White Paper

Voice over Long Term Evolution Migration Strategies

What You Will Learn

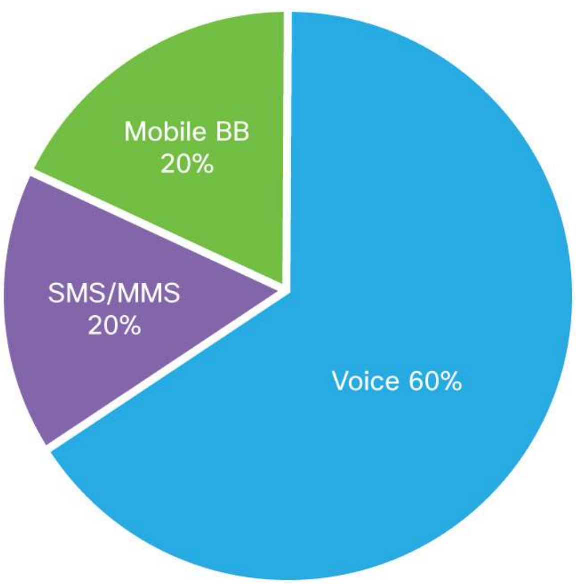
The evolution of mobile networks to the Voice over Long Term Evolution (VoLTE) all-IP technology standard has generated great excitement among operators due to the greatly enhanced quality of experience provided. Operators are currently faced with determining when and how to migrate to LTE services while providing continuity for traditional circuit-switched networks and balancing competitive factors with operational and capital expenditures.

This white paper presents the Cisco® VoLTE solution that includes 3rd Generation Partnership Project (3GPP) standards for IP Multimedia Subsystem (IMS) and interim solution steps on the way to ubiquitous LTE, including Circuit-Switched Fallback (CSFB), CSFB with Interworking Function (CSFB IWF), and Single Radio-Voice Call Continuity (SR-VCC). These technologies, available with the Cisco Converged Services Platform (CSP), are described in relation to both voice and short message service (SMS).

Overview

Voice remains the most popular and profitable mobile service. Despite the many diverse, new mobile services available today, Infonetics forecasted in 2010 that voice will still comprise 60 percent of the mobile services market by 2014, representing $522 billion in global mobile revenues (Figure 1).

Figure 1. Mobile Services Market Forecast for 2014



Source: Infonetics, December 2010.

So the decision among operators of how to deploy VoLTE to support the needs of different types of subscribers in urban, suburban, and rural service areas is an important one. Before LTE is ubiquitously available and while earlier networks and devices are still in use, cost-effective solutions must be found to introduce VoLTE services where possible while being backwards compatible with 2G and 3G networks and older user devices. This incremental migration strategy on the way to full VoLTE coverage has generated several different solutions, which are the subject of this document.

The Market

Myriad multimedia applications, the widespread use of smartphones and other multimedia devices, spiraling usage and subscriber numbers, and competition among mobile operators are all driving adoption of 4G LTE networks. LTE enables faster access networks and its many features provide an enhanced overall experience with always-on connectivity. Technical and business benefits include low latency, quality of service (QoS) features, new services (such as enhanced voice, video chat, collaboration, social preference, media sharing, location, and conferencing), the ability for operators to differentiate themselves and thereby compete more effectively, the ability to better control and monetize over-the-top (OTT) services, and the ability for operators to extend their value proposition to partners and customers.

For voice, LTE represents a dramatic departure from circuit-switched 2G and 3G networks. Previous voice standards, such as those available from the Global System for Mobile (GSM) communications, have had dedicated channels for circuit-switched telephony. LTE, however, provides an end-to-end all-IP connection from handsets or other devices to the core network and back.

The mobile industry has reached consensus around a long-term migration strategy to LTE based on IP Multimedia Subsystem (IMS), the 3GPP architecture that allows mobile operators to run voice, video, chat, and other real-time Session Initiation Protocol (SIP)-based services over an all-IP network. This new architecture necessitates large capital and operational expenditures to upgrade or replace network platforms and software. According to a 2010 Infonetics report, 35 percent of mobile operators will deploy VoLTE by 2013 despite these costs, deciding that the enhanced quality of experience is a significant competitive differentiator.

Interim Voice Solutions on the Way to LTE

With the requirement by mobile operators to simultaneously support existing 2G and 3G circuit-switched and 4G LTE packet-switched infrastructures due to the prohibitive costs of completely replacing the older network infrastructure with the newer one, interim solutions for 2G and 3G voice and VoLTE have been introduced. All of the following solutions are supported by Cisco through the Cisco ASR 5000 Series mobile multimedia gateway platform (providing a standards-based, market-leading evolved packet core [EPC] and LTE core solution) and the Cisco CSP, which supports a suite of capabilities at the applications layer.

