EPC | Voice over LTE | Circuit Switched Services

Technology Reports

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CS Fallback Function for Combined LTE and 3G Circuit Switched Services

The 3GPP, an international standardization body for creating a next-generation mobile communications system, has completed technical specifications for CS Fallback, a function for combining EPC supporting LTE and CS services like 3G voice calls. CS Fallback will enable early provision of voice terminals having LTE capabilities. This function consists of three elemental technologies: technology for notifying a mobile terminal in an LTE cell that a call request is being made from a 3G-CS system, technology for enabling the mobile terminal receiving the call request to switch radio access systems, and technology for LTE/3G combined mobility management.

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1. Introduction

Evolved Packet Core (EPC), the core network of next-generation mobile communications, can accommodate multiple radio access systems like 3G, Long Term Evolution (LTE), and wireless LAN in an integrated manner, and can provide mobility management*1 seamlessly among such systems [1]. Here, LTE, which is the new upcoming radio technology, provides all services using IP without existing Circuit Switched (CS) domain functions. Accordingly, services like voice calls and the Short Message Service (SMS) that have traditionally been provided over the CS domain will be replaced, in principle, by VoIP, for example. This will eventually require the deployment of the IP Multimedia Subsystem (IMS)*2 as a service control platform [2].

However, at the beginning of LTE deployment, it may take some time before IMS and VoIP services can be provided due to the size of the target coverage area, the time required for facility planning, etc. As a consequence, a scenario in which voice services are provided in a step-by-step approach has been discussed at 3GPP. Yet, a mobile terminal capable of LTE cannot utilise the 3G radio access system simultaneously while camping on LTE and, as a result, it would have no means of receiving a mobile terminating call from the 3G CS domain. Thus, for the time that IMS is not provided on LTE, the terminal would not be able to originate or terminate any voice calls at all.

*1 **Mobility management**: Management of terminals which provides transmission, reception and continuous communication even if terminals move.

*2 **IMS**: A communications system that integrates services provided by CS using Internet technology such as Session Initiation Protocol (SIP).

Nevertheless, voice is one of the most important services in mobile communications, and it is important that voice services can still be provided in some way even during the time that the LTE platform is providing high-speed data communications services without direct provision of voice by IMS.

In addition, the early provision of LTE that is not limited to data-card terminals but also includes voice-capable handheld-type terminals will mean even more convenient services for users.

Thus, after agreeing upon the above scenario for the stepwise provision of voice services, it was decided at 3GPP to standardize a mechanism for switching to 3G on originating or mobile terminating voice calls [3]. This function, called "CS Fallback," enables voice services using existing 3G-CS domain functions to be provided to users even if VoIP services are not being directly provided over LTE.

This article describes the functional requirements and technical realization of CS Fallback

2. Overview of CS Fallback

2.1 CS Fallback at a Glance

The basic concept of CS Fallback is shown in **Figure 1**. Given a mobile terminal camping on LTE, a mobile terminating voice call arrives at the terminal from the existing CS domain via EPC. On receiving a paging message, the mobile terminal recognises that the network is calling the mobile terminal for CS-based voice and therefore switches to 3G. The response confirming the acceptance of a call request is then sent from the mobile terminal to the 3G-CS system, and from that point on, all call control for the voice service is performed on the 3G side.

2.2 Architecture

The CS Fallback consists of a function to notify a mobile terminal of a call request from the CS domain and combined mobility management functions between CS domain and EPC for that purpose. The network architecture of CS Fallback is shown in **Figure 2**.

