A Design of Home Subscriber Server for IP Multimedia Service in All-IP UMTS Network

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Abstract—**This paper introduces the All IP UMTS based core networks concept for IP Multimedia service. The focus of the study is designing a Home Subscriber Server (HSS) system that satisfies the functional requirement in the defined 3GPP Release 5 standard for the deployment of IP based multimedia services. Initially, it is expected that the basic UMTS core network (CN) will be deployed, with the functional element of the IP multimedia subsystem (IMS) and the signaling protocol among the elements. Then, we propose a competent design scheme for HSS system to provide IP multimedia service. It is divided two parts, a user profile database and a functional scheme of application for easy implementation.**

I. Introduction

IP has opened up a whole range of communication applications that may allow operators to develop totally new value added applications as well as to enhance their existing solutions [1]. The open architecture and platforms supported by IP and operating systems has also led to creating new multimedia applications and changing existing network architecture in the mobile service environment. Currently there are several ongoing efforts to define mobile network architectures that would enable fully IP based delivery; i.e., not only data, but also voice service would be provided over the IP bearer. Such network architectures are usually referred to as All-IP UMTS CN proposed by the 3GPP(3rd Generation Partnership Project)[2].

Two phases in the evolution of the Universal Mobile Telecommunications System (UMTS), Release4 (R4) and Release5 (R5) specify how voice and multimedia can be supported by an IP transport service. Especially, R5 takes a more radical approach to the introduction of conversational and interactive multimedia services on to an end-to-end IP transport provided by an enhanced GPRS in the packed-switched domain. R5 specifies voice and various multimedia services that make use of General Packet Radio Service (GPRS) for transporting of speech and signaling, rather than the circuit-switched domain transport. A new core network domain, the IP multimedia subsystem (IMS) is introduced for the control of multimedia session and the interconnection to other networks, such as the PSTN and other UMTS.

The IMS provides a flexible architecture for the rapid deployment of innovative and sophisticated features. In order to accomplish this, the IMS introduces new two signaling protocol. In the first, the IMS utilizes the session initiation protocol (SIP), which is an IP application-layer control protocol that creates, modifies, and terminates sessions. In the second, protocol within the IMS core network, the Diameter protocol, the next generation Authentication, Authorization, Accounting (AAA) protocol standardized by IETF is used to provide user mobility management and to solve a wide AAA problem.

HSS is one of the functional elements in the IMS core network. It is the master database for a given user. It is responsible for keeping a master list of features and services (either directly or via servers) associated with a user, and for tracking location and means of access for its users. It provides user profile information, either directly or via servers. It is a superset of the 3GHLR functionality, since it is also communicates via a new IP-based interface.

In this paper, we propose a competent design scheme of the overall HSS system for IP multimedia service, which can handle user mobility management, user identification and so on. A user profile database schema is included in this design. It also meets the HSS functional requirements in [3].

The following section introduces the R5 IMS core network on the basis of a 3GPP All-IP reference model and the functionality of the network elements. In Section 3, we describe the functionality, signaling protocol architecture, and user profile UML model for the design. Then, we propose a design scheme for the HSS that can bring along good performance and easy implementation in Section 4. Finally conclusions are drawn.

II. IP Multimedia Subsystem Core Network

A. The Configuration of IMS

IP multimedia sessions provide the ability for users to invoke IP multimedia applications to send and receive voice and data communications, even when roaming. This includes interworking with existing voice and data networks for both

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fixed (e.g. PSTN, Internet) and mobile users. Thus IMS supports interworking with existing fixed and mobile voice and IP data networks, including PSTN, Mobile and Internet.

To meet the requirement of various service and external interface. The IMS includes several functional elements such as Call Session Control Function (CSCF), Home Subscriber Server (HSS), Media Gateway control Function (MGCF), Breakout Gateway Control Function (BGCF), Multimedia Resource Function (MRF) and Media Gateway (MG). An overview of the IMS core network and its relationship with the GPRS packet-switched domain is shown Fig1.

The CSCF acts as a call server and handles call signaling. It has been functionally decomposed into three main areas according to its location and role.

The proxy-CSCF (P-CSCF) is the first contact point within the IMS core network. Basically, the P-CSCF behaves like an SIP proxy as defined in RFC2543. The P-CSCF performs bridging of signaling between the terminal (UE) and Serving-CSCF (S-CSCF). The P-CSCF is also involved in bearer confirmation and decision, and resource aspects during session bearer establishment. It is mainly located in the GGSN.

