UIM Version 2

Hidetoshi Ishikawa, Chiaki Nogawa,
Kazuhiko Takahashi and Masahiro Furuse

UIM is a smart cards standard for mobile communications that allow storage of subscriber identification information of several networks. Conventionally, the usage of UIM was limited to USIM applications. In order to make it more sophisticated, we have developed UIM version 2, which implements the PKI function as well as GSM and PDC applications.

1. Introduction

A User Identity Module (UIM) smart card for mobile communications (the product name is FOMA card) is an integral part of the implementation of the Freedom Of Mobile multimedia Access (FOMA) service (**Photo 1**).

The UIM smart card has the same shape as common credit cards, but for some types of terminals, it is used by removing the part of the card where the IC chip is embedded (plug-in size part) and inserting this into the terminal.

FOMA terminals are equipped with a UIM socket (Universal Integrated Circuit Card (UICC) socket). Users are allowed to make and receive outgoing/incoming calls using their contracted phone numbers by inserting the UIM smart card into the UIM socket of their terminals.

The main feature of UIM version 2 (UIMv2) is that it is compatible with the third-generation mobile communication (International Mobile Telecommunications-2000 (IMT-2000)) terminals and Global System for Mobile communications (GSM) terminals of other service operators; it can be used by inserting it into such terminals as well.

In the Japanese second-generation mobile communication

Photo 1 FOMA card

system, in the same way as for the Advanced Mobile Phone System (AMPS) of the US, user identification information was integrated into and inseparable from terminals. The implementation of UIM allows separating subscriber information from the mobile terminals themselves, which means that users do not need to register model changes; they can use new mobile terminals as their registered terminals just by inserting the UIM smart card from their old mobile terminals into new ones.

Moreover, operators can implement their own security features in the UIM smart card.

2. Overview

It is specified to use a Universal Subscriber Identity Module (USIM) in all IMT-2000 terminals. Correspondingly, in GSM, which is mainly used in Europe and other countries, a Subscriber Identity Module (SIM) is utilized.

Since the equivalent identity module standard of DoCoMo implements its own functions in addition to the USIM and SIM applications specified in the standard specifications, we call it UIM (**Figure 1**).

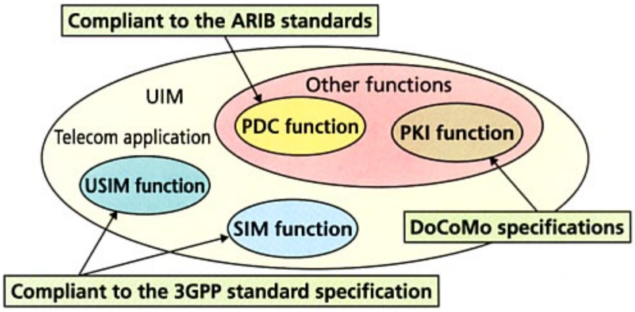


Figure 1 Relationship between UIM and USIM/SIM

Basically, UIM provides the following functionality (**Figure 2**).

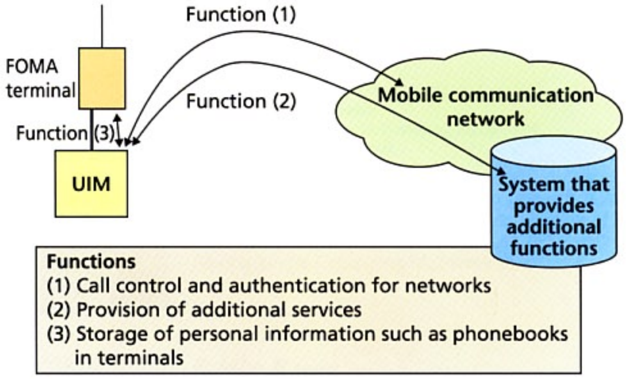

Function (1)
FOMA terminal
Function (2)
Mobile communication network
Function (3)
UIM
System that provides additional functions
Functions
(1) Call control and authentication for networks
(2) Provision of additional services
(3) Storage of personal information such as phonebooks in terminals

Figure 2 UIM functions

1) Function for Call Control and Authentication for Networks

This function is required when users use networks for activities such as making telephone calls, receiving/sending packet communication and roaming user communication. UIM allows supporting various types of networks to which the terminals can be connected, such as FOMA, GSM, or Personal Digital Cellular (PDC) systems (**Figure 3**).

