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A Number Portability Integrated IPX to Improve Traffic Routing Efficiency for VoLTE Services

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Abstract — Long Term Evolution (LTE) is proposed by 3GPP as the standard of next generation mobile network. Compared to existing 3G technology, LTE provides faster transmission speed, higher spectral efficiency, and reduced network complexity. In addition, LTE is designed with a flexibility to provide voice communication over pure IP packets, called VoIP over LTE (VoLTE). Unlike GSM and 3G networks, LTE operators have the need to provide IP interconnection among peer LTE operators, called IP Packet Exchange (IPX). For more market penetration, LTE operators need Number Portability (NP) services to attract potential subscribers imported from GSM or 3G networks. To optimise traffic routing efficiency, this paper describes a NP-IPX to integrate the functionality of IPX and Number Portability Data Base (NPDB) together. The NP-IPX platform will help LTE operators to optimally interconnect with peer operators, and reduce time and capacity redundancy for call set up procedure, compared to separated NPDB and IPX network configuration.

I. INTRODUCTION

A. LTE Evolved Packet System(EPS)

LTE technology first emerged in 3GPP Release 8 (Rel-8) specifications in December 2008, and included not only enhancements to the Evolved HSPA (HSPA+) technology, but also the important introduction of the Evolved Packet System (EPS). EPS consists of a flat IP-based all-packet core network (called SAE/EPC) together with a novel OFDMA access network (called E-UTRAN) [1][2]. SAE/EPC represents core network architecture of LTE, consisting of four main elements as listed below:

Mobility Management Entity (MME): The MME is the main control node for LTE access network. It provides a considerable level of overall control functionality to SAE/EPC such as Idle mode UE tracking, Bearer activation / de-activation, authentication and ciphering, etc..

Serving Gateway (SGW): The Serving Gateway is a data plane element within the SAE/EPC. Its main purpose is to manage the user plane mobility and acts as the border between the Radio Access Network (RAN) and the SAE/EPC core.

PDN Gateway (PGW): The PDN gateway provides connectivity for the UE to external packet data networks, performing the function of entrance and exit point for UE data flow. The UE may have connectivity with more than one PGW for accessing several packet data networks (PDNs).

Policy and Charging Rules Function (PCRF): The PCRF is referring to the entity within the SAE/EPC which monitors the service flow and executes charging policy. If the applications require dynamic policy or charging control, a network element named Applications Function (AF) is adopted.

The main elements of the SAE/EPC core network connect to the eNodeBs as shown in Fig. 1 below.

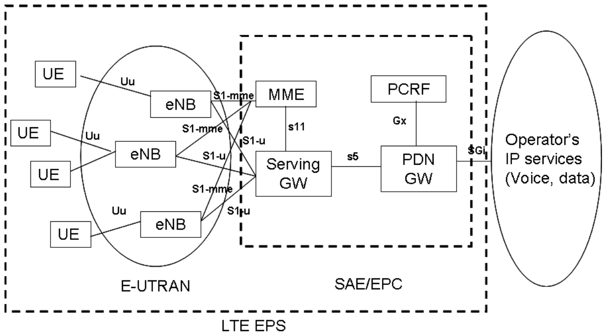

Fig. 1 LTE EPS overall network architecture

B. Voice over LTE via IP Multimedia Subsystem(IMS)

In order to provide high-speed broadband access, voice communications and multimedia services, the GSM Association (GSMA) has proposed *Voice over LTE (VoLTE) Profile* specification using *IP Multimedia Subsystem* (IMS) which is a system standardized by 3GPP for IP-based multimedia services and voice communications. Thus IMS works as a multimedia platform to offer voice services over LTE [2][3][5].

According to the VoLTE Profile, the LTE/IMS network is configured as shown in Fig. 2, specifying the mandatory functional entities of basic and optional features facilitated by IMS. The interface between the user terminal (UE) and LTE EPS is User-Network Interface (UNI), whereas the interface between LTE/IMS and external networks is Network-Network Interface (NNI).

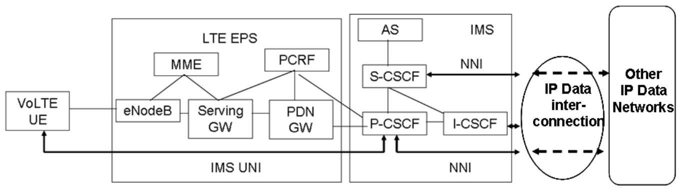

Fig. 2 LTE network configuration for VoLTE service

The IMS is comprised of four modules for voice session

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control : the Proxy Call Session Control Function (P-CSCF), the Serving Call Session Control Function (S-CSCF), the Interrogating Call Session Control Function (I-CSCF) and the Application Server (AS).