The Serving-CSCF (S-CSCF) performs operations for the session control. The S-CSCF maintains the session state for each ongoing session. The S-CSCF may invoke value-added services related to the session based on the subscriber profile download into the S-CSCF during registration.

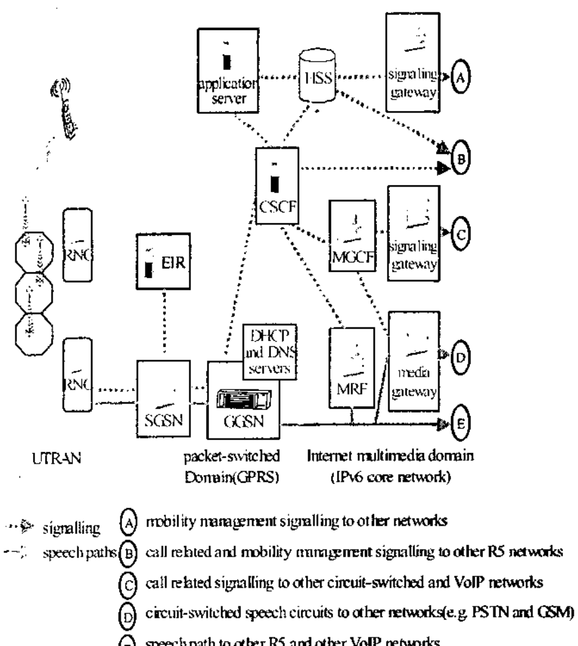

Figure 1. 3GPP IMS core network overview

The Interrogating CSCF (I-CSCF) is the contact point for all connections destined to the subscriber of the particular network where the I-CSCF is located. Further, all connections towards inbound roamers on that network are routed via-I-CSCF. The main task of the I-CSCF is to aid routing of session control messages to appropriate S-CSCF.

The IMS core network of the R5 architecture contains two types of Gateways: the Roaming Signaling Gateway (R-SGW) and the Breakout Gateway Control Function (BGCF), that is the PSTN Gateway. The former handles signaling conversions required for roaming to legacy networks. The latter handles interworking with PSTN and other switched circuit networks.

The MGCF performs signaling protocol conversion between the legacy (e.g. ISUP) and IP-specific session control protocol (SIP). The MG supports media conversion, bearer control and payload procession (e.g. codes, echo canceller, conference bridge) for support of different access interface options for circuited switched services.

The MRF performs all of the multiparty call and conferencing function. It may communicate with the CSCF for the service validation for multiparty/multimedia sessions.

B. Home Subscriber Server

The Databases in R5 architecture are condensed into the HSS. The HSS is the entity containing information on subscriptions for supporting the network entities actually handling call/sessions. It provides support to the call control servers in order to complete the routing/roaming procedures by solving authentication, authorization, naming/addressing resolution, location dependencies, etc. The HSS also generates User Security information for mutual authentication, communication integrity check and ciphering. Based on this user information, the HSS supports the call and session management entities of the different domains and subsystems of the operator.

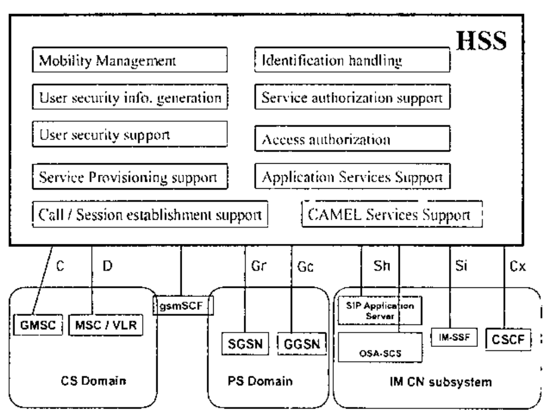

Figure 2. HSS logical functions

Fig 2 is a high level description of the HSS's logical functionality. Because the HSS is the superset of the 3GHLR, it provides support to PS domain entities such as the SGSN and

GGSN. through the Gr and Gc interfaces [4]. It also supports CS domain entities such as the MSC/MSC server through the C and D interfaces. The HSS also provides support to other IMS functional elements through Sh, Si, and Cx interface. It communicates with SIP Application Server and the OSA-SCS to support Application Services in the IMS core network. It communicates with the IM-SSF to support the CAMEL Services related to the IMS core network.

Basically, the HSS needs IP multimedia (IM) subscriber service profile data (service profile is a collection of service and user related data) in addition to the user profile data based IMSI identifier for the 3G HLR function. R5 specified a more general identifier for efficient user management with the introduction of the IMS core network. These identifiers are the private user identifier and public user identifier.

