

Novel UMTS Core Network Architectures to Support Pre-standardized Services

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Abstract— Many services are being introduced as mobile telecommunication technology advances and they provide profits to the mobile network operators (MNO). However, the adoptions of new services often require additional features in terminal devices or even in the networks. Some pre-standardized services may not be supported in the network or even require some changes in the network architectures, which makes the deployment of new services challenging. In this paper we propose a UMTS core network architecture to support various services with the service map. The proposed architecture supports the easy adoption/test of the pre-standardized services and easy creation of specialized services for networks.

Keywords— UMTS, core network architecture, mobile services, terminal capability, network capability

I. INTRODUCTION

Telecommunication network supported only voice call at the beginning and the network was developed to support supplementary services such as Call Forwarding. As mobile phone is used everywhere and the capacity of wireless network is exploding, the demand for new services is ever increasing.

Next Generation Network (NGN) is being designed into multiple functional groups decoupling services and transport which will enhance service delivery to users [2]. In accordance, 4G technologies such as Long Term Evolution (LTE) and mobile Worldwide Interoperability for Microwave Access (WiMAX) will provide services through IP Multimedia Subsystem (IMS) architecture, providing open, standard-based network that delivers integrated multimedia services. However, 4G technologies will take years to be used by the majority of people, since reasonable profit expectation must proceed the upgrade of network.

In contrast, Universal Mobile Telecommunications System (UMTS), a 3G technology being standardized by 3rd Generation Partnership Project (3GPP), is expected to be the dominant in the years to come. However, it takes much more effort to deploy new service to the UMTS networks compared to the NGN. So it seems rational to design the simple methods to facilitate easy

service development for the existing networks, UMTS networks in particular. In this paper, we propose a UMTS core network architecture to support various services with the service map. The service map is generated using type allocation code (TAC) and software version number (SVN) filed in the 3GPP standard to check the service capability. The proposed architecture supports the easy adoption/test of the pre-standardized services and easy creation of specialized services for networks.

The remainder of this paper is organized as follows. In section 2, we explain the standardized UMTS features related to the ability of the User Equipment (UE), or the terminal. Section 3 describes a review on the practical architecture ensuring service continuity of Multimedia Messaging Service (MMS) after changing a UE to another UE with different capability. After that, the general framework to facilitate the development and propagation of terminal-specific or network-specific services is described in section 4. Section 5 concludes this paper with future work.

II. RELATED WORKS IN THE STANDARDS

A. User Equipment Specific Behaviour Information (UESBI)

3GPP had worked on a feature to take care of terminal capabilities. A technical specification of 3GPP standards named 'Provision of User Equipment Specific Behaviour Information (UESBI)' is published to prevent connection errors that might occur from some early imperfect UEs, which lack some standardized functions. The architecture for UESBI provisioning is depicted in Figure 1. The information of a terminal is given to the access network through the Uu-interface (between the UE and the access network) and the Iu-interface (between the core network and the access network). The information provisioned through the Iu-interface, called UESBI-Iu, is passed from the core network to the Radio Network Controller (RNC) by checking International Mobile Equipment Identity and MS Software Version Number (IMEISV). IMEISV is an identity indicating UE by one-to-one mapping with subversion of the UE, to provide necessary information for equipment specific behaviour of access network. On the other hand, the information provisioned through the Uu-interface, called UESBI-Uu, is

directly passed to the access network by UE. UESBI-Uu includes the information that based on which phase of Global Systems for Mobile communications (GSM) or release version of UMTS the UE is built [15]. RNC can expect the UE's access capability from the phase or release version.