Circuit-Switched Fallback

Most mobile operators have chosen to deploy 4G and LTE networks alongside their existing 2G and 3G assets, using CSFB for voice services until they are ready to deploy IMS throughout their network. CSFB allows LTE user equipment (UE) to drop their LTE connection and fall back to a 2G or 3G radio network when a call is made or received. When the call ends, the user equipment reregisters with the LTE network.

3GPP has defined a standard for CSFB for Global System for Mobile Operators (GSM) operators, based mainly on TS 23.272. 3GPP also defined a standard for operators with Code Division Multiple Access (CDMA) networks, which is functionally equivalent but defines a different set of interfaces and network components. Industry adoption for CDMA CSFB has been limited today, so this document focuses on the 3GPP standard version of CSFB.

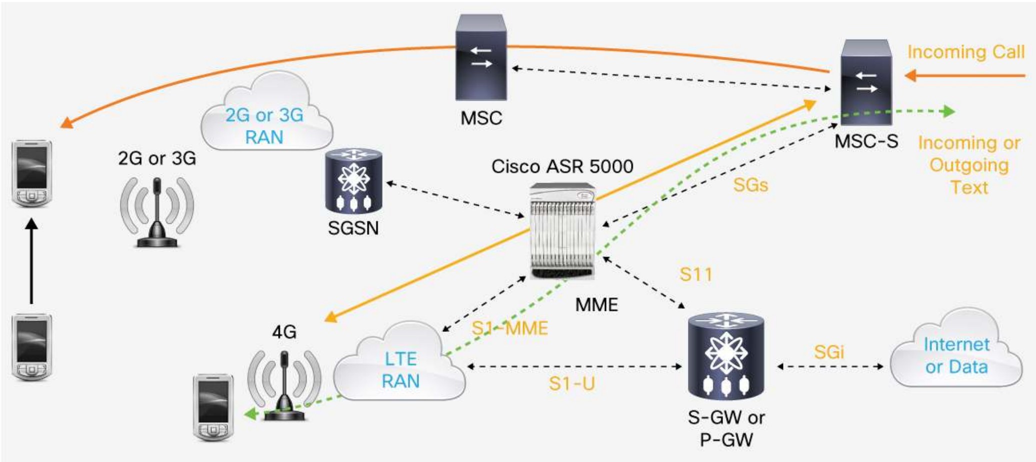
Here is how CSFB works. Prior to CSFB user equipment registration on the network, a static mapping of 4G tracking areas (TAs) to 3G location areas (LAs) must be configured on all Mobility Management Entities (MMEs) in the mobile operator’s network. This static mapping of tracking areas to location areas is used to update the appropriate 2G or 3G Serving Mobile Switching Center - with the location of the user equipment on the 4G LTE network. During Evolved Packet System registration, the CSFB-capable user equipment registers with the MME in the packet core and advertises its CSFB capabilities. If the MME is CSFB-capable (is supported by SGsit will acknowledge the registration and the user equipment will be registered as a CSFB-capable device. Once the CSFB user equipment is properly registered, the MME will then send and update over the SGs interface to the appropriate S-MSC using the previously configured tracking area to location area mapping table.

In CSFB, the user equipment MIN is still “owned” by the 2G or 3G S-MSC. For mobile originated (MO) calls, the CSFB client detects an outgoing call and notifies the MME of the event. The MME then issues a handover command back to the user equipment to initiate the Radio Access Technology (RAT) change to 3G. Upon successful registration in the 3G network the user equipment originates the request for voice service to the MSC and visitor location register (VLR) and the call is cut through. In the use case for a mobile terminated (MT) call to the CSFB-enabled user equipment, the call is initially routed to the 2G or 3G S-MSC during call setup. The MSC then sends a page message out through the SGs interface to the MME that previously advertised itself as having the user equipment registered on it. The MME forwards that page message out to the LTE-attached user equipment and informs it that it has an incoming call. The CSFB client on the user equipment first terminates its registration with the LTE network and then initiates registration on the 2G or 3G RAN using the location area’s information pass-along in the page message. Once 2G or 3G registration is complete, the call is sent through to the user equipment through normal 2G or 3G call setup procedures.

Support for delivery of mobile originated and mobile terminated Short Message Service (SMS) is also defined in 3GPP 23.272. The standard defines support of mobile originated and mobile terminated delivery to and from the CSFB without fallback to the circuit-switched network. In the case of MT SMS traffic, the S-MSC receives the SMS though normal 2G or 3G procedures. Through the update from the EPC MME over the SGs interface, the S-MSC knows where on the LTE network the user equipment is and the S-MSC then forwards the SMS over the SGs interface to the appropriate MME. The MME then forwards the SMS to the LTE user equipment for delivery without having the LTE user equipment fall back to the 2G or 3G network.

