VoLTE Roaming | S8HR | IMS Platform

Technology Reports

VoLTE Roaming Service Using New VoLTE Roaming Architecture "S8HR"

NTT DOCOMO has been providing VoLTE services to domestic users in Japan since June 2014. Now, to make VoLTE services even more convenient for users, it has developed roaming-out and roaming-in functions to enable VoLTE to be used by NTT DOCOMO users on trips abroad and overseas users visiting Japan. For these functions, NTT DOCOMO has adopted the S8HR VoLTE roaming architecture that is now the focus of studies throughout the world.

This article describes the background to why NTT DOCOMO chose the development of VoLTE roaming using S8HR and overviews the functions added to the network and User Equipment (UE) of NTT DOCOMO for achieving VoLTE roaming.

Core Network Development Department
Mana Kaneko
Shinichi Minamimoto
Zhen Miao †
Tomonori Kagi
Communication Device Development Department
Shinya Takeda

1. Introduction

Voice over LTE (VoLTE) is a technology for providing voice services over Long Term Evolution (LTE). NTT DOCOMO has been providing VoLTE to domestic users in Japan since June 2014 in a form conforming to technologies specified by 3rd Generation Partnership Project (3GPP) and Global System for Mobile communications Association (GSMA)*1 [1] [2]. VoLTE services have also been launched in South Korea, the United States, and other countries—the number of operators providing VoLTE is increasing throughout the world.

At NTT DOCOMO, VoLTE-capable UE went on sale starting with the 2014 summer models. However, in the case of roaming, this UE, while being capable of data communications on LTE the same as conventional non-VoLTE-capable UE, could only achieve voice communications by making connections via 3G circuit switching [3]. To enable NTT DOCOMO users to use VoLTE when overseas, NTT DOCOMO has developed a VoLTE roaming function for its network and UE. Future NTT DOCOMO VoLTE-capable UE will progressively support VoLTE roaming. This will enable users to enjoy the distinctive features of VoLTE such as high-quality calls, quick call connections, high-speed multiple access*2, and video calls even when out of the country. In addition, users from other countries having a VoLTE-capable UE will also be able to use VoLTE services when camping on the NTT DOCOMO network. Moreover, since control of voice communications is achieved over LTE data roaming (data communications), it will now be possible to conclude an VoLTE roaming agreement even with non-W-CDMA providers with which a 3G roam-

† Currently DOCOMO Technology Inc., Packet Network Division

*1 **GSMA:** An association that supports and manages activities of the mobile industry, such as formulating roaming rules. The largest mobile communications industry association in the world, with members in related businesses including mobile communications providers, IPX operators, and UE, equipment and software vendors.

*2 **Multiple-access:** Accessing different bearers from a single UE (called Multi-Call in 3G).

ing agreement could not be concluded in the past due to differences in Radio Access Technologies (RAT)*3.

There are two major architectures for VoLTE roaming: Local Breakout architecture (hereinafter referred to as "LBO") and S8 Home Routed architecture (hereinafter referred to as "S8HR"). NTT DOCOMO is using S8HR that is now being studied throughout the world as one new type of architecture for VoLTE roaming. S8HR enables the provision of services not provided in the visited network and shortens the time-to-market of VoLTE roaming.

In this article, we describe the background to NTT DOCOMO's development of VoLTE roaming using S8HR and overview the functions added to the network and UE of NTT DOCOMO for achieving VoLTE roaming.

2. Background to Adoption of VoLTE Roaming with S8HR

2.1 Features of LBO and S8HR

As described above, the two major types of architecture for VoLTE roaming are LBO and S8HR. These are compared in **Figure 1**.

LBO implements Evolved Packet Core (EPC)*4 entities and Proxy-Call Session Control Function (P-CSCF)*5 in the Visited Public Mobile Network (VPMN) and Serving-Call Session Control Function (S-CSCF)*6, Application Server (AS)*7, Home Subscriber Server (HSS)*8, etc. in the Home Public Mobile Network (HPMN). The assumption here is that a voice connection (Session Initiation Protocol (SIP)*9/Real Time Protocol (RTP)*10 connection) will be made