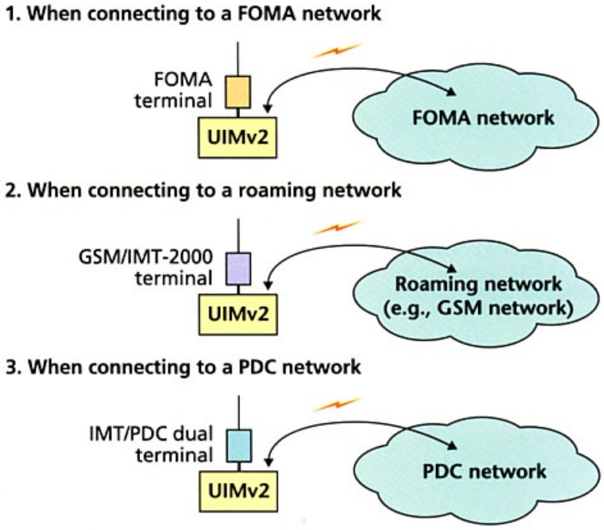

1. When connecting to a FOMA network
FOMA terminal
UIMv2
FOMA network
2. When connecting to a roaming network
GSM/IMT-2000 terminal
UIMv2
Roaming network (e.g., GSM network)
3. When connecting to a PDC network
IMT/PDC dual terminal
UIMv2
PDC network

Figure 3 Function for call control and authentication for networks

2) Function for Providing Additional Services

In addition to the basic services such as telephone calls, UIM also allows to provide DoCoMo's own services such as the FirstPass (Secure Sockets Layer (SSL) client authentication) digital certificate service.

3) Function to Store Personal Information (e.g., phonebook) in Terminals

This function allows accessing phonebooks and writing/viewing short messages, used locally within terminals.

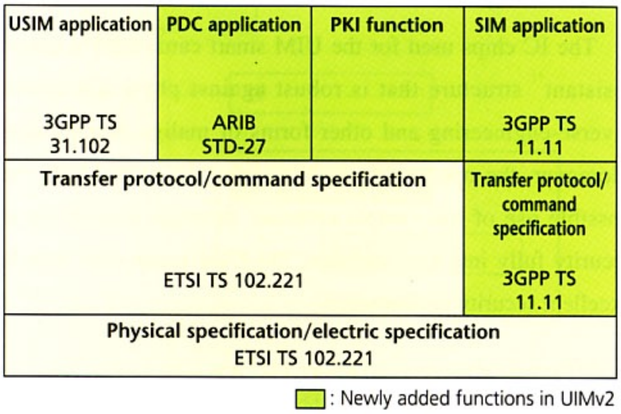
In addition to the above, UIM provides functions to link to customer systems and so forth.

The FOMA UIM smart card is supplied in two versions: version 1 (UIMv1: blue FOMA card) and version 2 (UIMv2: green FOMA card) (**Figure 4**).

In UIM version 1 (UIMv1), which was launched at the same time as the start of the FOMA service, only USIM application subscriber information was stored. In UIMv2, we have added the following functions in addition to the functions of UIMv1.

1) SIM Application

The UIMv2 smart card can be inserted into GSM terminals; this allows affiliated GSM operators to provide international roaming services. This service is provided under the name "WORLD WING."



USIM application — 3GPP TS 31.102

PDC application — ARIB STD-27

PKI function

SIM application — 3GPP TS 11.11

Transfer protocol/command specification — ETSI TS 102.221

Transfer protocol/ command specification — 3GPP TS 11.11

Physical specification/electric specification — ETSI TS 102.221

🟩: Newly added functions in UIMv2

Figure 4 Overall architecture of the UIM

2) PDC Application

The UIMv2 smart card can be inserted into IMT/PDC dual terminals (terminals used for both IMT-2000 and PDC: as of July 2003, FOMA N2701 is compliant to both of these standards); it allows using both FOMA and PDC services from the same terminal.

3) PKI Function

UIMv2 allows FirstPass SSL client authentication.

Some of the functions specified by the USIM and SIM standard specifications are not implemented in UIM for FOMA. Typical examples include the USIM Application Tool kit (USAT) and the SIM Application Tool kit (SAT).