In the case of mobile originated SMS, the LTE user equipment simply forwards the SMS to the MME and the MME sends over the SGs to the S-MSC in its tracking area-to-location area mapping table. The S-MSC follows normal SMS delivery procedures from there. Figure 2 illustrates the 3GPP 24.272 standard for CSFB.

Figure 2. Circuit-Switched Fallback for Voice and SMS



Possible Concerns with 3GPP Standard CSFB

Signaling

3GPP TS 23.272 CSFB requires increased signaling between the user equipment and the network, and requires retuning of the user equipment radios to the older network. These additional steps inject increased post-dial delay into the call setup time.

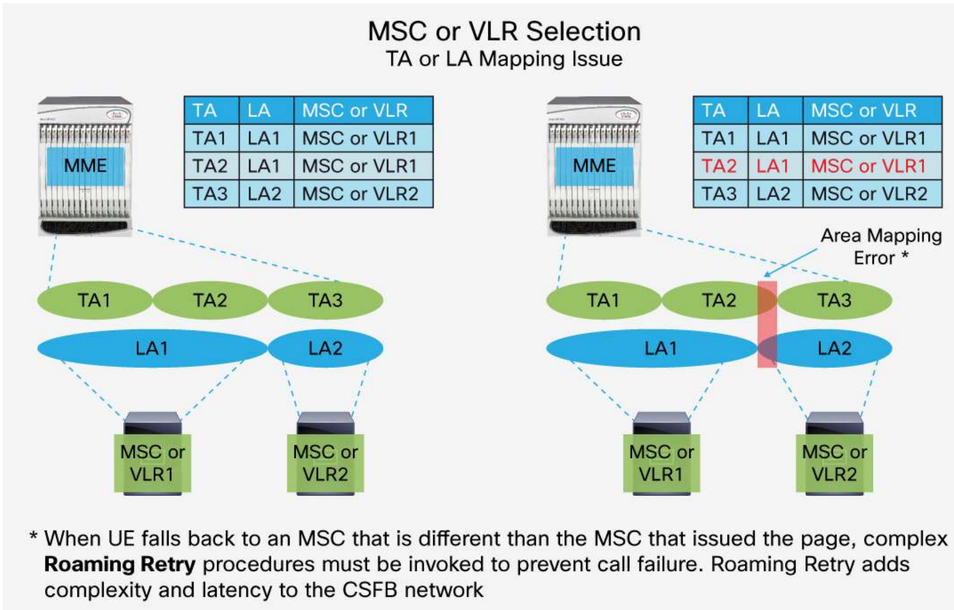
Network Upgrades

To enable TS 23.272 CSFB, upgrades to the LTE MME, 2G and 3G MSCs, and the user equipment are required. The S-MSC must be R4 compliant and must be upgraded to support the SGs interface. Operators with hundreds of MSCs may be reluctant to do these upgrades due to the high capital costs and the operational time required to deploy the upgrades. SGs support is also required on the LTE MME. A CSFB client is also required on the LTE user equipment.

Tracking Area-to-Location Area Mapping

3GPP TS 23.272 CSFB requires the MME to maintain static mapping of the tracking areas to location areas. This mapping is used by the MME for information on the corresponding 2G or 3G location area that overlaps with the 4G tracking area the LTE user equipment is registered on. The tracking area to location area mapping is a static and manual process on the MME. The Reverse Path Forwarding (RFP) planning group within the mobile operator must review the overlap of tracking area to location area and input that information into the MME. The overlap of tracking area to location area does not always map out perfectly. Often there are multiple location areas that overlap with the tracking areas. In this situation it is possible for the user equipment to fall back to a location area that is not served by the S-MSC that “owns” the establishment of the current call. In this situation the operator has the choice of dropping the call or implementing the network Roaming Retry procedure. Figure 3 illustrates the tracking area to location area mapping issue.