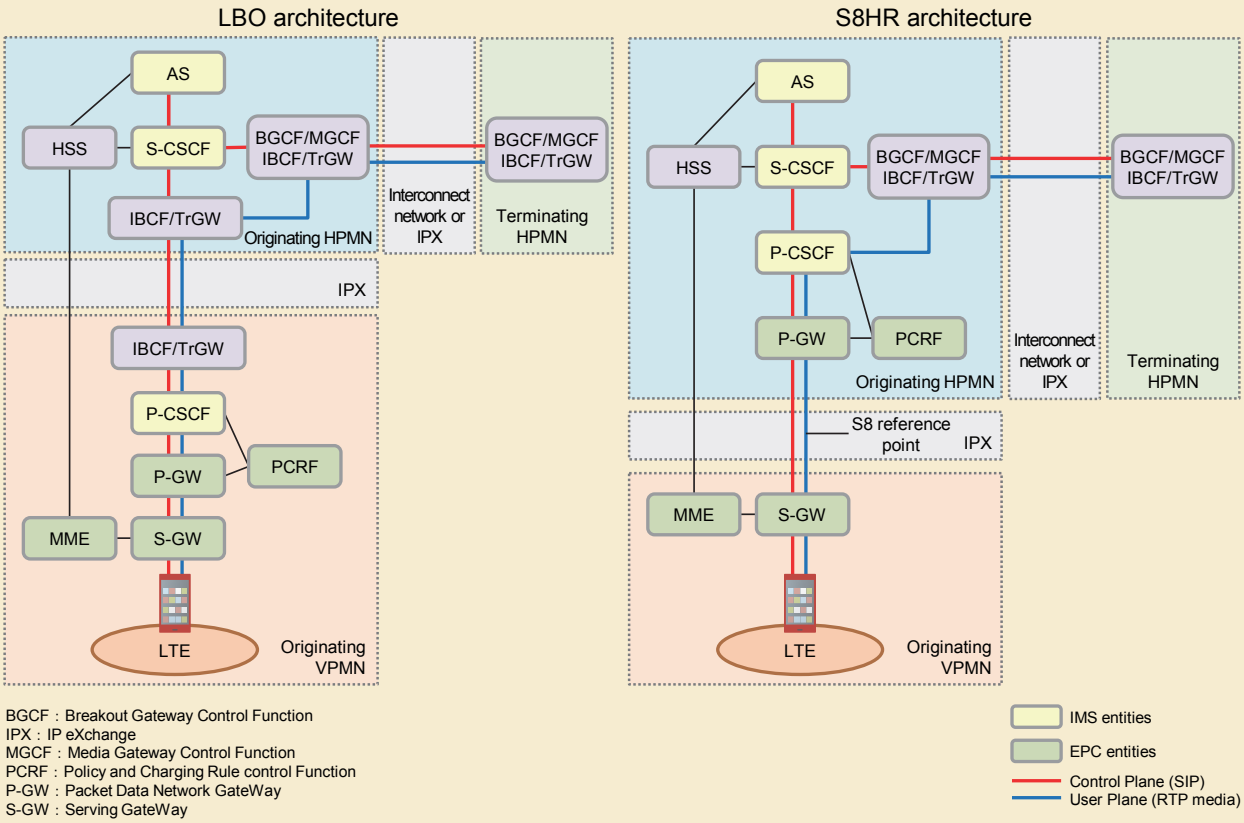


Figure 1 Comparison of LBO and S8HR methods

*3 **RAT:** A mobile communications circuit such as LTE and 3G (W-CDMA).

*4 **EPC:** A core network accommodating a radio access network such as LTE. It consists of MME, SGW, P-GW, and PCRF and provides functions such as authentication, mobility control, bearer management, and QoS control.

*5 **P-CSCF:** A function deployed at the connection point with EPC and at the connection point with S-CSCF and I-CSCF. It has the roles of linking with EPC to initiate QoS control and of relaying SIP signals between the mobile UE and S-CSCF and I-CSCF.

*6 **S-CSCF:** A SIP server performing UE session control and user authentication.

*7 **AS:** A server that executes an application to provide a service.

*8 **HSS:** A subscriber information database in a 3GPP mobile communications network managing authentication information and visited-network information.

*9 **SIP:** A call control protocol defined by the Internet Engineering Task Force (IETF) and used for IP telephony with VoIP, etc.