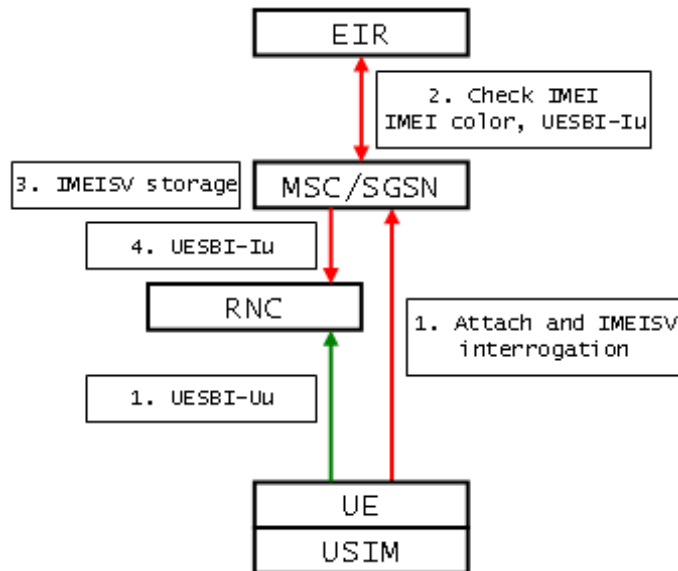


Figure 1. Architecture for provisioning UESBI

The architecture was designed to cope with early terminals with defects that can cause errors when working with standard networks. It presented the idea that information related to UE can be stored in the core network and each model of UE can be distinguished based on the information.

However, specific behaviour is intended only for the access network, and no practical scenario was introduced as a technical specification. This is because there are not many terminals having defects enough to make this specification meaningful. Due to these limits, no more work is going on UESBI.

B. Automatic Device Detection (ADD)

Subscriber Identity Module (SIM)-only or Universal Subscriber Identity Module (USIM)-only deals are becoming common nowadays [5]. It takes advantage of a novel concept that all information related to the subscriber be put into Universal Integrated Circuit Cards (UICC) and separating the information from the terminal. The concept is realized by GSM and has been inherited to UMTS [6]. The rise of SIM-only deal can promote the reuse of UE, especially high-end UE since the subscribers can change its terminals by just buying or lending them and inserting their SIM into it.

Automatic Device Detection (ADD) is designed for the Home Environment (HE) to know when its user, identified by International Mobile Subscriber Identity (IMSI), has changed

the UE attached to it. Visitor Network (VN) sends IMEISV and IMSI to Home Location Register (HLR) so that Home Public Land Mobile Network (HPLMN) can be aware of the change [11]. ADD is a new concept that the HE can receive the device information even when the subscriber is roaming to other countries.

However, ADD has an implicit limitation in that it cannot prevent errors caused by unknown features. If a terminal requests a service unknown to the network, Mobile Switching Center (MSC)/Visitor Location Register (VLR) or Serving GPRS Support Node (SGSN) should detect it and decide whether to proceed with the service request or not. In other words, ADD is adequate for the services only using functions allowed by the standards. So, to proliferate mobile services and to support various pre-standardized services, more powerful architecture is needed, which is the contribution of this paper.

III. A PRACTICE REVIEW

Korea Telecom Freetel (KTF) constructed nation-wide UMTS network in 2007 and UMTS handsets are introduced simultaneously. KTF has been dealing with handset-related issues such as migrations of all services provided on CDMA2000 [3] to UMTS since a lot of services were operator-specific and not based on UMTS standard. Here, we reviewed an example scheme developed to repair MMS service discontinuity problem arose due to SIM unlock.

A. Background

KTF has commercialized CDMA in 1800MHz spectrum in 1996. The 1800MHz spectrum is rarely used worldwide so that global roaming cannot be supported. And the operator controlled its lineup of terminals to provide KTF specific services with the terminals. With its own terminals and subscribers, services are provided based on subscription data without considering capabilities of various terminals since subscribers are not able to subscribe for services unless their terminals are capable for them. HLR could handle the information to distinguish whether the subscribers can use the services since every subscriber is distinguished by Electronic Serial Number (ESN).

KTF has controlled CDMA environment because of the spectrum issue, but the situation is in stark contrast for UMTS network. Many countries are using UMTS or GSM technology, and KTF has chosen 2.1GHz spectrum which enables the global roaming. Furthermore, UMTS technology came with the novel concept of putting subscriber's information into USIM and separation of UE and USIM, resulting in making attentive management for UE important. In addition, roamers with their terminals from other countries should be handled properly. The issue has become essential when KTF started to provide SIM-unlock.