The USAT and SAT provide functions that allow USIM and SIM smart cards to control the terminals, enabling them to show characters in the display and access networks (Short Message Services (SMS) transmission). Therefore, by implementing the USAT and SAT functions in USIM and SIM, it would become possible for operators to provide their own unique services. Moreover, a user would be able to enjoy the same services even if they were to move a USIM/SIM smart card from one terminal with USAT/SAT support to another terminal supporting USAT/SAT. However, DoCoMo had no special needs to implement the USAT and SAT functions in UIMv1 and UIMv2 because the i-mode service has already become popular.

3. Specifications

3.1 Physical Specifications

The UIMv2 smart card has the same physical size as a credit card, i.e., ID-1 size (full size), and the base material is treated with plug-in cutting. A material called PET-G is employed for the card base material, taking temperature and weather resistance into consideration. PET-G satisfies the temperature characteristics of the standard specifications and causes little environmental load at disposal. In the SIM and smart card markets in general, materials such as PolyVinyl Chloride (PVC) and ABS resin are often used.

3.2 Electric Specifications

The UIMv2 smart card can operate with power supply voltages (Vcc) of 5 V and 3 V. Its maximum current consumption is compliant to the Technical Specification (TS) 102.221 R99 specification of European Telecommunications Standards Institute (ETSI); i.e., it is 7.5 mA or less, which is the minimum current that should be supplied from the UIM interface part of a terminal. Moreover, it supports a clock stop mode in which the clock signal is no longer supplied from the terminal when no command is executed for a period of time.

3.3 Protocol Specifications

We employed the Direct Convention for the data encoding. Direct Convention is a transfer method of individual bytes. Each byte is first sent with the Least Significant Bit (LSB) and using positive logic, i.e., logic values of 1 and 0 correspond to high and low electric potential, respectively. The standard specifications for the 3rd Generation Partnership Project (3GPP) specify both the T=0 protocol (mandatory: half-duplex asynchronous character transfer protocol) and the T=1 protocol (optional: half-duplex asynchronous block transfer protocol) as transfer protocols of USIM. UIMv2, however, adopts only the T=0 protocol.

3.4 Command Specifications

1) USIM Commands

UIMv2 supports the class byte 00h and 80h commands specified by the ETSI TS 102.221 specification, however it does not support commands related to USAT.

Types of commands include file selection (SELECT), acquisition of file selection status (STATUS), file read (READ BINARY, READ RECORD), file update (UPDATE BINARY, UPDATE RECORD), record search (SEARCH RECORD), addition to setup value (INCREASE), PIN related commands such as checking/changing PIN (VERIFY PIN, CHANGE PIN, DISABLE PIN, UNBLOCK PIN), network authentication (AUTHENTICATE), file activation/deactivation (DEACTIVATE FILE, ACTIVATE FILE) and information acquisition (GET RESPONSE).

2) SIM Commands

UIMv2 supports the class byte A0h commands specified by the 3GPP TS 11.11 specification, however it does not support commands related to SAT.

The functions provided by these commands are similar to those provided by USIM commands, but some of the names are different. Commands unique to the SIM commands include network authentication (RUN GSM ALGORITHM) and SIM control (SLEEP).

3) PDC Commands

UIMv2 is equipped with class byte 00h and 80h commands equivalent to the USIM commands, which are specified by the ARIB STD-27 standard of Association of Radio Industries and Businesses (ARIB).

They are basically the same as the USIM commands. This is because the ARIB STD-27 standard refers to the specifications of the USIM commands so that they can be used commonly with the PDC commands. However, the network authentication command (PDC AUTHENTICATE) is a unique PDC command.

4) Command Modes

UIMv2 supports two separate command modes: the USIM mode (a status in which the USIM commands and PDC commands are operable) and the SIM mode (a status in which the SIM commands are operable).

The UIMv2 smart card determines which command mode to choose by the class byte of the first command it receives from the UIM interface of a terminal after it completes the startup processing, sends Answer To Reset (ATR) and performs the Protocol and Parameters Selection (PPS) procedure. The UIMv2 smart card chooses the SIM mode if the class byte in question is A0h, and the USIM mode in other cases.

After judging the command mode, the command mode cannot be changed until the UIMv2 smart card is reset the next time.

3.5 File Specifications

UIM adopts a file system where various files for providing each of the functions are stored (**Figure 5**).