*10 **RTP:** A transmission protocol for streaming video and voice media. As a UDP type of protocol, no countermeasures to packet loss are performed. Generally used in combination with a communications status report provided by RTCP.

between the VPMN and HPMN via the Interconnection Border Control Function (IBCF)*11/Transition GateWay (TrGW)*12, which acts as a gateway node between IP Multimedia Subsystem (IMS)*13 networks [4]. In contrast, S8HR adopts an architecture based on LTE data roaming and utilizes the S8 reference point*14 that lies between the VPMN and HPMN. This means that all IMS entities such as the P-CSCF can be implemented on the HPMN side [5].

2.2 Advantages of S8HR

The advantages of S8HR in comparison with LBO are summarized below.

(1) Signaling on the IMS layer conducted by SIP protocol is performed directly between the UE and P-CSCF in the HPMN. This enables control by HPMN without having to rely on IMS entities in the VPMN. For example, when providing a video call service to a roaming-out user, LBO requires that video call functionalities be supported by P-CSCF/IBCF/TrGW in the VPMN, but S8HR has no need for such capabilities in the VPMN thereby simplifying the provision of services.

(2) Since the IMS entities do not span the HPMN and VPMN, gateway nodes (IBCF/TrGW) are not required between HPMN and VPMN.

(3) The P-CSCF in the HPMN is only accessed by UE that is deployed in the HPMN—it is not accessed by any other UE. This means that the IMS stack in the UE and P-CSCF connectivity for domestic VoLTE service can be directly used for VoLTE roaming.

To provide users with VoLTE roaming with high connectivity as soon as possible, NTT DOCOMO decided to develop VoLTE roaming and to launch services with S8HR having the advantages described above. NTT DOCOMO is also active in S8HR standardization activities in parallel with commercial launches—S8HR architecture was officially endorsed by GSMA as a VoLTE roaming architecture in May 2015.

3. Overview of VoLTE Roaming Functions

3.1 Conditions for Providing VoLTE Roaming

The architecture of VoLTE roaming using S8HR is based on LTE data roaming. The following conditions must therefore be met to provide VoLTE roaming to a user.

- HPMN and VPMN must have concluded an LTE data roaming agreement.
- HPMN and VPMN must have concluded an VoLTE roaming agreement with S8HR.
- The user must be using UE supporting VoLTE roaming.

If the above conditions are met, the user can use VoLTE services in the VPMN.

The following describes the distinctive features to be added to the UE and the network to achieve VoLTE roaming-out and roaming-in with S8HR. We note here that added functions mainly concern the roaming-out service since it is the HPMN that controls roaming-out users when using S8HR.

3.2 Overview of Roaming-out Functions

Since the UE cannot recognize whether the VoLTE roaming architecture between HPMN and VPMN is S8HR or LBO, the UE proceeds to operate without being aware of it.

1) Attach*15/IMS Registration*16 of Roaming-out User

Section 4 of Ref. [3] described UE operation according to the conditions of the VPMN in LTE roaming scenarios. In this article, we assume UE supporting VoLTE roaming and describe UE operations up to the point at which voice, data and SMS can be used after the UE has initiated the Attach procedure in various networks. Furthermore, while the article referenced above took up voice-centric, data-centric, and data as types of UE, we point out here that all

*11 **IBCF:** A function deployed on both sides of a network border for interconnecting IMS cores and networks. It serves to relay SIP signals and conceal the internal network.

*12 **TrGW:** A gateway controlled by IBCF performing media communication control (network-address/port conversion, IPv4/IPv6 protocol conversion, etc.).

*13 **IMS:** A call control procedure that realizes multimedia communications by consolidating 3GPP standardized communication services offered over fixed and mobile networks through the use of SIP, which is a protocol used on the Internet and in Internet phones.

*14 **S8 reference point:** An interface connecting P-GW and S-GW.

*15 **Attach:** The processing of registering a mobile UE with a network when UE power is turned on, or the state of being registered.

*16 **Registration:** In IMS, mobile UE register current location data in HSS with SIP.

VoLTE-capable UE are voice-centric. Additionally, considering the possibility of using the Circuit Switched FallBack (CSFB)*17 procedure when camping on a non-VoLTE-capable network or when VoLTE is temporarily unavailable, current UE will send an Attach Request for both the Packet Switched (PS) and Circuit Switched (CS) domains. Operation of a VoLTE-capable UE that does not support the CS domain will be taken up as a future topic of study.