There were many non-standard operator-specific services of KTF, served for many years under the controlled environment. The services should be examined to find out whether those can be served comprehensively within the global UMTS environment. New functions had to be developed in order to continue to provide the same services of CDMA network. Without the functions, the services had critical problems to be served in UMTS network. A few examples are as follows. For the Short Message Service Center (SMSC), transform functions between KTF's Korean-specific encoding/decoding and standard encoding/decoding scheme was developed. For the Multimedia Messaging Service Center (MMSC), a real-time checking function for UE-USIM mapping was added since MMSC must know terminal capability to send MMS in appropriate form. Also, the real-time checking function is needed for supplementary services owing to some kind of terminals that lack the standard functionality and work wrongly when standard messages were received.

B. Architecture

We will have a closer look into whole architecture of the function developed for processing MMS mentioned above, which is depicted in Figure 2.

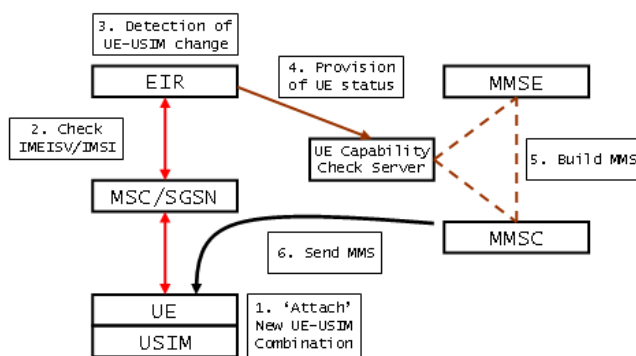


Figure 2. Architecture of checking UE capability for MMS

As specified in the 3GPP standards, in UMTS or GSM networks, identity of UE may be checked in the following cases – IMSI attach, IMSI detach, Location Update, and during the establishment of mobile originated calls and terminated calls such as voice call, video call, SMS and data services: PDP context activation [11], [12], [13].

- (1) In certain cases like IMSI-attach, combination of UE-USIM might be changed from the combination of UE-USIM checked for the last time with the same USIM because the USIM has attached to a different UE. The MSC or the SGSN requests the identity of the UE to detect the change. Network operators can decide when to check the identity [8].

- (2) The MSC or the SGSN sends *check IMEI request* to EIR. The IMEI of UE attained in step 1 is combined with the IMSI of USIM attached to the UE and passed to EIR. *Check IMEI request* must include either IMEI or IMEISV, but IMSI is also commonly included for checking if the combination of IMEI and IMSI is allowed to be registered by the network [1].
- (3) EIR is a network node which maintains status of user equipments by keeping their IMEIs into three separate lists: White, Gray, Black. White list contains IMEIs that are permitted to use the network, gray list contains IMEIs which are so conspicuous as to be tracked, and black list contains IMEIs banned from the network [4]. EIR gives response to the *check IMEI request*; it returns the color of the list where the requested IMEI is included. However, EIR has another function in this KTF-specific architecture, detecting any change of combination of UE-USIM with respect to the IMEI and IMSI in the *check IMEI request*. To support this function, EIR in the depicted architecture maintains up-to-date information of every IMEI and the IMSI attached to it, for the IMEIs and IMSIs of users subscribed to its HPLMN.
- (4) EIR detects it when the IMSI, included in the *check IMEI request*, is not attached to the IMEI of up-to-date information of EIR. In this case, EIR makes a provision of this information to UE Capability Check Server as soon as the EIR returns 'white' or 'gray' in *check IMEI response*. Which means the combination of UE and USIM is changed, and the network has accepted new combination allowing the user to connect to the network. The information should contain IMEI and IMSI so UE Capability Check Server can rearrange capabilities of the UE.
- (5) Multimedia Messaging Service Entity (MMSE) should inquire the capability of UE to the UE Capability Check Server. Omitting this process might lead to loss of the MMS because multimedia message cannot be recognized if the UE is not able to play or show the message. Which might happen when the user changed its UE-USIM combination in advance receives an MMS, and the capability of new UE is different from that of old UE. Hence, previous steps should be done in real-time to provide continuous MMS service to the users.
- (6) After making the appropriate MMS based on the retrieved information from the UE Capability Check Server, MMSC sends the MMS to the intended user.