One of the remarkable characteris-

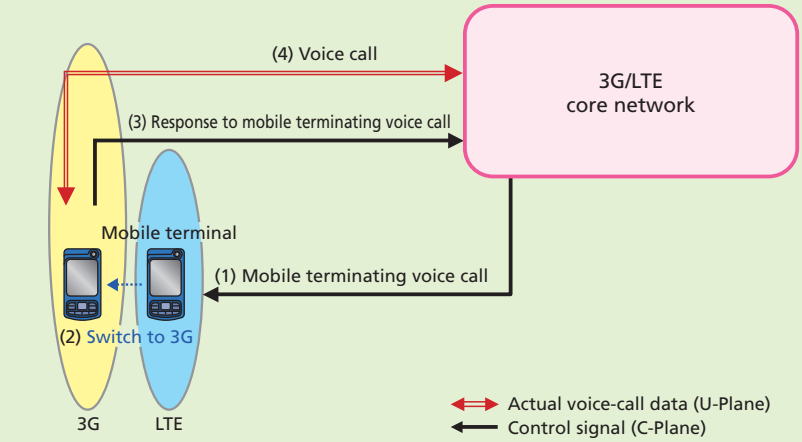

Figure 1 Overview of CS Fallback

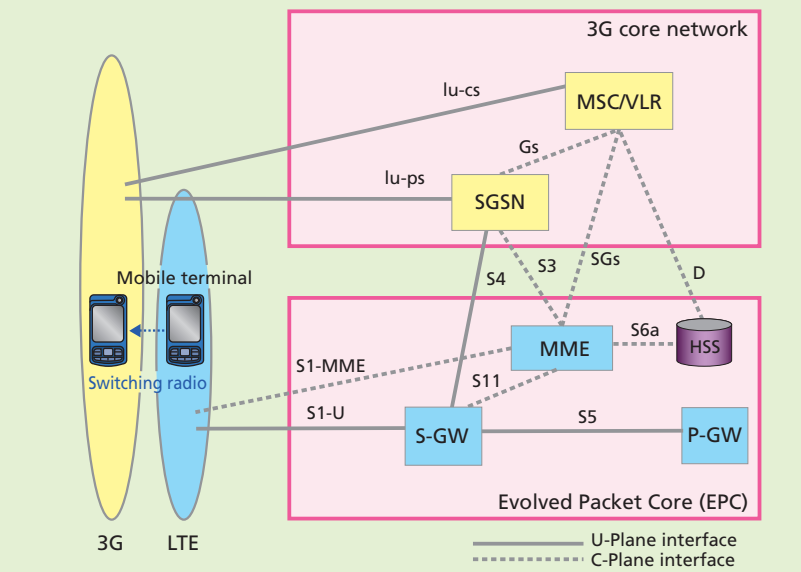

Figure 2 CS Fallback network architecture

tics of the EPC supporting CS Fallback is that it connects the Mobile Switching Center (MSC)[*3] and Visited Location Register (VLR)[*4] in the 3G CS domain with the Mobility Management Entity (MME)[*5], which provides EPC mobility management functionality. The interface connecting MSC/VLR and MME is called an SGs reference point. This interface is based on the concept of the Gs[*6] reference point that exchanges signalling with MSC, which connects to the Serving General Packet Radio Service Support Node (SGSN)[*7], a 3G packet switch. The SGs provides nearly all the functions provided by the existing Gs.

The CS Fallback function uses this SGs reference point to transfer the mobile terminating call requests from the CS domain to LTE. It also provides combined mobility management between the 3G CS domain and the EPC to enable this transfer to take place.

3. Combined Mobility Management between CS Domain and EPC Network

3.1 Basic Policy

A mobile communications network must always know where a mobile terminal is located to deliver mobile terminating service requests to the mobile user on the mobile terminating side. The procedure for determining terminal location is called "mobility management." As a basic function of mobile communications, 3G and LTE each provide a mobility management function.

To complete a call using the CS Fallback function, the CS domain needs to know which LTE location registration area the mobile terminal is currently camping on. To this end, the MME must correlate mobility management control of the CS domain with that of EPC and inform MSC/VLR that the mobile terminal is present in an LTE location registration area.

The 3G core network already incorporates a function for linking mobility management of the CS domain with that of the Packet Switched (PS) domain providing packet-switching functions. As described above, the CS domain and PS domain functions are provided via separate switches. Thus, if combined mobility management can be used, the mobility management procedure for the terminal only needs to be performed once, which has the effect of reducing signal traffic in the network. This concept of combined mobility management is appropriated by the CS Fallback function. Specifically, MSC/VLR uses the same logic for receiving a location registration request from SGSN as that for receiving a location registration request from MME. This achieves a more efficient combined mobility management between the CS domain and EPC while reducing the development impact on MSC.