The procedure up to the point at which VoLTE with S8HR can be used is described in Ref. [5]. However, when the UE attempts to initiate VoLTE roaming, it can be assumed that the VPMN response to an Attach Request will differ depending on the type of VoLTE and RAT support provided by the VPMN, whether a VoLTE roaming agreement has been concluded, etc. The operations performed by the UE for various types of network responses to Attach Request are summarized in **Figures 2** and **3** and explained below. Operation by UE not supporting VoLTE roaming is also shown for reference.

In relation to the above, an IMS Voice over PS session indicator (hereinafter referred to as "IMS VoPS") has been specified by 3GPP [6]. IMS VoPS indicates whether or not the VPMN supports VoLTE per user. This value is set according to the VoLTE roaming agreement between HPMN and VPMN. The UE can check IMS VoPS to decide whether to provide voice calls in the PS domain or in the CS domain [7].

(a) Attach successful for both CS/PS domains and VoLTE can be used

In the event that the VPMN provides not only LTE but also W-CDMA/GSM, that is, RAT having a CS domain, the network will respond to a Combined Attach Request from the UE with a message indicating that Attach was successful for both the PS and CS domains. In addition, if VoLTE is supported and a VoLTE roaming agreement has been con-

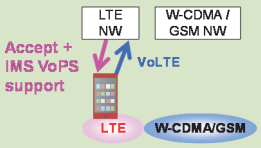
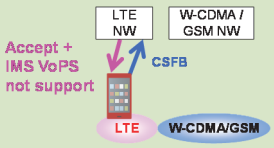
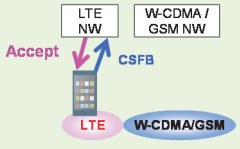
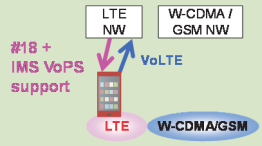
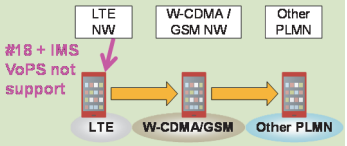
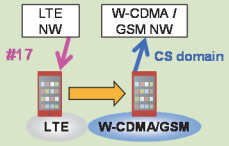
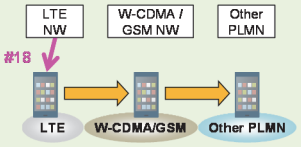
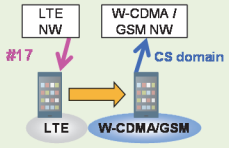
<table>
<tr><th rowspan="3">UE Type</th><th colspan="2">Response from the VPMN</th></tr>
<tr><th colspan="2">PS/CS domains successful</th></tr>
<tr><th>(a) VoLTE can be used
(IMS VoPS support)</th><th>(b) VoLTE cannot be used
(IMS VoPS not support)</th></tr>
<tr><td rowspan="3">Voice-centric, VoLTE-roaming capable</td><td>Camps on LTE, performs IMS Registration</td><td>Camps on LTE, performs IMS Registration</td></tr>
<tr><td>Voice: can be used via VoLTE
Data: can be used via LTE
SMS: can be used via SMS over IP</td><td>Voice: can be used via CSFB
Data: can be used via LTE
SMS: can be used via SMS over IP or SMS over SGs</td></tr>
<tr><td> 
</td><td> 
</td></tr>
<tr><td rowspan="3">Voice-centric, non-VoLTE-roaming capable</td><td colspan="2">Camps on LTE</td></tr>
<tr><td colspan="2">Voice: can be used via CSFB; Data: can be used via LTE; SMS: can be used via SMS over SGs</td></tr>
<tr><td colspan="2"> 
</td></tr>
</table>

Figure 2 UE operation when Attach succeeds

*17 **CSFB:** A procedure for switching to a radio access system having a CS domain, when a UE sends/receives a circuit switched communication such as voice while camped on an LTE network.