C. Result and Evaluation

This architecture makes real-time adjustments on encoding of MMS feasible when the combination of UE-USIM is changed freely on user's will. So the network operator can utilize the capability of UE on MMS to its extreme with no fear of the

MMS being not delivered to or recognized by the user. This additional function does not affect access network and critical nodes in the core network such as MSC, SGSN and HLR. So KTF could develop this functionality without severely disrupting standard UMTS network.

Run for more than a year, the stability of this scheme is confirmed by the fact that no unexpected problem has been reported.

The necessity of this scheme is also proved. Super USIM, used for special tests by KTF engineers, do not go through the process of UE-USIM combination detection and adjustment of capability information. The testers using the super USIM frequently change their UE for tests. They have reported that many times have they lost MMS messages that they should have received. Since the changes of combination of UE and super USIM are not provisioned to UE Capability Check Server, MMS messages sent to the UEs are not appropriate for the UEs. The reports show that MMS cannot be sent and received in the environment of USIM unlock without this scheme.

The architecture is efficient only when it comes to MMS problem. Even though other issues can be solved by designing new scheme for every single issue as well, this kind of approach is still time-consuming. It is a burden for operators and vendors, making development of new services tough. This approach can solve the problems but finding a more general and refined architecture can further facilitate deployment of new functions.

IV. NEW ARCHITECTURE

Standardized features are optimally designed so that network and terminal functions are stable and having no conflicts among them. But it takes a long time discussing to make agreements on the features, making the need for some architecture that can facilitate fast-deployment of services.

HLR is responsible for information of home subscribers including whether the user is subscribed for services. In contrast, terminals are developed much so that terminals should be differentiated with each service whether a handset is capable of providing that service to its owner. Therefore, the network should take control of terminal capability to encourage use of these services and treat the features safely.

A. Background

Many standardized services are usually commercialized by few operators before it is fully standardized. Such as Customized Ringing Signal (CRS), a service enables the called subscriber to listen to a ringing signal, which is set by either the calling party or the called party arbitrarily, instead of default ringing signal from the network [9], is dependent on network capability to create and play the signal to users and also dependent on

whether the terminal has functionality to receive and play the ringing signal transferred from the network.

The Service Change and UDI Fallback (SCUDIF) is another example showing that certain terminal capability and network capability is required for the service [14]. The network nodes and both terminals of the calling party and the called party need to support 'service change and fallback' between voice and video call from the establishment to the end of a call.

Such services should be fully standardized in order to be used since the network and the terminals have to be developed. It would be preferable to have more useful services like CRS and SCUDIF. The key barrier against active trial of new services on commercial network is the interworking problem between different networks and the terminals. The problem is also the biggest barrier of wide-spreading of services confirmed of their benefits. Hence, we propose a method which can ensure the interworking of networks and terminals.

B. Architecture

In this part we will explain about a new architecture, which is an exemplary for managing terminal-dependant service information and the way of managing it is similar to that of managing user information held by HLR. It is depicted in the following image and the role of each node will be described in turn.

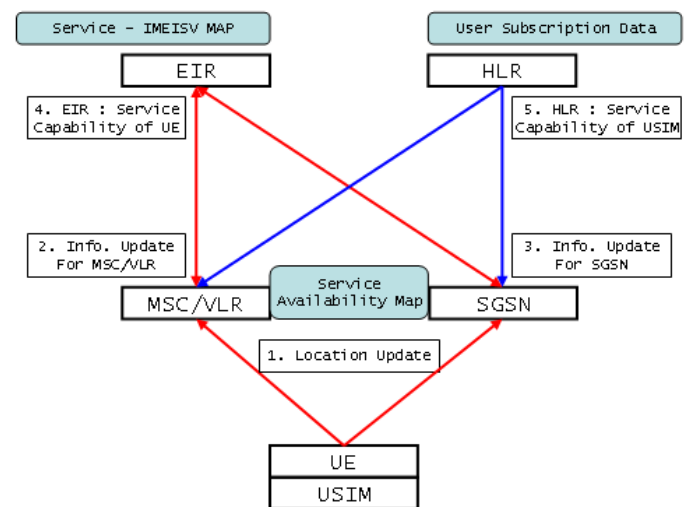


Figure 3. Architecture for service capability check

- (1) UE/USIM ask for update location when their location is changed, then MSC/VLR and SGSN serving the UE/USIM are aware of the responsibility of controlling service capability. When user try to trigger a service, UE/USIM sends the request to the network unless they already know

the UE or network do not have capability to provide the service.