As described above, a mobile terminal using LTE cannot use 3G at the same time. This implies that the MME, which contains the LTE location registration area (Tracking Area (TA)), is unable to identify which MSC/VLR it should send the mobility management messages to from the TA alone. To solve this problem, the mapping of TAs and 3G Location Areas (LA) within MME has been adopted. The concept behind TA/LA mapping is shown in **Figure 3**. Here, MME stores a data-

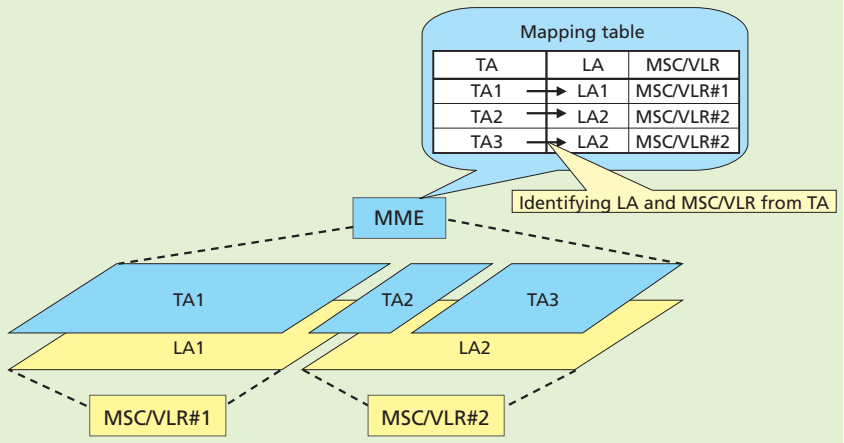

Figure 3 Location registration area mapping

*3 **MSC**: A logical node having CS functions specified by 3GPP.

*4 **VLR**: A logical node located between the mobile terminal and Home Location Register (HLR)/HSS. It serves as a database storing and managing subscriber information and provides functions such as terminal mobility management.

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

*6 **Gs**: An interface for exchanging information between MSC/VLR and SGSN (see *7).

*7 **SGSN**: A logical node that performs packet switching and transfer as well as mobility management for mobile terminals.

base that manages the correspondence between physically overlapping TAs and LAs. This information is used to determine which MSC/VLR to target for location registration.

3.2 Combined Mobility Management Procedures

The combined TA/LA update procedure for CS fallback is shown in detail in **Figure 4**. First, the mobile terminal sends to the MME a Tracking Area Update (TAU) request message indicating a combined TAU and the current TA in which the mobile terminal is currently present (Fig. 4 (1)). The MME then performs a location update procedure towards Home Subscriber Server (HSS), which is a database used for managing subscriber profiles (Fig. 4 (2)). Next, the MME uses the TA/LA correspondence database to identify the corresponding LA and the MSC/VLR that is managing that area, and uses the SGs reference point to send a Location Area Update (LAU) request message to the MSC/VLR together with the LA so identified (Fig. 4 (3)). The MSC/VLR that receives the LAU request message stores the correspondence between the ID of the MME originating the request and an ID such as the International Mobile Subscriber Identity (IMSI)[*8] that identifies the subscriber (Fig. 4 (4)). This enables the MSC/VLR to know which MME the mobile terminal is currently connected to and that the mobile terminal is camping on LTE.