<table>
<tr><th rowspan="3">UE Type</th><th colspan="3">Response from the VPMN</th></tr>
<tr><th colspan="2">Only PS domain succeeds (e.g., receives #18 (CS domain not available))</th><th rowspan="2">(e) PS/CS domains both fail (e.g., receives #17 (Network failure))</th></tr>
<tr><th>(c) VoLTE can be used (IMS VoPS support)</th><th>(d) VoLTE cannot be used (IMS VoPS not support)</th></tr>
<tr><td rowspan="3">Voice-centric, VoLTE-roaming capable</td><td>Camps on LTE, performs IMS Registration</td><td>Disables LTE and selects another operator if W-CDMA/GSM is unavailable</td><td>After 5 Attach attempts, disables LTE and moves to W-CDMA/GSM</td></tr>
<tr><td>Voice: can be used via VoLTE
Data: can be used via LTE
SMS: can be used via SMS over IP</td><td>Voice, data, SMS: can be used via W-CDMA/GSM
(or another operator)</td><td>Voice, data, SMS: can be used via W-CDMA/GSM</td></tr>
<tr><td> 
</td><td> 
</td><td> 
</td></tr>
<tr><td rowspan="3">Voice-centric, non-VoLTE-roaming capable</td><td colspan="2">Disables LTE and selects another operator if W-CDMA/GSM is unavailable</td><td>After 5 Attach attempts, disables LTE and moves to W-CDMA/GSM</td></tr>
<tr><td colspan="2">Voice, data, SMS: can be used via W-CDMA/GSM
(or another operator)</td><td>Voice, data, SMS: can be used via W-CDMA/GSM</td></tr>
<tr><td colspan="2"> 
</td><td> 
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</table>

PLMN : Public Land Mobile Network

Figure 3 UE operation when Attach fails

cluded, IMS VoPS will be set to "supported" in the Attach Accept [8]. If the UE supporting VoLTE roaming camps on such a network and its voice domain preference [6] is set to "IMS PS voice preferred, CS Voice as secondary," a Packet Data Network (PDN) connection for IMS will be established and IMS Registration will be completed according the procedure in Ref. [5]. At this point, VoLTE will be prioritized for voice [7] and SMS over IP*18 will be prioritized for SMS.

(b) Attach successful for both CS/PS domains but VoLTE cannot be used

When in an LTE area, UE supporting VoLTE roaming will attempt to establish a PDN connection for IMS and perform IMS Registration. If the Attach has been initiated in the VPMN that provides CSFB but no VoLTE or the VPMN has not concluded a VoLTE roaming agreement, the UE will receive IMS VoPS set to "not supported" [8] while the Attach procedure succeeds in both CS/PS domains. In this case, the UE supporting VoLTE roaming will determine that VoLTE cannot be used even if a PDN connection for IMS has been established and IMS Registration has been completed and that the CS domain must instead be used for voice via CSFB.

Moreover, while IMS VoPS indicates whether the VPMN is VoLTE capable or not, using the indicator to determine whether SMS should be used via SMS over IP or SMS over SGs*19 has not yet been specified in 3GPP. Current NTT DOCOMO UE uses SMS over IP if a PDN connection for IMS has been established

*18 **SMS over IP:** SMS that sends/receives messages using SIP protocol.

*19 **SMS over SGs:** SMS via a SGs interface connecting MSC and MME. Non-VoLTE-capable UE sends/receives SMS messages via SMS over SGs when camped on an LTE network.

and SIP Registration has been completed.

(c) Attach successful for only PS domain and VoLTE can be used

Some networks do not provide a CS domain (W-CDMA). Combined Attach Request will be accepted for PS domain only with cause value #18 (CS domain not available) by such a network. In the case of UE not supporting VoLTE roaming, it is assumed that the UE will disable the LTE capability and make a transition to another VPMN that provides a CS domain in which voice can be used. However, in the case of UEs supporting VoLTE roaming that receives IMS VoPS set to "supported," the UE will perform IMS Registration after establishing a PDN connection for IMS without disabling LTE and proceed to use VoLTE. These procedures achieve VoLTE roaming with VPMNs not providing W-CDMA. Here, SMS over IP will be used for SMS.

(d) Attach successful for only PS domain but VoLTE cannot be used

If no W-CDMA is provided by an operator that does not provide VoLTE or has not concluded a VoLTE roaming agreement, IMS VoPS received by the UE will be set to "not supported" and the Combined Attach Request will be accepted for PS domain only with cause value #18 (CS domain not available). In this case, VoLTE roaming cannot be used and neither can voice in the CS domain, so only data roaming can be used.

UE camped on such a network must perform some type of operation to use voice, so it is assumed that the UE will disable LTE and move to another VPMN that provides voice services.

(e) Attach fails for both domains

In the case that Attach procedure fails for both PS and CS domains owing, for example, to no LTE data roaming agreement, no services at all including voice can be used even if camped on an LTE network. The UE can therefore disable the LTE capability and move to a W-CDMA network to enable the use of voice, data, and SMS services. This operation is the same for UE not supporting VoLTE roaming.