P-CSCF: A server for relaying SIP messages located at the interface point to the SAE/EPC. It not only relays SIP messages but also has the role of triggering QoS control in coordination with the SAE/EPC.

S-CSCF: A SIP server for performing session control and user authentication.

I-CSCF: A SIP gateway server that a remote network first connects to, when interconnecting networks or roaming. It has the roles of identifying the proper S-CSCF and relaying messages.

AS: AS is a service execution server on which one or more IMS services are deployed.

SIP: A standardized protocol performing session initiation, modification and termination procedures to provide communication functions for voice, video, and data among different users in IMS network.

The basic call control functions provided by IMS, are registration control, user authentication, call originating and call terminating functions. These functions are executed in IMS entities and controlled by Session Initiation Protocol (SIP).

II. IPX FOR VOLTE TRAFFIC INTERCONNECTION

A. The need of IPX for VoLTE Traffic Interconnection

Following the widespread deployment of packet infrastructures among GSM and UMTS networks, Mobile Network Operators (MNOs) are expected to launch a wide range of new data services, such as HSPA+ and LTE. IP interconnection among MNOs is required to support IP interworking of various mobile data services. Meanwhile, Fixed Network Operators (FNOs) and ISPs are deploying Next-Generation Networks (NGNs), offering a variety of new data services [6]. Though competing one another, Service Providers (MNOs, FNOs, and ISPs) have the common objective of successfully delivering traffic to subscribers in a reliable, profitable and cost-effective way [7]. The common protocol of these networks and services is the Internet Protocol (IP). Service Providers need to maximize their interconnection for IP traffic. The need for IP interconnection leads to the idea of IP Packet Exchange (IPX). The IPX provides the interworking functions for IP traffic of different Service Providers, in terms of the interconnection at the service level [7].

VoLTE services rely on IMS to perform call originating, routing and terminating of Voice over IP (VoIP) traffic. For commercial VoLTE services, the interconnection with other Service Providers must be reliable, trusted, secure and with good quality controlled.

B. The Architecture of IPX Model

For the purpose of achieving global roaming, traffic interconnection, and routing, the GSMA has established the architecture of IPX model as a global, trusted and controlled IP backbone that will interconnect Service Providers according to mutually beneficial agreements. The aim of an IPX is designed to offer highly efficient and commercially workable methods of establishing traffic routing and interconnection arrangements for end-to-end IP services [8]-[10]. A general GSMA IPX model is depicted in Fig. 3.

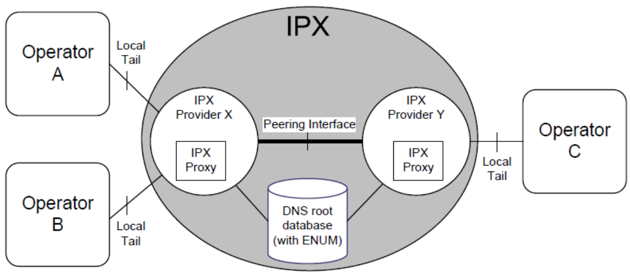

Fig. 3 GSMA IPX model

The IPX is required to support quality of service and end-to-end traffic transportation. That is, the parties involved in the transport of a service from the originating up to the terminating service provider's Border Gateways (BGs), are bound by end-to-end Service Level Agreements (SLAs) [10].

C. Interworking Functions of IPX

The IPX uses common root DNS and also introduces IPX proxy elements. These proxies support interworking of specified IP services and make it possible to use cascading interconnected billing and a multilateral interconnected model.