- (2) MSC/VLR updates information of subscribers when the subscriber initially gets into its area or any information has changed. User information is retrieved from HLR and terminal capability information would be sent from EIR if the terminal is white listed in EIR. UE information can also be handed over from old MSC/VLR as a form of a parameter of MAP Handover Preparation message. Combining the information received from EIR and HLR with MSC/VLR capability of services, a service availability map can be made and stored in the VLR. At this point, MSC/VLR capability also needs to be taken into consideration, e.g. If the MSC/VLR does not support SCUDIF, then SCUDIF trial from the terminal shall not be accepted. If CRS providing server is not present, the CRS trial from the terminal shall not be accepted, either.
- (3) SGSN updates information of subscribers; the case is same with MSC/VLR. User information is retrieved from HLR as well as the terminal capability from EIR if the terminal is white listed in EIR. Combining the information sent from EIR and HLR with SGSN capability of services, a service availability map can be made and stored in the SGSN. In addition, when SGSN receives service request on Packet Switched (PS) domain from UE/USIM, it checks the capability and send back negative response defined in case of not supporting the service.
- (4) EIR is a network node maintaining IMEIs, and the IMEI or IMEISV together with IMSI is always checked by EIR, making it easy to develop new function of mapping service capability to UE/USIM information. Map field will enable mapping of IMEISV and availability of each services registered. Each service is registered by assigning a unique service number. Service numbers can be defined and distributed to network operators and vendors to provide their own services. IMEISV is 16 digits long and composed of Type Allocation Code (TAC), Serial Number (SNR), and Software Version Number (SVN) as shown in the figure 4 [10]. MAP field can be defined as the SVN to have backward compatibility with existing UEs. SVN is in the standard so most UEs already have the field and its usage have no conflict with current standard, which makes provision of terminal capability from EIR to MSC/VLR or SGSN. SVN is 2 digits long, so in this case up to 256 cases can be made for each type of UE, and the limited number resource should be controlled with care. The type of UE can be distinguished by TAC. As depicted in the picture, TAC and SVN may be combined to be mapped to a series of enabled services. Namely, EIR can detect terminal model type with TAC in IMEISV and more specific service-

capability within a model can be distinguished by SVN in the same IMEISV. However, we claim to extend existing message to by making new parameters dedicated for mapping numerous services in the long run.

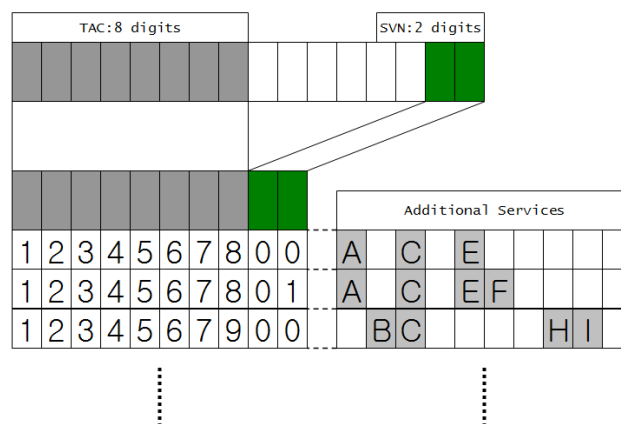


Figure 4. Example of Service – IMEISV MAP

If it is hard for MSC/VLR or SGSN to implement all the functions to have full service availability map, MSC/VLR or SGSN may ask EIR for service capability of UE each time terminal-related service is required from the terminal. While service capability of USIM is decided from HLR and the data is stored in VLR or SGSN. And network capability, whether the network has every function needed for providing certain service, should be stored and decided by MSC/VLR or SGSN.

- (5) HLR in HPLMN of subscriber gives user information to VLR or SGSN as usual.

