendor-InterOperability Test
OPLMN: Operator controlled PLMN
PDP: Packet Data Protocol
PKT: PacKeT
PS: Packet Switching
RAT: Radio Access Technology
RF: Radio Frequency
RPLMN: Registered PLMN
RST: Regenerator Section Termination
SIM: Subscriber Identity Module
SM: Short Message
SMS: Short Message Service
SRI: Send Routing Info
TCP: Transmission Control Protocol
TFT: Thin Film Transistor
UIM: User Identity Module
U-Plane: User-Plane
UPLMN: User controlled PLMN
USIM: Universal Subscriber Identity Module
WPCG: Wireless Protocol Conversion Gateway