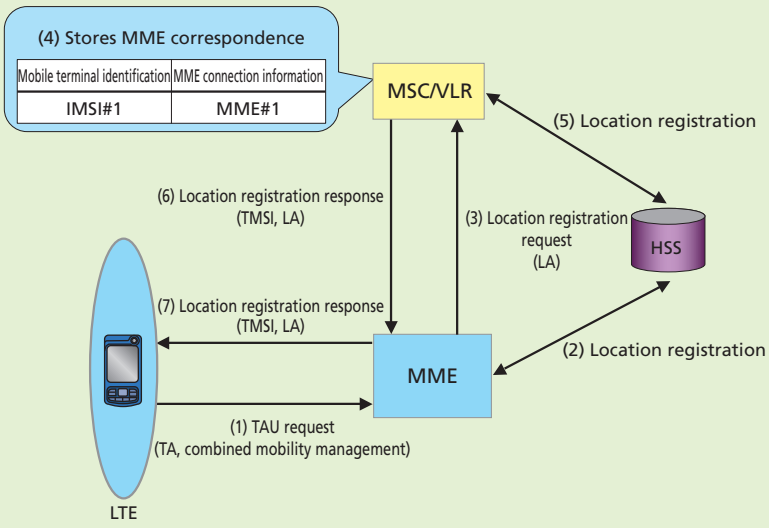

Figure 4 Procedure of combined location registration

Following this, the MSC/VLR performs a location registration procedure with the HSS (Fig. 4 (5)). Finally, the MSC/VLR informs the MME of temporary user identity (Temporary Mobile Subscriber Identity (TMSI))[*9], which is used at the time of a mobile terminating call in the CS domain, and indicates that location registration has been completed. The MME then informs the mobile terminal of the TMSI and of the LA that the mobile terminal has been registered with thereby completing combined location registration (Fig. 4 (6) (7)).

4. CS Fallback Call Control Procedures

4.1 Mobile Originating Call

To originate a voice call using the CS Fallback function, a mobile terminal in the LTE location registration area must first switch (fall back) to 3G. The mobile-originating voice call procedure is shown in **Figure 5**.

To originate a call, the mobile terminal begins by sending a CS fallback service request message to the MME (Fig. 5 (1)). Since a packet-communications transmission path (bearer) must always exist in EPC for the purpose of providing an always-on connection [4], the bearer also has to be handed over to 3G. To accomplish this, the MME issues a handover command to the mobile terminal in LTE and initiates a handover procedure (Fig. 5 (2)). The mobile terminal changes its radio from LTE to 3G during this procedure (Fig. 5 (3)). On completion of handover, the mobile terminal issues an originating request for voice service to the MSC/VLR. A voice-call connection is then established using an existing call-originating procedure on 3G and the CS Fallback procedure is completed (Fig.

*8 **IMSI**: A number for identifying an individual user in Global System for Mobile communications (GSM) and 3G networks. The number is stored in a SIM card and is unknown to the user.

*9 **TMSI**: A number allocated within the network for identifying a mobile terminal.

5(4)).

4.2 Mobile Terminating Call

The mobile terminating voice call procedure using CS Fallback is shown in **Figure 6**. When the MSC/VLR receives a message indicating the occurrence of a mobile terminating call (Fig. 6 (1)), the MSC/VLR identifies the corresponding MME from the call information received (Fig. 6 (2)). Then, the MSC/VLR sends a paging message (Fig. 6 (3)) towards the MME. Next, the MME sends a paging message to the mobile terminal in LTE (Fig. 6 (4)). This paging message includes an indication that the call is a CS service, and on identifying the call as such, the mobile terminal sends a CS fallback service request signal to the MME (Fig. 6 (5)). Following this, a handover procedure to 3G as described above takes place (Fig. 6 (6), (7)). The mobile terminal that is now switched to 3G sends a paging response message to the MSC/VLR at which it is registered (Fig. 6 (8)). Finally, an existing mobile terminating call procedure on 3G is executed and the CS Fallback procedure is completed (Fig. 6 (9)).