No matter if user terminals (UE) can be identified by a host name which is translated to an IP address by DNS or alternatively, user terminals are equipped with an E.164 number, the common DNS root database of the IPX will also need to support E.164 number translation to IP address. At present, the ENUM capable of DNS is used to map telephone numbers into IP addresses, by constructing a domain name from the E.164 number and performing DNS Naming Authority Pointer Records (NAPTR) lookup. The result of NAPTR lookup is a Uniform Resource Identifier (URI), which contains a signaling protocol and a host name [9][11]. An example of NAPTR lookup response from ENUM-DNS is shown as Fig. 4.

```
$ORIGIN 4.3.2.1.5.5.5.8.9.0.6.8.8.e164.arpa
IN NAPTR 100 10 “u” “sip+E2U”
“!^.*$!sip:Xuser@abc_network.net.tw!” .
IN NAPTR 102 10 “u” “mailto+E2U”
“!^.*$!mailto:Xuser@abc_network.net.tw!” .
IN NAPTR 102 10 “u” “tel+E2U”
“!^.*$!tel:+886098555l234!” .
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Fig. 4 An example of NAPTR record

To assist with the translation of E.164 telephone numbers to URI, the common DNS root database of the IPX will support ENUM capability for IP traffic routing and interworking [12].

III. NUMBER PORTABILITY SERVICE FOR VOLTE

As known, Number Portability service is already implemented in GSM and 3G networks for subscribers to move among the service providers without changing their telephone number [4]. Likewise, LTE operators also have the need to support Number Portability when offering their commercial VoLTE services. In the LTE network, IMS is responsible for call originating, routing and terminating.

Considering an All-Call-Query(ACQ) Number Portability services for VoLTE calls, the originating calls of IMS will issue an Routing Number (RN) interrogation signal to Number Portability Data Base (NPDB) and find out the ported status of the Called Party Number (CdPN). The call scenario is depicted on Fig 5. The following is the procedure of NPDB query for VoLTE calls.

Step 1. The Breakout gateway control function (BGCF) receives SIP INVITE message from the LTE/IMS network that points to a called user identity described via SIP URI. The tel URI contains CdPN of the called subscriber. For example: "INVITE tel:+886-098-555-1234 SIP/2.0".

Step 2. BGCF will then send a Routing Number (RN) interrogation message to Number Portability Data Base (NPDB). NPDB checks out whether CdPN is ported. If the number is ported out from its home network, then NPDB will respond BGCF with RN which points to the recipient network. For example: "RN= 1400".

Step 3. when BGCF receives RN message from NPDB, the RN analysis process will perform to decide whether the recipient network is PSTN, Circuit Switched PLMN (CS-PLMN) network or pure Packet Switched Network. For PSTN and CS-PLMN, the BGCF selects a media gateway control function (MGCF) to setup the call to the recipient network by using "RN + CdPN".

Step 4. When RN is reflecting to a pure Packet Switched Network such as LTE network, the BGCF will need to translate the "RN+CdPN" number to an IP address pointing to recipient network domain. Based on provided RN+CdPN, a domain name is created and used for DNS NAPTR query towards DNS with ENUM capability. For example:
"4.3.2.1.5.5.5.8.9.0.0.0.4.1.e164.arpa.".

Step 5. When receiving ENUM-DNS response, the BGCF applies selection of those NAPTR Records that support E.164 to URI (E2U) resolution. For example, a NAPTR record for ported number, using a SIP URI scheme looks like:

$ORIGIN 4.3.2.1.5.5.5.8.9.0.0.0.4.1.e164.arpa
NAPTR 10 100 "u" "E2U+psn:tel"
"!^.*$!sip:+886-1400-098-555-1234;npdi;
rn=+886-1400-098-555-1234@abc_network.net.tw;
user=ltephone!".

As routing number (RN) is present in SIP URI, the subscriber is considered as ported. The 'npdi' field is included in order to prevent subsequent NP lookup.

Step 6. The BGCF sets up a SIP call to abc_network.net.tw domain by sending INVITE message with obtained RN and npdi indicator.

INVITE sip: +886-1400-098-555-1234;
rn=+886-1400-098-555-1234@abc_network.net.tw;
user=ltephone;npdi=yes SIP/2.0

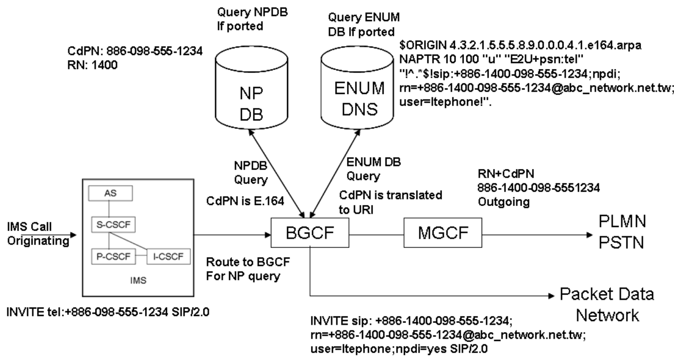

Fig. 5 VoLTE with Number Portability Service (ACQ)

Above depicted VoLTE call flow with ACQ number portability reveals that there are two lookups to the databases, one for RN query to NPDB and the other for NAPTR lookup to ENUM-DNS. As such, when subscriber call attempt is increasing, the extensive database lookups will bring up setup time, efficiency, and capacity issues for LTE operators. When LTE penetration rate and subscriber number is increasing, as discussed in Section II, VoLTE will need IPX to provide end-to-end services by interworking with peer LTE operators and other MNOs. It is required to implement number translation of E.164 to URI by the common DNS root database together with ENUM capability for IP traffic routing and interworking. To optimize the routing efficiency and reduce the redundancy of capacity, it is wise to incorporate the NPDB functionality with IPX to improve the Number Portability functions and routing efficiency for VoLTE services.