In fig. 5, the Elementary Files (EF) correspond to files in a PC-based file system (e.g., a Microsoft Windows operating system). The Master File (MF), Application Dedicated Files (ADF) and Dedicated Files (DF) correspond to folders (directories). The MF, in particular, corresponds to the root directory. An ADF is essentially a DF with a special file ID called an Application IDentifier (AID).

3.6 Security

The IC chips used for the UIM smart cards have a tamper-resistant[*1] structure that is robust against physical/electrical reverse-engineering and other forms of malign manipulation. Moreover, the operating system is designed to make the best possible use of this tamper resistant structure and taking the security fully into consideration; the UIM smart card thus has excellent security performance.

4. Telecommunication Applications

4.1 Overview

In the 3GPP and ETSI standard specifications, the file trees expanded under the main ADFs and DFs are sometimes called applications. This term is different from application software used in general PCs and does not necessarily refer to cases where software functions (e.g., commands) and files are paired.

1) USIM Application

The USIM application stores subscriber information used in FOMA terminals. It can store up to 20 messages of SMS and 50 phonebooks (Global Phonebook), among others. It can store prioritized operator lists containing up to 20 entries on the user side and 40 entries on the DoCoMo side.

2) SIM Application

The SIM application stores subscriber information used in GSM terminals, in the same way as for the USIM application.

Some of the EFs have the same structure as the USIM application and allows linking files (file link).

3) PDC Application

It is used by IMT/PDC dual terminals to connect to a PDC network. The PDC application shares the phonebooks (Global Phonebook) of the USIM application.

4.2 Common Specifications Among the Applications

1) Phonebook

UIMv2 supports Global Phonebooks, and UIMv2 smart cards are thus not equipped with Local Phonebooks.

2) File Link

For historical reasons, the EFs supported by the USIM application and GSM application have many structural similarities, which means that EFs assigned to logically different locations can use common information by referring to the same memory area in the IC chip.

[*1] Tamper-resistant: Confidential information stored inside a device cannot be disclosed nor tampered with by anyone other than legitimate right holders.