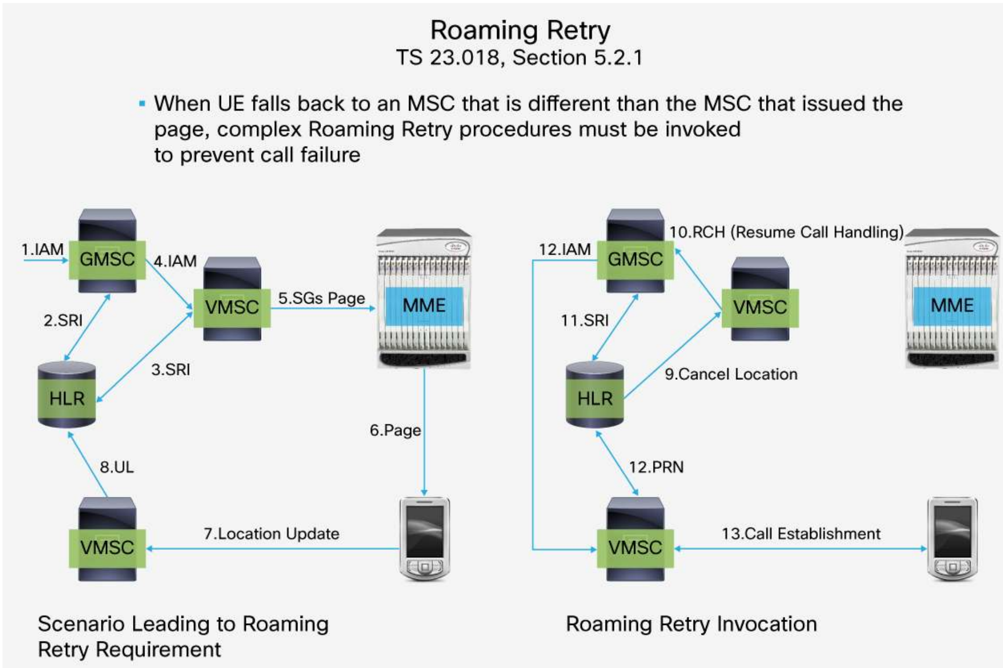
Figure 3. Tracking Area to Location Area Mapping Issue



Roaming Retry

The Roaming Retry procedure is required to locate the LTE user equipment that registers in the wrong location area due to incorrect tracking area to location area mapping. An upgrade to the MSC and Home Location Register (HLR) are required for Roaming Retry to work. These upgrades often entail large capital expenditures. Roaming Retry also adds additional latency to the post-dial delay, as additional signaling is required to locate the user equipment in the 2G or 3G network. Figure 4 illustrates the Roaming Retry procedure.

Figure 4. Roaming Retry Procedure

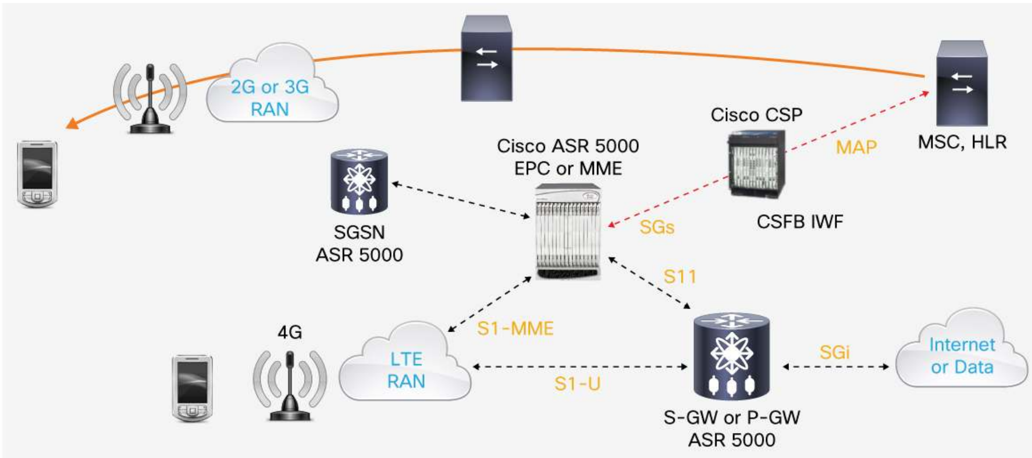


With Roaming Retry, after registering on the 2G or 3G network to receive the call, the user equipment sends a Location Area Identity (LAI) to an MSC and VLR where location registration has not been performed. Since, in this example, the user equipment is in the wrong location area, the MSC and VLR that receive the LAI are not the target MSC that the call is registered on. Because of this, the MSC sends back a rejection to the user equipment's LAI. The rejection message triggers the user equipment to resend a Location Area Update (LAU) message to the MSC and VLR that handle the location area where the user equipment is currently located. This MSC and VLR perform the location update with the Home Subscriber Server (HSS). Upon reception of the location update request message, the HSS deletes the location registration information in the old MSC and VLR, triggering submission of a resend request to the MSC and VLR that originated the call request. The originating MSC and VLR then resend the call request to the new MSC and VLR, and the call is run on the 3G network. As seen in the steps above, using Roaming Retry is costly and time-consuming and adds latency and call setup time.

Cisco CSFB Interworking Function (CSFB-IWF)

Cisco's Converged Services Platform (Cisco CSP) supports CSFB-IWF and addresses the tracking area to location area mapping and Roaming Retry function. CSFB-IWF allows an operator's existing circuit-switched infrastructure to serve LTE subscribers over the circuit-switched domain without the need for MSC upgrades, thus reducing ongoing operational expenses. With Cisco CSFB IWF, the MME must still support the SGs interface (Figure 5). CSFB-IWF communicates with the HLR over the Mobile Application Part (MAP) protocol for location management, subscriber management, and call handling.