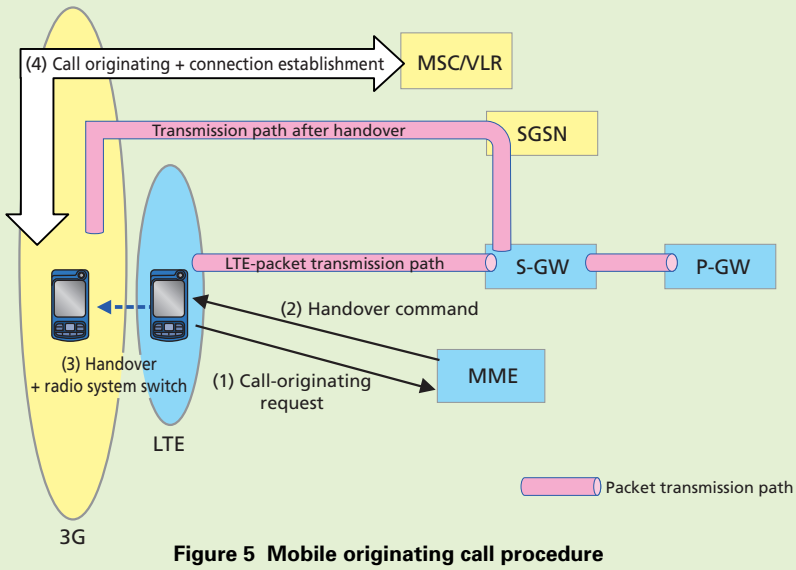

Figure 5 Mobile originating call procedure

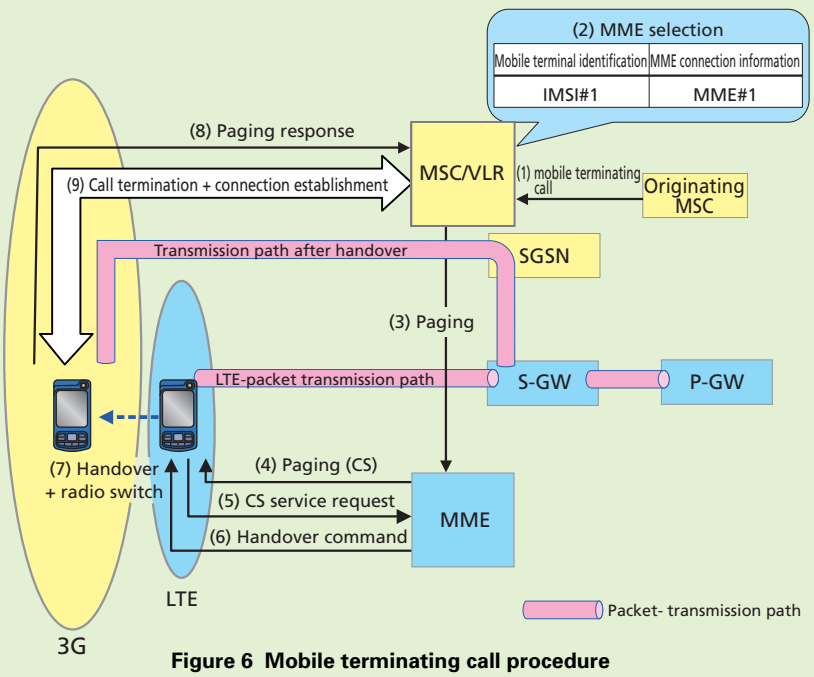

Figure 6 Mobile terminating call procedure

5. Technique for Improving Call-termination Success Rate

Capter 3 described how TA/LA mapping is performed in conjunction with mobility management. In actuality, however, mapping errors can occur due to physical radio factors, and such errors can prevent a mobile terminal from registering its location with the MSC/VLR (**Figure 7**) to which it should actually be registered. As a result, it may turn out that an originating call or response to a paging message, for example, is made to an inappropriate MSC/VLR.

In short, normal communications cannot be performed if an originating or mobile terminating call is handled via an MSC/VLR with which the mobile terminal has not been appropriately registered. To solve this problem, the "Roaming Retry" procedure has been adopted in CS Fallback.

Using a mobile terminating call as an example, the Roaming Retry procedure is shown in **Figure 8**. After receiving a mobile terminating call and switching to 3G, the mobile terminal sends a paging response to an MSC/VLR with which location registration has not been performed (hereinafter referred to as "old MSC/VLR"). The old MSC/VLR cannot determine what that response is for and therefore returns a rejection to the mobile terminal in response to that request (Fig. 8 (1) (2)). This reject message triggers the mobile terminal to resend an LAU message. This LAU message is sent to the MSC/VLR that accommodates the LA in which the mobile terminal is currently located (hereinafter referred to as "new MSC/VLR") (Fig. 8 (3)).