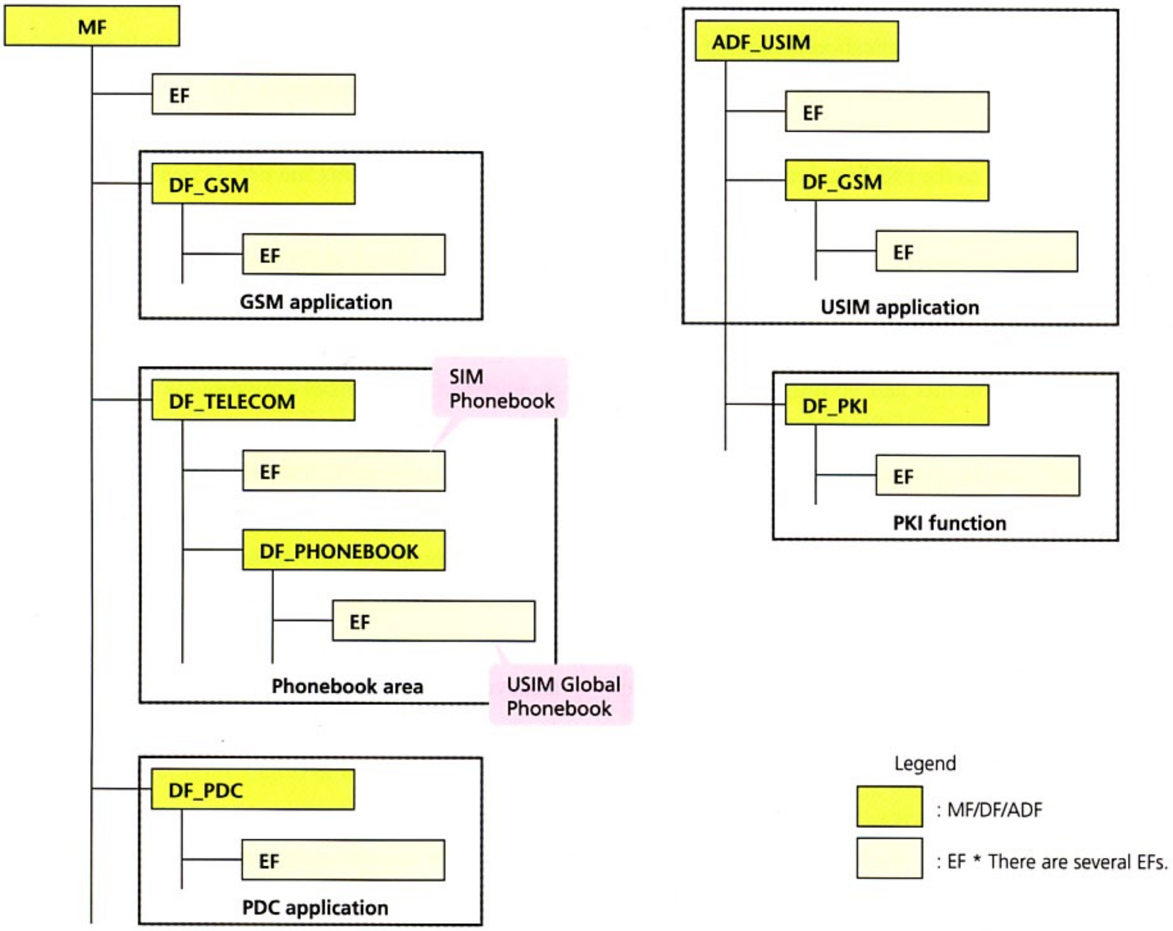


Figure 5 UIMv2 file system

For example, the Global Phonebooks of the USIM application share the same physical memory areas as the phonebooks of the SIM application via a file link. This can reduce the physical memory area to approximately half of the logically required memory capacity.

Moreover, this allows simplifying the processing procedure involved in issuing the UIM smart card in customer management systems ALl Around DoCoMo INformation systems (ALADIN).

5. PKI Function

5.1 Advantages of Implementing PKI Function in UIM

The Public Key Infrastructure (PKI) function is necessary for the digital certificate service.

One of the important issues of the PKI function is how private keys paired with public keys can be managed and operated safely. The solution chosen here, to manage the private keys within the UIM smart card, is beneficial in terms of tamper resistance viewpoint.

The signature generation function will require entry of a Personal Identity Number (PIN) 2 code for the USIM application every time it generates a signature, rather than a PIN1 code. This prevents unauthorized use by third parties and improves the security of the signature-based identification. Moreover, this system has the further advantage of both high security and portability. The same certificate of the same user can be utilized commonly among different FOMA terminals supporting the PKI function by mounting the UIMv2 smart card in the terminals.

5.2 Basic Design

In order to implement the PKI function in UIMv2, we adopted the RSA[*2] public key cryptosystem, which has become the standard on the Internet. This section provides an outline of the UIM design related to the PKI function.

(1) File Layout

We allocated a dedicated DF in the USIM application and put all data related to the PKI function there, such as user cer-

[*2] RSA: Public key cryptosystem. "RSA" are the initials of the three scientists who invented the system, R. Rivest, A. Shamir and L. Adleman.

tificates and RSA public keys. This allows terminals to access the PKI function while the USIM application is running without using logical channels.

(2) Commands

As commands dedicated to the PKI function, we added original commands for generating RSA key pairs, downloading user certificates and generating signatures.

(3) Security

We classified the security related design into two categories: design related to information that can be referenced from the outside including user certificates, and design related to information and functions that must be protected against access from the outside by security measures such as private keys and methods for storing user certificates while downloading from the certificate authority. For the latter, we made the design so that secure procedures are established as a self-contained system and sufficient security is maintained for operation of the UIM smart card itself, in order to prevent access other than authorized operations.

(4) Restrictions on the Memory and Operation Speed

In order to carry out the complex calculations involved in the RSA algorithm at high speeds, we selected an IC chip with built-in co-processor function; processing times well under half a second were achieved.

RSA key pair generation process on the IC chip, on the other hand, generally takes a long time. For this reason, we judged that dynamic generation is impractical while the UIM smart card is mounted on terminals, considering the operation in mobile communication. We therefore decided to store five RSA key pairs in advance during production of the UIM smart card.

6. Tests of UIMv2

6.1 Command Test

UIMv2 smart cards are supplied from several UIM smart card manufacturers, and their products must operate according to identical specifications. It is, however, difficult to exactly obtain identical operations including those under the interface level of commands, simply by specifying standard specifications and so forth for reference purposes.