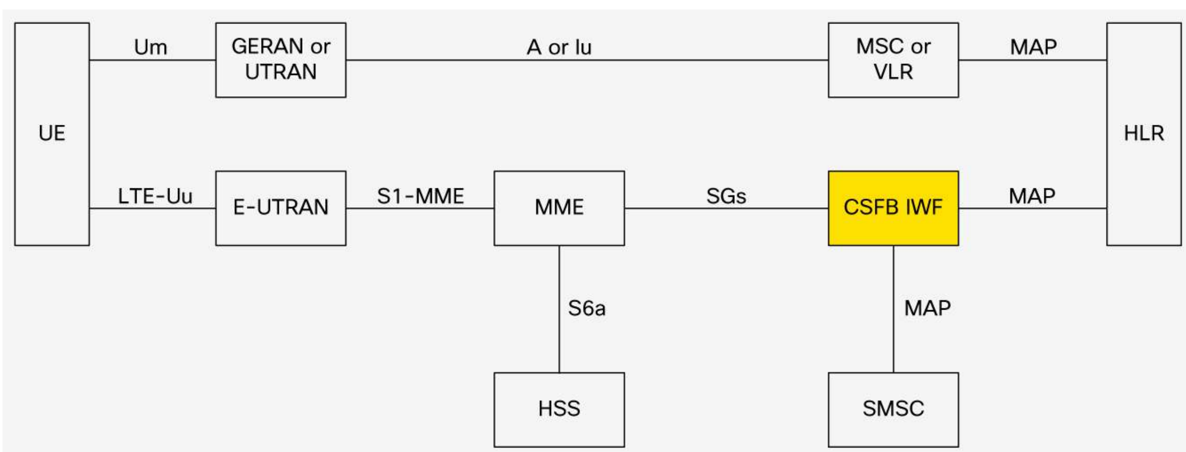
Figure 5. Circuit-Switched Fallback Interworking Function



LTE user equipment using CSFB-IWF network registration takes the following steps (Figure 6):

- User equipment registers with the LTE network
- The serving MME registers with HSS
- The serving MME informs the VLR registered to CSFB IWF
- CSFB-IWF registers as the serving MSC with HLR

Figure 6. CSFB IWF Call Flows

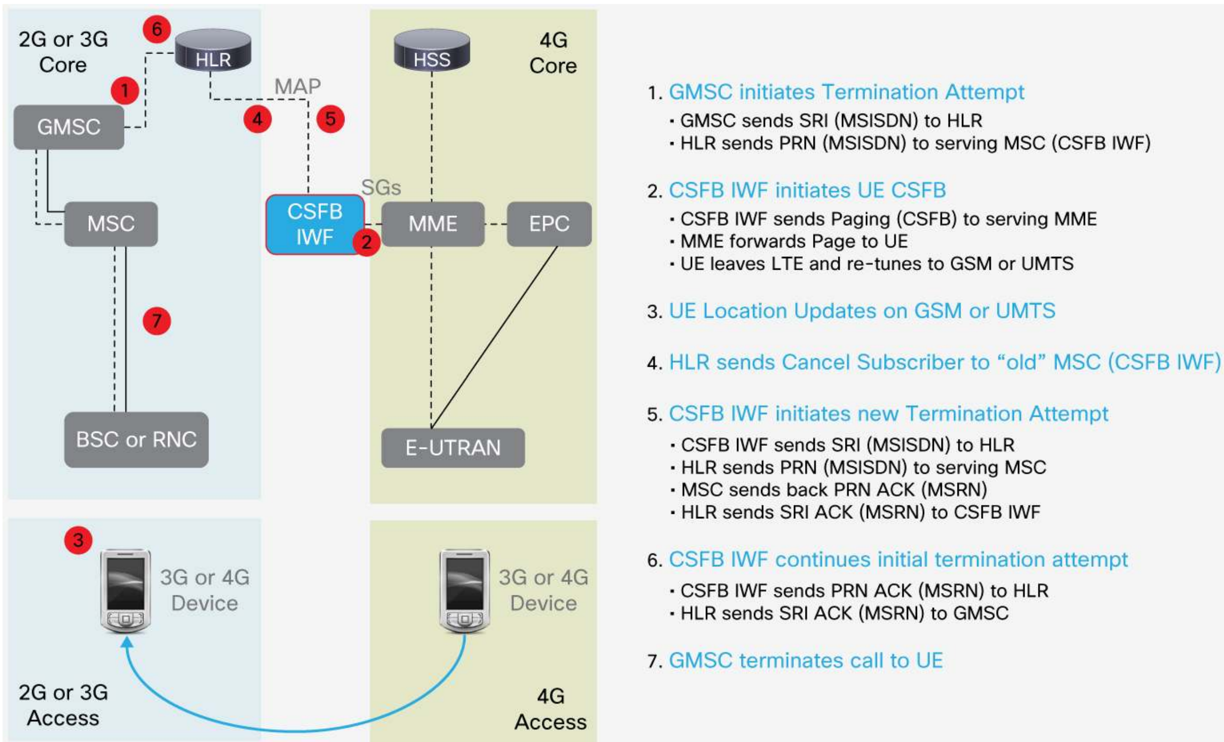


Mobile origination and termination is shown in Figure 7.