2) Voice Originating/Terminating

In 1) above, we described the procedures of UE supporting VoLTE roaming for making voice calls and sending SMS messages when camped on various VPMNs. In the following, we describe network procedures.

Since call processing for originating/terminating voice calls in VoLTE roaming-out uses IMS entities in the HPMN, the sequence is the same as that of non-roaming calls [2]. The key changes in a network for originating/terminating voice calls in VoLTE roaming-out are summarized below.

(a) Determining existence of VoLTE roaming agreement

When the UE is camped on a VPMN having no VoLTE roaming agreement but having a LTE data roaming agreement, it is assumed that the Mobility Management Entity (MME)*20 in the VPMN will return the IMS VoPS indicator set to "not supported" and that the UE will perform conventional CSFB calling based on that information. However, if MME in the VPMN should return IMS VoPS set to "supported" at this time, IMS Registration can proceed, which means that the UE may attempt to originate a VoLTE call. For this reason, the AS in the HPMN is equipped with a function for prohibiting VoLTE originating/terminating calls from a VPMN with no VoLTE roaming agreement. This function is achieved by having the AS determine whether the VPMN has a VoLTE roaming agreement at the time of voice originating/terminating calls based on VPMN information obtained from the HSS.

(b) User dialing operation

With user convenience in mind, the aim was to make the VoLTE roaming-out user dialing operation

*20 **MME:** A logical node accommodating a base station (eNB) and providing mobility management and other functions.

the same as that of 3G roaming-out, so call-originating and call-terminating functions were added as described below.

(1) Call-originating function

The comparison of call originating for 3G roaming-out and VoLTE roaming-out is shown in **Figure 4**.

For 3G roaming-out, number analysis when the roaming-out user is originating a voice call has been performed at an entity in the VPMN. For example, if the roaming-out user makes a call to a fixed-line number in the VPMN, routing can be performed by dialing the number starting with the area code without affixing the plus key (+) and Country Code (CC).

For VoLTE roaming, however, number analysis is performed at AS in the HPMN, so the AS is equipped with a function for translating the number dialed by the user and converting it to a routable number. For example, in the event that a roaming-out user originates a call to a fixed-line number in the VPMN, the AS in the HPMN will connect the call to the VPMN by deriving the country of the visited operator and adding the CC of that country to the dialed number.

(2) Call-terminating function

Given a call made from a domestic user to a roaming-out user, this function affixes a CC to the originating number at the AS server as part of the call-termination process. This is done considering the possibility that a call to that number will be returned to HPMN from the roam-