For this reason, we developed an original command test system that allows checking all the command functions of UIMv2. This has made it possible to achieve uniform and improved operation quality for UIM smart cards produced by different manufacturers.

6.2 File Test

Since file configuration and default values of files are important for each application, it is necessary to conduct a thorough file test. We specified a list of file parameters necessary to interface with terminals and networks and require all the tests to be conducted for delivered products.

7. Interoperability

Interoperability refers to connectivity between devices. That is, interoperable devices are products of various vendors that can be mutually connected and used because they are designed to be compliant to well-defined interface specifications.

As the number of vendors and products increase, the importance of interoperability becomes higher and the number of items to be checked and the amount of necessary tasks will increase. In other words, a multi-vendor market can only be achieved in systems with interoperability.

1) Interoperability of IMT-2000

Since IMT-2000 assumes international roaming, USIM smart cards, terminals and networks from any vendor can be freely combined and used mutually as far as the products are compliant to the 3GPP specifications and others.

2) Interoperability of FOMA Networks

In the development of DoCoMo's FOMA network devices, interoperability is secured by being compliant to the 3GPP specifications and so forth. Moreover, we constantly conduct interoperability tests on actual products, so that the interoperability can be guaranteed in a reliable manner.

3) Interoperability with FOMA Terminals

In the development of UIMv2, connectivity tests with UIMv2 smart cards are conducted on both FOMA terminals under development and all the FOMA terminals that have been commercialized already in order to secure interoperability with existing FOMA terminals.

4) Interoperability with GSM Terminals

Since UIMv2 smart cards are equipped with the GSM application, it was necessary to verify that they would operate normally when they are inserted into GSM terminals. During the development of UIMv2, we conducted interoperability verification tests with more than 60 GSM terminal models from 12 manufacturers.

5) Interoperability with IMT-2000 Terminals

Since the IMT-2000 network service has been launched by several overseas operators, several IMT-2000 terminal models other than FOMA terminals have already been introduced on the market. We verified the interoperability of such terminals with UIMv2 as well.

8. Standardization Activities

The standard specifications related to USIM and SIM are examined at 3GPP TSG-TWG3 and ETSI Smart Card Platform (SCP). DoCoMo also continuously contributes to the creation of specifications and clarification of the contents of the specifications through participation in various standardization conferences.

In order to achieve better interoperability, the activities at standardization conferences are essential. In such conferences, it is first necessary to coordinate specifications—both design specifications and test specifications—and upgrade the documents. Secondly, it is important to make the descriptions of the standard specifications more accurate, so that each participant (vendor and operator) agrees on the same understanding.

9. Conclusion

Presently, various types of smart cards for ID are used and going to be used in the near future such as identification cards, driver's licenses, credit cards, telephone cards, transportation system cards, electronic settlement of small amount and railway commuting passes, and some are now being tested in practical use. A social infrastructure based on these smart cards will penetrate into our lives, the services will be developed, and the convenience of using them will become more and more higher.

It is expected that some of these service applications will be able to function in cooperation with the UIM smart card, or there will be further development when it's integrated into the UIM smart card itself. A society where we can handle most of our daily activities just by carrying around a terminal with an advanced UIM smart card may become reality in the immediate future.

ABBREVIATIONS

3GPP: 3rd Generation Partnership Project
ADF: Application Dedicated File
AID: Application IDentifier
ALADIN: ALl Around DoCoMo INformation systems
ARIB: Association of Radio Industries and Businesses
ATR: Answer To Reset
DF: Dedicated File
EF: Elementary File
ETSI: European Telecommunications Standards Institute
FOMA: Freedom Of Mobile multimedia Access
GSM: Global System for Mobile communications
IMT-2000: International Mobile Telecommunications-2000
MF: Master File
OS: Operating System
PDC: Personal Digital Cellular
PIN: Personal Identity Number
PKI: Public Key Infrastructure
PPS: Protocol and Parameters Selection
PVC: PolyVinyl Chloride
SAT: SIM Application Tool kit
SCP: Smart Card Platform
SIM: Subscriber Identity Module
SMS: Short Message Service
SSL: Secure Sockets Layer
TS: Technical Specification
UICC: Universal Integrated Circuit Card
UIM: User Identity Module
UIMv1: UIM version 1
UIMv2: UIM version 2
USAT: USIM Application Tool kit
USIM: Universal Subscriber Identity Module