Every IM subscriber has a private user identifier. The private identifier is assigned by the home network operator, and used, for Registration, Authorization, Administration, and Accounting purposes. This identifier takes the form of a Network Access Identifier (NAI) as defined in RFC2468.The private user identifier is a unique global identifier from a network perspective within the home network. It is the key value in identifying each user's information stored in the user profile database.

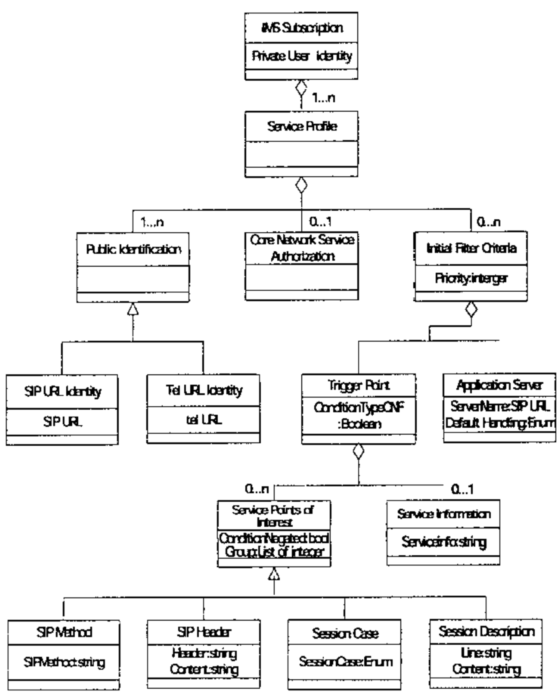

Figure 3. UML model of user profile database

Every IMS subscriber has one or more public user identifier. The public user identifiers are used for requesting communications to other users. Both telecom numbering and Internet naming schemes can be used to address users depending on the public user identifier. The public user identifiers take the form of an SIP URL (as defined in RFC 3261 RFC 2396) or the "tel:" URL format. Each public user identifier is associated with one and only one service profile. Each service profile is associated with one or more public user identifier.

On the basis of the these user identifiers, the user profile UML model works by R5 specification in order to define in an abstract level of the user profile and describe the different information classes included in the user profile. Fig 3 gives an outline of the UML model of the user profile of the IMS subscriber.

Fig 3 also represents the relationship between the private user identifier and public user identifier. It is also downloaded from the HSS to the S-CSCF through a user registration procedure. The full descriptions of the model are explained in [5].

III. PROPOSED HOME SUBSCRIBER SERVER DESIGN

A. User Profile Database Design

Some new information is needed for IP multimedia service in addition to the existing user database in the 3GHLR environment. Thus, the user profile database design of the IM subscriber is an important part of building the HSS system for efficient database control and system performance. With the previous UML model, we designed the user profile database schema. Fig4 shows a schema of the user profile database.

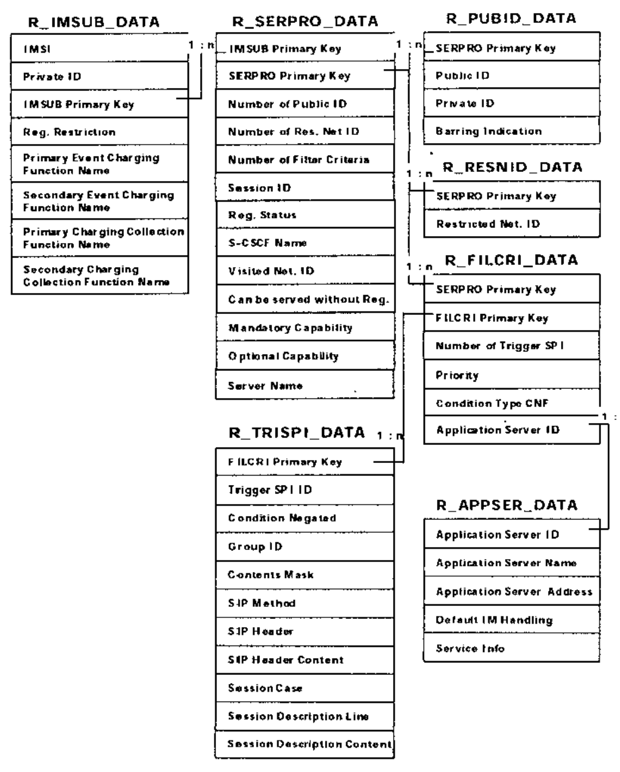

Figure 4. User profile database schema for IM service

The user profile database schema consists of a total of seven relations. Each relation is connected with others one or one to N instance mapping by each primary keys. The schema of the basic structure is similar to UML model but not same. Some classes of the UML model are merged for easy implementation. And additional information fields, not included in the UML model are also inserted in the schema.