The new MSC/VLR now performs location update procedures with the HSS. Upon reception of the location update request message, HSS deletes the location registration information in the old MSC/VLR (Fig. 8 (4) (5)). This deletion of location registration information now triggers the old MSC/VLR to submit a resend request to the MSC that originated the call request (Fig. 8 (6)). Finally, the originating MSC resends the call request to the new MSC/VLR, and from that point on, the mobile terminating call is executed on the 3G side (Fig. 8 (7)).

This procedure enables a connection to be made without losing a mobile terminating call even if mapping of location registration areas between LTE and 3G has not been correctly performed.

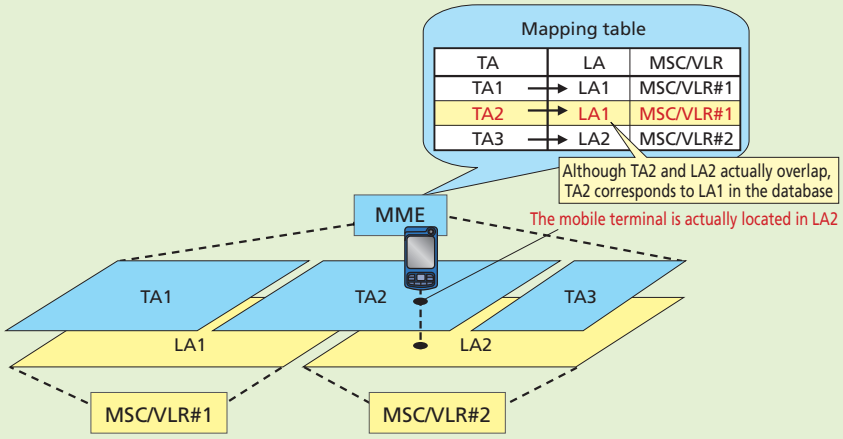

Figure 7 Mapping error problem

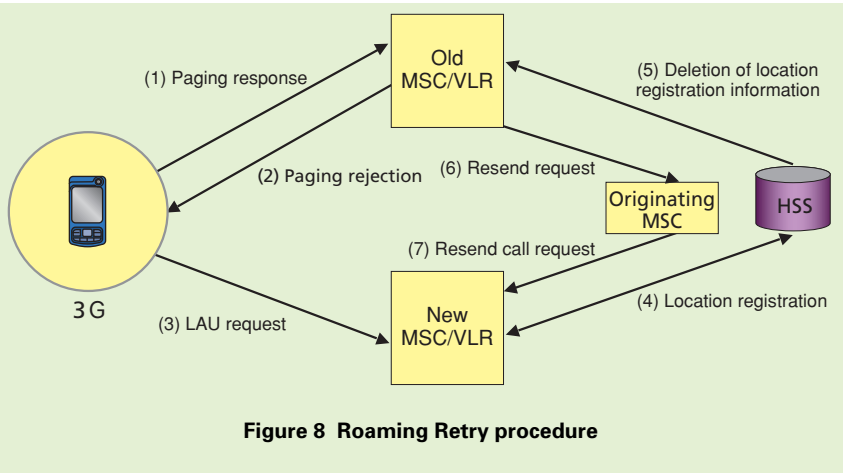

Figure 8 Roaming Retry procedure

6. Conclusion

This article described the CS Fallback function as one method of providing voice services on LTE by combining 3G and EPC mobility management during the initial LTE rollout period prior to providing direct voice services like VoIP. The CS Fallback function makes possible the early provision of voice terminals using LTE services without having to wait for the completion of VoIP/IMS facilities while also making LTE services more convenient

for users. Going forward, future issues include improving the CS Fallback function by shortening connection time, enhancing the handover protocol, etc.

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