- **Mobile origination:** The user equipment leaves the LTE network and re-tunes to the 3G network where its location is updated. The HLR then sends a Cancel Subscriber command to CSFB IWF and the subscriber is removed. The user equipment initiates the call.

- **Mobile termination:** The Gateway Mobile Switching Center (GMSC) initiates a termination attempt (sending the Send Routing Information [SRI] message to the HLR). The HLR sends the Provide Routing Number (PRN) message to the CSFB-IWF (acting as VLR). The CSFB-IWF sends a page to the serving MME. The MME forwards the page to the user equipment. Upon receipt of the page message, the user equipment leaves the LTE network and re-tunes to the 3G network. Upon registration in the 2G or 3G network, the user equipment sends out an LAI. This LAI is forwarded to the HLR, which then sends a Cancel Subscriber command to the CSFB IWF MSC. The CSFB IWF initiates a new termination attempt (sending an SRI to the HLR). The HLR sends PRN to the serving MSC and the MSC sends back a PRN acknowledgement (ACK). The HLR sends a SRI ACK to CSFB IWF. CSFB IWF sends the PRN ACK to HRL and HRL sends the SRI ACK to the GMSC, which terminates the call to the user equipment.

Figure 7. Mobile Initiation and Termination with CSFB IWF



Both CSFB and CSFB IWF solutions support the delivery of SMS over LTE through the MAP interface between the CSFB IWF and the SMS Center (SMSC). The MAP interface between the CSFB IWF and HLR is used for location management, subscriber management, and call handling procedures. The MAP interface between CSFB IWF and the SMSC is used for mobile originated and mobile terminated SMS. SMS messages to 2G and 3G devices go to the MSC for delivery to the older network through the SGs interface, allowing for intercommunication between circuit-switched and packet-switched networks. Messages coming to and from an LTE user equipment from another LTE user equipment on the LTE network do not have to fall back and are sent through a peer-to-peer session using SIP.

Benefits of Cisco CSFB IWF for voice and SMS include:

- Reduced operational rollout costs and complexity.
- No need to perform upgrades to MSC and HLR platforms.

- Requires no specific tracking area to location area mapping changes on MME (MME is provisioned as if it is connecting to a standard SGs interface).
- No disruption to existing network elements.
- Support for SMS over SGs and CSFB through a centralized gateway.
- Does not require SGs software licensing or IP hardware upgrades on any network MSC.
- Operators no longer locked into existing vendors (such as current MSC suppliers) for the CSFB solution.
- Common platform for MSC Telephony Application Services (TAS) and other Cisco CSP services for investment protection as IMS evolves to include services such as voice over Wi-Fi and voice over femtocell.
- Does not require or use Roaming Retry.
- A signalling-only solution with no bearer impact.

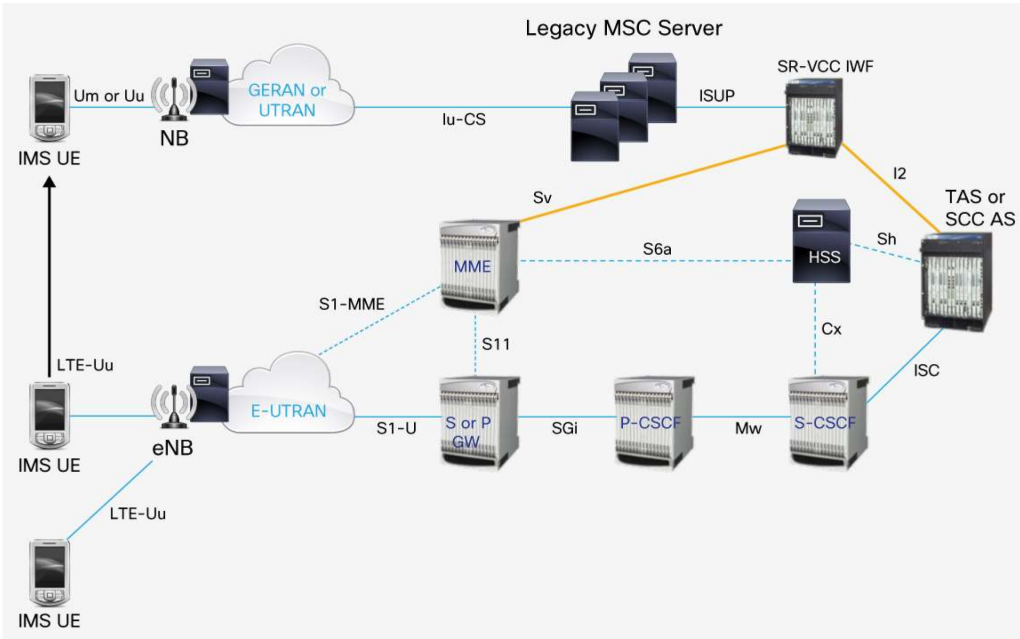
As mentioned previously, the route to LTE for most mobile operators will involve an incremental migration from circuit-switched to packet-switched voice. In one migration scenario, an operator will deploy LTE technology for data traffic, and Cisco CSFB IWF for voice on the older network. Finally, when the operator is ready to turn off their 2G and 3G voice infrastructure and replace it with VoLTE for the majority of their service areas, another technology solution is available.