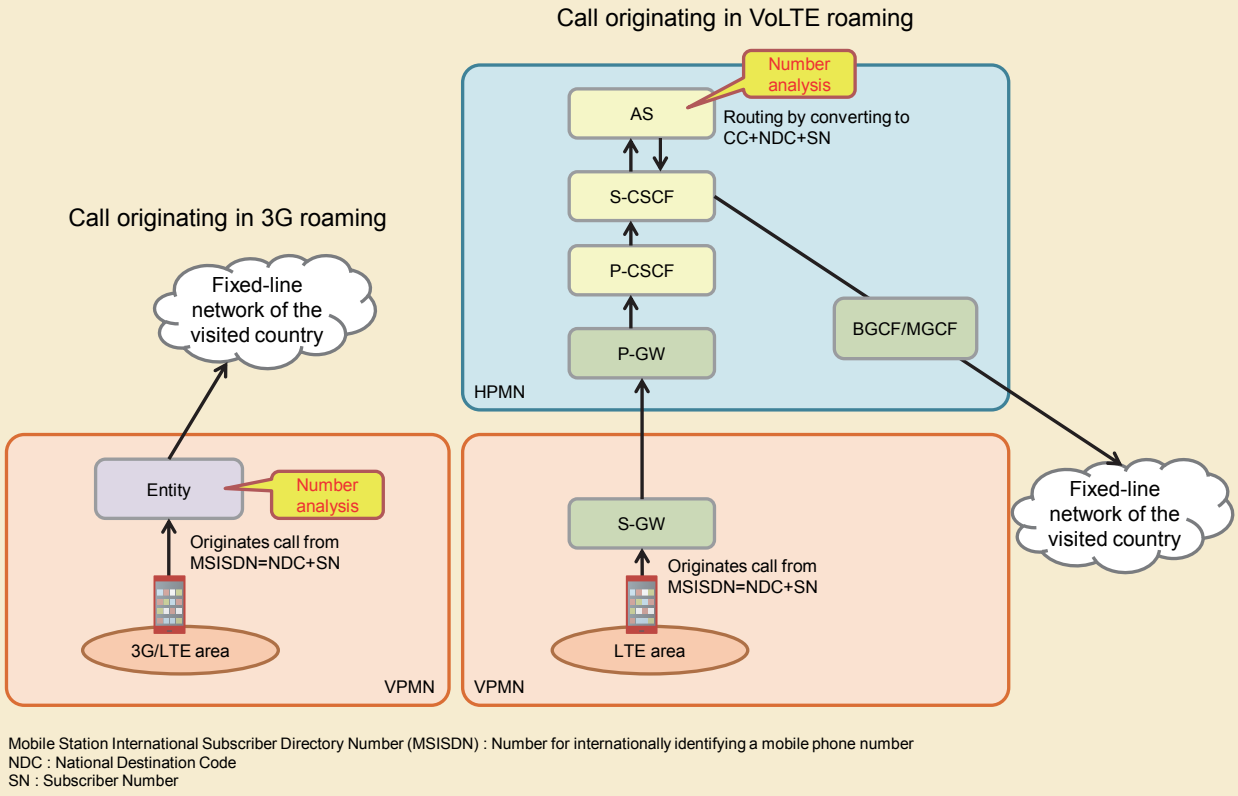

Figure 4 Call originating compared between 3G roaming-out and VoLTE roaming-out

ing-out user. In other words, this function converts the originating number to a format that enables a return call to be correctly connected from the VPMN.

(c) Domain selection at call termination

Similar to domestic VoLTE, there are times when it is unclear at HSS whether the user is camped on 3G or LTE. In such a case, HSS will execute the Terminating Access Domain Selection (T-ADS)*21 function to identify the RAT in which the call is terminated. The T-ADS process flow is shown in **Figure 5**.

To begin with, the terminating AS determines whether the VPMN has a VoLTE roaming agreement based on VPMN information obtained from HSS. At this time, AS selects 3G termination if there is no agreement and initiates T-ADS if there is an agreement. For the latter case, HSS on receiving the T-ADS initiation request from the AS sends an inquiry to both the MME and Serving General packet radio service Support Node (SGSN)*22 to retrieve the time of the last location registration request from the UE. It then compares those two time stamps and informs AS of the RAT corresponding to the most recent time stamp so that call termination can be performed in the appropriate domain.

It is generally considered that the VPMN's MME and SGSN will support the T-ADS function if there is a roaming agreement between the HPMN and VPMN, but NTT DOCOMO adopts the following policy considering that T-ADS support may not yet be provided.

(1) Since a VPMN supporting T-ADS can be expected to notify HSS of "T-ADS capability" from MME and SGSN at the time of