For example, IMSI and Charging Function Name fields of the R_IMSUB_DATA, Registration Status, Session ID and S-CSCF Name field of the R_SERPRO_DATA, and all the R_RESNID_DATA relation. This additional information is needed to meet the functional requirement of the HSS for IP multimedia services. The IMSI field is used to satisfy mutual authentication between the UE and the home IMS core network. For this procedure, the HSS must generate the security information and download to S-CSCF authentication data such as AUTS and RAND. The Charging Function Name fields are the address of the Charging Collection Function (CCF) for offline charging and the Event Charging Function (ECF) for online charging. The charging information is delivered to the S-CSCF from the HSS via the IM subscriber registration procedure. The R_RESNID_DATA relation means that restriction network id is the visited network id in which the IM subscriber is not allowed to roam. It is used when the HSS check the roaming network of the user via user registration status query by I-CSCF.

B. Home Subscriber Server System Design

The HSS system structure must be designed to support the standard signaling protocol with the external domain on the basis of the logical function mentioned in the previous chapter. The internal functional subsystem of the HSS is also designed with consideration to making performance and transplantation work efficiently.

Fig 5 depicts the signaling protocol stack architecture of the HSS to communicate with the external domain. The HSS largely has a dual protocol stack to support CS/PS domain and IM CN domain. CS/PS domain interface is divided each different structure according to their network environment, that is 3G UMTS or All-IP.

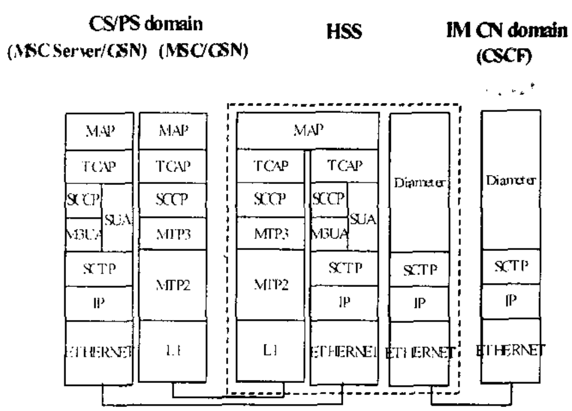

Figure 5. HSS protocol stack architecture

The internal structure of the HSS system is composed of five functional subsystems: The Transport Protocol Subsystem (TPS), Multimedia Application Subsystem (MAS), Database Subsystem (DBS), Legacy Application Subsystem (LAS), Operation & Maintenance Subsystem (OMS). The subsystem descriptions are as follows.

- *DBS*: This subsystem includes the main database of all the subscriber profile and its management module such as Operation Administration Maintenance (OAH) and Database Administration (DBA) that has a database access procedure for database updating in online processing. Meanwhile, this has a Customer Service Interface (CSI) module for connection to customer center over the TCP/IP protocol.
- *LAS*: This subsystem is consists of the Transaction Capability Application Protocol (TCAP) and Mobile Application Protocol (MAP) module of the SS7 standard stack for connection with the PS/CS domain. It communicates to all other subsystems and especially it connects to the MAS subsystem for the generation and delivery of the IM subscriber's authentication information.
- *TPS*: This is the Transport Protocol Subsystem. It is charge of the transportation of the signaling message to the external node. It includes both the IP-based SS7 protocol and ATM-based or E1-based SS7 protocol. This subsystem connects the Stack Manager module (S7SM, STSM) of the OMS subsystem that provides operating, statistics, peer signaling node state management, and maintenance for each protocol stack.