Single Radio Voice Call Continuity

SR-VCC is a standards-based solution that allows an operator to deploy VoLTE when they do not have ubiquitous LTE coverage. When a user roams out of LTE coverage, the handset switches to the 3G radio and maintains the continuity of the call on the 3G network within 300 milliseconds. The solution moves the call back and forth from the circuit-switched to the packet-switched networks.

Two new interfaces are defined by 3GPP for support of SR-VCC. These interfaces are i2 and Sv, between the MSC server and the MME and the MSC and the Call Session Control Function (CSCF) for enabling this continuity per call. Upgrading the older MSCs in the network is a complex, time-consuming process that requires substantial operational costs. As with the Cisco CSFB IWF solution, Cisco’s SR-VCC Interworking Function (SR-VCC IWF) alleviates the need for mobile operators to upgrade their older MSCs (Figure 8). The IWF provides support for the SR-VCC function without requiring Sv and i2 interface support on the MSC. The Cisco CSP provides support for the TAS and Session Centralization and Continuity Application Server (SCC-AS), which provide these features through the i2 interface.

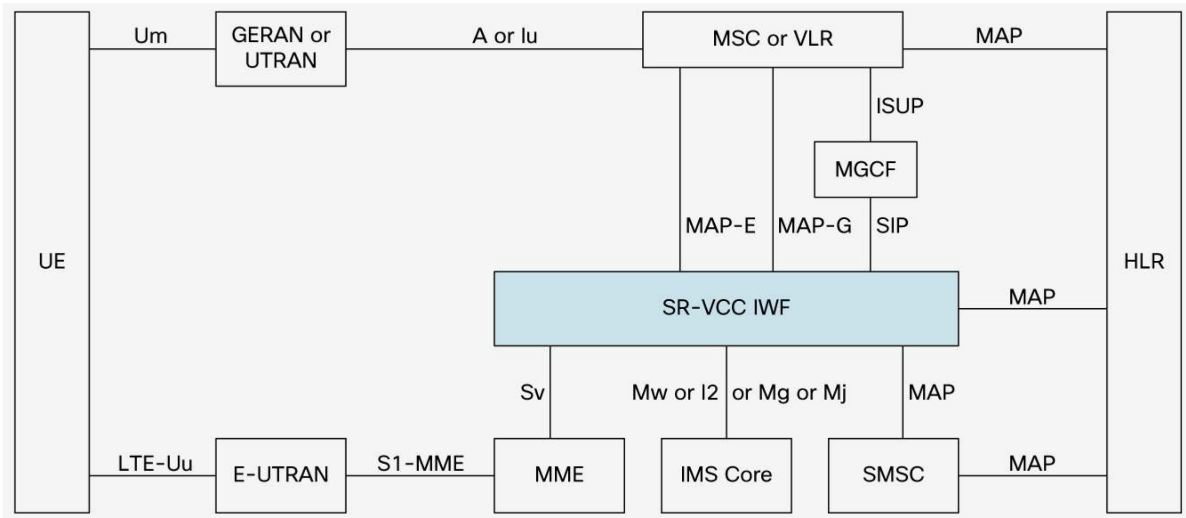
Figure 8. Single Radio-Voice Call Continuity Interworking Function



The IWF acts as a MSC and VLR enhanced for SR-VCC and supports the following interfaces (Figure 9):