HLR can take the additional role of EIR in this special architecture by applying ADD. But placing Service – IMEISV MAP at EIR is better than placing it at HLR for three reasons. First, EIR has less number of functions, which makes modification and addition of the MAP message of EIR easier compared to that of HLR. Next, EIR is designed for dealing with terminal's information, so it is conceptually better to differentiate service information of UE to EIR and that of USIM to HLR. Last, the operator can differentiate the event of location updating and checking IMEI, for instance, to reduce network traffic. In this aspect, the operator might choose to separate service availability check from *check IMEI request* to make a service capability checking server apart from the EIR and provide a new message to ask for service capabilities of UEs.

C. Discussion

To use the proposed architecture, engaged network operators and vendors should make an agreement on the format. The map

should include numbering field so large as to take in a lot of services to be made in the future. Each operator or vendor will get a range of the number so they can assign the numbers to newly developed services. Initial setting for the service field will be all unset. And with each service they can provide, they will assign a number and set the field. The assignment of numbers should be informed to other operators and vendors. When a new type of UE is sold on market, service availability mapping of it should be informed to every network operators so that the network operators can build the map for every type of usable UE on its network. Network capability map in the MSC/VLR and SGSN and service availability map of USIM on HLR should be properly updated as well.

Service capability of UE, USIM, and the network nodes will be compared and a service will be provided only if every service capability field is set. This will prevent any network or terminal error that could be caused by trying to give service that cannot be served.

When other models of devices or networks want to deploy the service used by other operators or vendors, they can simply do it by asking for the number information and updating the map. After developing all the functions needed, they just need to set the field for the service. Being so will enable rapid distribution of useful services tested by few operator or vendor by ensuring no conflict on existing networks and interworking between them.

Even a new service supported by single model of terminal devices and one operator will securely be deployed with this architecture. Assign a new number and setting its field on the single model of terminal. Then, rest of the models of terminals are not allowed use the service. In addition, regional trial will also be possible with selected MSC/VLR or SGSN with MSC/VLR or SGSN with their service field set. In this case, devices for trial will be able to use the service only in the area of the selected MSC/VLR or SGSN otherwise the service will be blocked by service availability map in the core network. Blocking of the new service can be done by the network by just unsetting the service field in the MSC/VLR or SGSN.

V. CONCLUSION

In this paper, we propose a novel UMTS core network architecture to support pre-standardized services. By introducing a service map maintained in the EIR, the proposed architecture can support new services which can not be supported in the traditional UMTS network when there is an inconsistency between the network and terminal capabilities. Also, the proposed architecture supports environments for experiments and tests for the new pre-standardized services with limited network nodes. As our future work, we will work further on optimizing the general architecture to facilitate deployment of pre-standardized functions so that useful services can be commercialized easily. We will also develop schemes to solve network- and terminal-related problems, which are out of scope for the standard.

VI. REFERENCES

- [1] Airguard EIR - <http://www.airwidesolutions.com/AirGuardEIR.html>
- [2] Knightson, K. Morita, N. Towle, T. NGN architecture: generic principles, functional architecture, and implementation. *IEEE Communications Magazine*, Vol 43. Issue 10, Oct 2005.
- [3] Knisely, D.N. Kumar, S. Laha, S. Nanda, S. Evolution of wireless data services: IS-95 to cdma2000. *IEEE Communications Magazine*, Vol 35. Issue 10, Oct 1998.
- [4] Rahnema, M. Overview of the GSM system and protocol architecture. *IEEE Communications Magazine*, Vol31. Issue 4, Apr 1993.
- [5] Raymond Yu. Emeka Obiodu. SIM-only emerges from the shadows. *OVUM report*, Apr 2009.
- [6] 3GPP TS 21.111 : USIM and IC card requirements
- [7] 3GPP TS 22.101 : Service aspects; Service principles
- [8] 3GPP TS 22.016 : International Mobile station Equipment Identities
- [9] 3GPP TS 22.183 : Customized Ringing Signal requirements
- [10] 3GPP TS 23.003 : Numbering, addressing and identification
- [11] 3GPP TS 23.012 : Location Management Procedure
- [12] 3GPP TS 23.018 : Basic Call Handling; Technical realization
- [13] 3GPP TS 23.060 : General Packet Radio Service; Service description
- [14] 3GPP TS 23.172 : Technical realization of Circuit Switched multimedia service UDI/RDI fallback and service modification
- [15] 3GPP TS 23.195 : Provision of User Equipment Specific Behaviour Information to network entities