IV. THE NP-IPX MODEL

A. The Architecture of NP-IPX Model

The IPX will need ENUM-DNS to translate the CdPN to an IP address which is used to route the VoLTE call to the appropriate IP networks [9][12]. However, it is unlikely for IPX to find out whether the CdPN is ported or not. Therefore, the NPDB lookup is supposed to be done before LTE/IMS route the VoLTE calls to the IPX for interworking. However, the configuration of separated NPDB and ENUM-DNS has drawbacks on efficiency and capacity due to double CdPN queries in NPDB to get RN and in ENUM-DNS to resolve URI. To avoid this redundancy of query signalings, the IPX with built in NPDB and ENUM-DNS together can have the benefit of one-time query for CdPN to acquire expected information of RN and URI. The network configuration of NP-IPX model is described as Fig. 6.

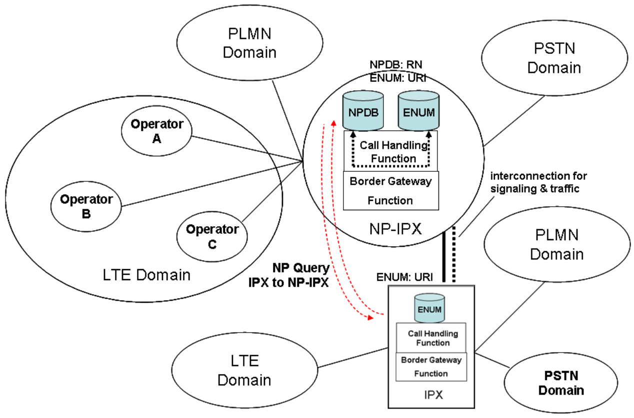

Fig. 6 NP-IPX reference configuration for VoLTE

The combined RN and URI Query procedures for NP-IPX platform is illustrated as below:

Step1. LTE operators pass the VoLTE call from LTE/IMS to the connected NP-IPX through BGCF.

Step2. The Call Handling Function (CHF) of NP-IPX will query the combined NPDB and ENUM-DNS database for CdPN's RN and URI.

Step3. Once the lookup is performed, the CHF will then pass the RN+URI information to BGCF.

Step4. The BGCF of NP-IPX will then route the VoLTE calls to the appropriate destinations based on CdPN's RN+URI information.

B. The Advantages of NP-IPX

Currently, most operators are using NPDB to check out the RN of ported subscribers and ENUM-DNS to get the CdPN's URI. IPX works as a traffic aggregator that is supposed to handle routing and interconnection of IP traffic. Integrated NP-IPX can improve routing efficiency for LTE operators with the following advantages:

- To provide connectivity with any type of Service Providers and secure voice interconnection with peer LTE operators and other PSTN as well as PLMN operators.
- To provide one-stop full Number Portability services to LTE operators with cost-effective way to increase market penetration and to reduce churn.
- To supply an error-free, efficient and controlled traffic routing mechanism with end-to-end QoS for roaming and interworking as well as to avoid over-charged for unnecessary or mistaked traffic routing.

V. Conclusion

When different network technologies, PSTN, PLMN and IP networks, are all interconnected, a need for traffic interconnection and number portability across different network types (i.e. PSTN, GSM, 3G and LTE) comes forth. The existing number portability services used in GSM and 3G networks only provides resolution for RN+CdPN which are ported among Circuit Switched domain. For the cases of Circuit Switched domain to IP domain or IP to IP domain interconnection, the ENUM-DNS solution will be implemented to facilitate interconnection of systems that rely on telephone numbers with those that use URIs to route transactions. The IPX works as the traffic aggregator to provide interworking and routing which is necessary for LTE operators to interconnect with. Therefore, to integrate Number Portability service with IPX becomes a potentially feasible solution for interconnected peer LTE/IMS networks. Both NPDB and IPX have standard specifications and commercial implementations are already available. However, these implementations do not contain number portability capabilities across different network types. The future work in this area will be related to coordinating subscriber status in between NPDB and ENUM databases, which must be kept up–to-date to avoid wrongly or inefficiently routed calls. Currently the NPDB update is performed by NP Administration Center (NPAC) automatically but the ENUM-DNS for LTE/IMS is uncoordinated among service providers. This will become a burden in the future, especially when LTE services launch with number portability services, causing increasing update frequencies and the risk of wrong and incompatible RN+URI information. An automated approach for synchronizing information between service providers is needed. The strategy of IPX integrated with NP and ENUM-DNS functions together looks promising to cope with this issue.

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