- The Sv interface (based on the General Packet Radio Service [GPRS] Tunneling Protocol version 2-C [GTPv2-C]) to the MME is used to appear as an MSC server enhanced for SR-VCC.
- The MAP-D interface to the HLR is used for location management, subscriber management, and call handling procedures.
- The MAP-G interface to the VLR is used to allow the MSC and VLR to retrieve the International Mobile Subscriber Identity (IMSI).
- The MAP-E interface to the MSC is used for handover of calls from Evolved Universal Terrestrial Radio Access Network (E-UTRAN) to UTRAN/GSM EDGE Radio Access Network (GERAN) during SR-VCC access transfer.
- The SIP Interface to the Media Gateway Controller Function (MGCF) is used as a bearer control protocol during and after the SR-VCC handover. The MGCF will interwork SIP to ISDN User Part (ISUP) towards the MSC.
- The MAP interface to the SMSC is used for mobile originated and terminated SMS.
- The Mw, Mg and Mj reference points towards the IMS core are used for appearing as a MSC enhanced for SR-VCC with the SIP interface, I-MGCF, and O-MGCF, respectively.

Figure 9. SR-VCC IWF Interfaces

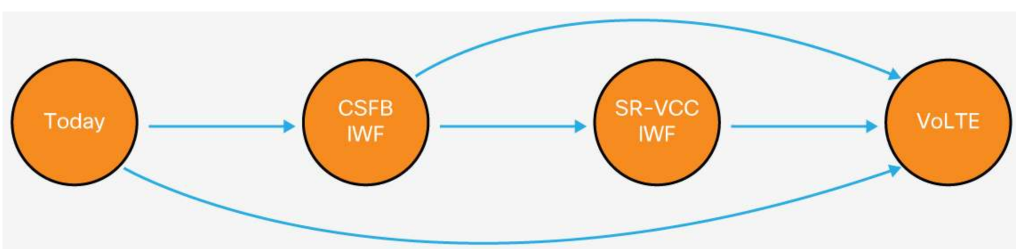


The Cisco CSFB IWF and Cisco SR-VCC IWF solutions share the same hardware and software platform - the Cisco CSP - so mobile operators can deploy CSFB IWF as an interim solution and then SR-VCC IWF through a software upgrade when LTE coverage is more widespread and the need to fall back to 2G or 3G networks is less frequent. A final step is disconnecting the previous voice infrastructure along with SR-VCC IWF when VoLTE is truly ubiquitously supported.

Other Technologies Beyond VoLTE

Mobile operators must choose which path they take on the way to VoLTE (Figure 10). Some are opting to make the investment in upgrading their networks to provide ubiquitous VoLTE coverage now. Others will find CSFB and SR-VCC technologies attractive as interim steps. With Cisco's IWF available for these two solution architectures, operators can bypass costly MSC upgrades, simplifying the introduction of VoLTE while maintaining 2G and 3G voice support.

Figure 10. The Evolution to VoLTE



Beyond the introduction of IMS in LTE networks for voice and video over LTE (V2oLTE), Cisco is working to extend the features of the Cisco CSP and Cisco Evolved Packet Core (EPC) to provide innovative solutions, such as voice over Wi-Fi (VoWi-Fi) and voice over small cell technologies such as femtocell.

With the coming of IMS Centralized Services (ICS) in the mobile core, all network elements will eventually become IMS-capable. This environment will support older voice networks while also supporting fixed-mobile convergence of wireless or wireline access. It will also enable support of:

- Multiple devices associated with the same user account
- Older mobile devices
- Video calling, picture sharing, and other media streams
- A standardized approach to support of services such as call forwarding, hold, and three-way calling

Why Cisco

Cisco has the breadth of products, technologies and experience to provide a dependable VoLTE transitional solution and the expertise to help customers implement it for measurable benefits. The Cisco ASR 5000 Series Multimedia Core Platform provides a market-leading LTE and EPC solution, with high performance and integrated intelligence. As part of the platform, the Cisco CSP supports CSFB, CSFB IWF, SR-VCC, and SR-VCC IWF as baseline capabilities. Cisco also provides a fully compliant OneVoice IMS solution that uses the same elements as the CSFB IWF and SR-VCC IWF solutions. This provides for a transparent upgrade from CSFB IWF and SR-VCC IWF to OneVoice, the industry initiative that defined the minimum set of functions an implementation must support to provide VoLTE.

The same Cisco ASR 5000 Series supports the full high-performance IMS CSCF core functionality, which can be provided as a standalone function or integrated into the EPC functions to reduce the cost of entry for the VoLTE solution for OneVoice, reducing the number of network elements, interfaces, and call setup latency. Cisco provides all of the essential application server functionality required to deploy VoLTE, including the voice, messaging, and mobility servers on the Cisco CSP.

For More Information

- Cisco Mobile Internet: http://www.cisco.com/en/US/netsol/ns973/networking_solutions_market_segment_solution.html.
- Cisco Voice and Video Over LTE - Solution Overview: http://www.cisco.com/en/US/solutions/collateral/ns341/ns973/solution_overview_c22-643109_ns1129_Networking_Solution_Solution_Overview.html.

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