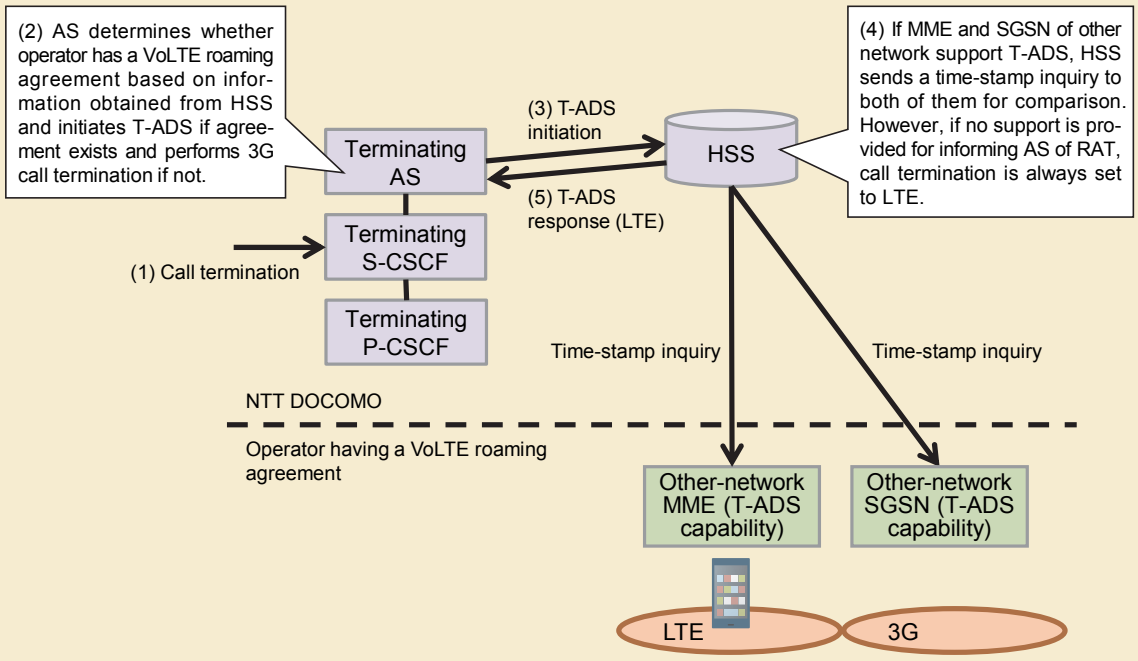

Figure 5 T-ADS process flow

*21 **T-ADS:** A function that specifies the access network in which the UE is currently camped.

*22 **SGSN:** A logical node in 3GPP standard specifications providing functions such as mobility management for a mobile UE performing packet switching and packet communications.

UE location registration, T-ADS will always be initiated in the event that HSS is notified of that parameter.

(2) If HSS is not notified of T-ADS capability, the RAT of the terminating call must be determined without initiating T-ADS. Thus, taking into account the fact that some operators provide only LTE, all call terminations will be of the VoLTE type if no notification of T-ADS capability is received.

3) Supplementary Services

In 3G roaming-out, the architecture is such that call control is performed at entities in the VPMN. This makes it difficult to provide an operator's unique services (such as Melody Call and call recording which are provided by NTT DOCOMO). In contrast, the architecture for VoLTE roaming-out enables call control to be performed using IMS entities in the HPMN, which enables the HPMN to provide the same unique services to both roaming and non-roaming users.

3.3 Overview of Roaming-in Functions

The launching of a VoLTE roaming-in service means that roaming-in users with VoLTE-capable UE will be camped on networks other than their HPMN. These users, however, will be a mixture of those having and not having a VoLTE roaming agreement. For this reason, NTT DOCOMO has configured their network entities according to 3GPP TS23.401 [8]. Here, if the roaming-in user belongs to a HPMN that has concluded a VoLTE roaming agreement, the NTT DOCOMO MME returns IMS VoPS set to "supported" to the UE upon the Attach Accept and proceeds to provide VoLTE functions. However, if the roaming-in user belongs to a HPMN that has not concluded a VoLTE roaming agreement, MME returns IMS VoPS set to "not supported" to the UE and disables VoLTE functions. Consequently, if the roaming-in user attempts to originate a voice call, it will likely be handled via the CS domain.

Furthermore, as shown in Fig. 4, the network that performs number analysis differs between 3G roaming and VoLTE roaming, so in the event that the user originates a call to an emergency number that cannot be recognized as such by the UE, that call would have to be determined to be an emergency call by the AS in the HPMN, which would make it necessary to manage emergency-call numbers of the VPMN on the HPMN side. To prevent this, the NTT DOCOMO MME is being equipped with a function for providing the roaming-in UE with an Emergency Numbers List as specified by 3GPP TS 24.301 [6] at the time of a location-registration response. With this information, the UE is made aware of emergency-call numbers. Thus, if the roaming-in user needs to make an emergency call (110, 118, or 119), the UE itself will be able to recognize the number as an emergency call with no need for a function to do that on the HPMN side under the NTT DOCOMO network. This capability enables the appropriate domain to be selected and an emergency call to be connected.

4. Conclusion

In this article, we described the background to why NTT DOCOMO chose the development of VoLTE roaming with S8HR architecture and overviewed the functions added to the network entities/UE of NTT DOCOMO for achieving VoLTE roaming-out and roaming-in services. This development/deployment will unleash the VoLTE user experience that was originally limited to Japan to roaming users visiting operators abroad that have concluded a VoLTE roaming agreement with NTT DOCOMO. With the aim of further expanding VoLTE coverage in the future, NTT DOCOMO plans to make even more contributions to standardization activities and to promote studies with operators/vendors.

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