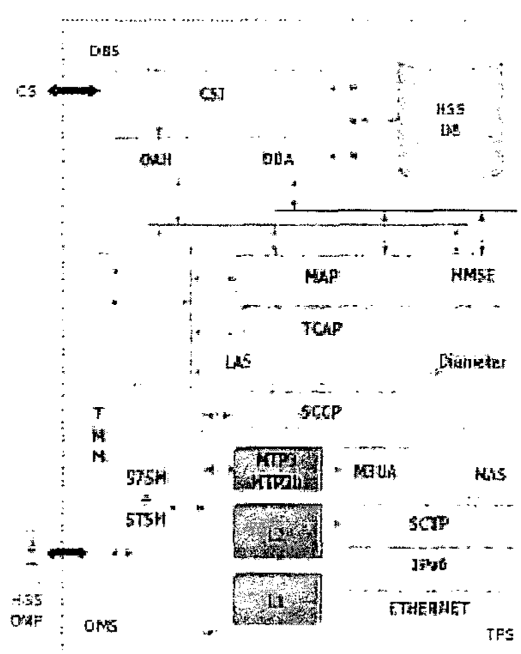

Figure 6. HSS system design architecture

- *MAS:* This subsystem supports the mobility management of the IM subscriber. For this purpose, it has the Diameter and Multimedia Mobility Service Element (MMSE) module. The Diameter module satisfies the IETF Diameter standard and 3GPP Application of Diameter. The Diameter module provides state management of the peer CSCF nodes, capability negotiation, and association establishment. The MMSE provides the mobility management of the IM subscriber, which is registration, location query, authentication, and authorization.
- *OMS*: This subsystem consists of the Transmission Management Module (TMM) and Stack Management module (S7SM, STSM) for the TPS subsystem control. The internal communication method of each subsystem is the message queue. The TMM offers protocol conversion from the internal message queue method to the TCP/IP socket communication, which is the method to external OMP processor.

The validation of the HSS functionalities is necessary from the viewpoints of service provision and the signaling protocol test. Fig 7 shows our test environment to verifying the HSS system implemented on the basis of the proposed design. We used the IPv6 Link-Local type address.

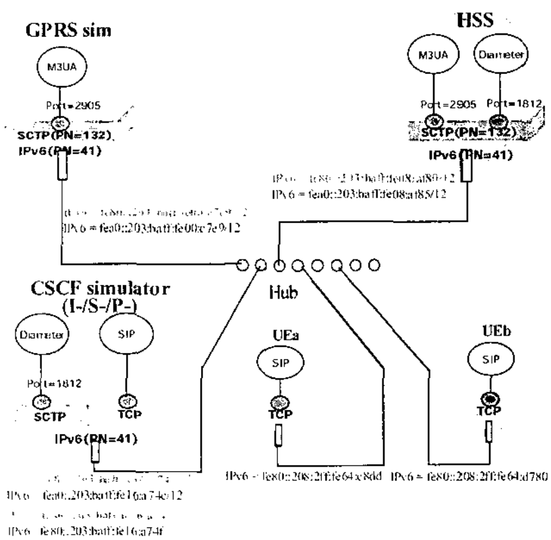

Figure 7. HSS test environment network

There are 3 nodes in Fig 7. HSS, GPRSsim and CSCF simulator, -which run on the UNIX platform. UEs are notebook PCs loaded with the SIP protocol for the support of the UE function on the Windows OS platform. Because our test places priority on the HSS system, some nodes are omitted or simplified by the simulator level. The GPRSsim represents the CS/PS domain. It generates a MAP signaling message. It includes the MSC server and GSN (GGSN, SGSN) of Fig 3. The GPRSsim for the UMTS network is not included in our test environment, because it is the same in the case of the All-IP network from the viewpoint of the HSS. The CSCF simulator includes all the CSCF. Therefore it should support both the Diameter and SIP protocol in addition to the SCTP and TCP. Especially, it should also have 2:1 logical connections with the HSS in 1:1 physical connection in order to support I-CSCF and S-CSCF at the same the time. It is also connected with the UEs as the P-CSCF function. UEs (UEa,UEb) play the role of originating and terminating UE each other. It has the SIP protocol stack and it supports GPRS functions due to the wire connection with the P-CSCF.

With our HSS design scheme, we verified the HSS system both as the existing 3GHLR in terms of the signaling test by the simulator level and the new additional functionality to provide multimedia service. Using the two UE connecting video camera, we sent and received real-time video traffic.

IV. CONCLUSION

The HSS is the key element for mobility management of a given user. It supports existing CS/PS domain subscribers and new IM subscribers for IP multimedia service. We have described a design scheme of the HSS system for new IP multimedia services. It is divided into user profile design and system architecture design. First, on the draft of the IM user profile UML model in the stand specification, we designed a IM user DB efficiently in consideration of service requirement, easy handling, and system performance. Then, we design the compact system architecture including related signaling protocol and functional block. With the design schema in this paper, we implemented the HSS system and then integrated with basic IMS core network that can provide IP-based multimedia services such as voice and video over the IP.

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