



**Scenarios for EPS / LTE Interoperability
Testing**

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MultiService Forum Implementation Agreement

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Abstract:

The MultiService Forum (MSF) is responsible for developing Implementation Agreements or Architectural Frameworks which can be used by developers and network operators to ensure interoperability between components from different vendors. MSF Implementation Agreements are formally ratified via a Straw Ballot and then a Principal Member Ballot.

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The goal of the MSF is to promote multi-vendor interoperability as part of a drive to accelerate the deployment of next generation networks. To this end the MSF looks to adopt pragmatic solutions in order to maximize the chances for early deployment in real world networks.

To date the MSF has defined a number of detailed Implementation Agreements and detailed Test Plans for the signaling protocols between network components and is developing additional Implementation Agreements and Test Plans addressing some of the other technical issues such as QoS and Security to assist vendors and operators in deploying interoperable solutions.

The MSF welcomes feedback and comment and would encourage interested parties to get involved in this work program. Information about the MSF and membership options can be found on the MSF website <http://www.msforum.org/>

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I. The MultiService Forum

The MultiService Forum (MSF) is a global association of service providers, system suppliers and other organizations committed to developing and promoting open-architecture, multiservice communication systems. Founded in 1998, the MSF is an open-membership organization comprised of the world's leading telecommunications companies.

The MSF's activities include developing implementation agreements, promoting worldwide compatibility and interoperability, and encouraging input to appropriate national and international standards bodies.

As part of MSF's effort to drive and promote interoperability, the MSF has created a number of programs geared toward accelerating real world network deployments:

1. Global MSF Interoperability (GMI) events. GMI events provide a real-world setting for vendors to test their solutions and provide evidence that vendor products meet the interoperability standards set forth by MSF Implementation Agreements. Each MSF GMI event is built around a set of capabilities defined for a given release of the MSF Architecture.
2. Next Generation Network (NGN) Test Bed. The NGN test bed provides a facility to enable carriers and vendors to perform in-depth testing of a specific interface as defined in a given release of the MSF architecture.
3. Certification Programs. For more mature technologies the MSF can provide Certification of compliance to a given Implementation Agreement where MSF members believe that it is of value to the industry to do so.

II. An introduction to MSF R5 documentation

This document is part of the MSF Release 5 set of architectural, protocol and test documentation.

The MSF Release 5 Architecture is a physical implementation of the functional architectures that have been proposed by the key Standards Development Organizations. As such the MSF Release 5 Architecture represents the current state of the industry and it identifies current open interfaces between physically separate network elements.

MSF Implementation Agreements define the protocols to be used over specific open interfaces. Where possible MSF Implementation Agreements are based on industry standard protocols augmented with additional information so as to ensure interoperability between communicating network elements. This level of interoperability is achieved by closing any gaps and tightening any optional capabilities in those industry standards to remove the danger of mutually incompatible selections by vendors. An MSF Implementation Agreement is targeted at a given release of the MSF architecture but can be used in any circumstance where an operator wishes to deploy the open interface and its functionality within their own network.

The MSF Release 5 architecture and its associated implementation agreements are used as the basis for MSF Interoperability Events in the 2009-10 timeframe.

Detailed test scenarios will be developed and a number of test plans defined for any given MSF Interoperability Event. Test plans contain the set of test cases required to demonstrate a given MSF Release 5 capability and serve to exercise and validate the set of Implementation Agreements required to realize the capability.

Following the completion of a MSF Interoperability Event, the MSF Release 5 architecture and individual implementation agreements will be updated if the testing identifies any deficiencies in the documents.

For more information about the scope of MSF Interoperability Events, please go to <http://www.msforum.org>

III. Impact on previously published MSF documents

This is a new specification for MSF release 5.

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1 Introduction

The Evolved Packet System (EPS) is an evolution of the 3GPP defined architecture aimed at coping with the rapid growth in IP data traffic. EPS was defined in 3GPP Release 8 and comprised two main components.

- **Radio Access Network.** The Evolved Universal Terrestrial Radio Access Network (E-UTRAN); this is often referred to as 3G Long Term Evolution (LTE).
- **Core Network.** The Evolved Packet Core (EPC), this is often referred to as the System Architecture Evolution (SAE).

The figure below shows the main components of the EPS in the simplest (non-roaming) configuration.

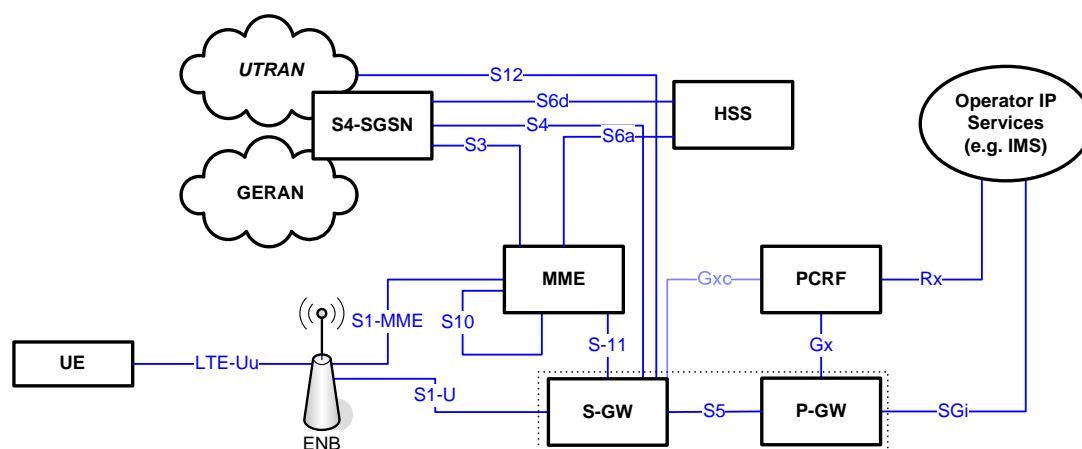


Figure 1 - EPS Architecture

The main components of the Architecture are described below.

- **UE (User Equipment).** The User Equipment that is used to connect to the EPS, in the figure above this is an LTE capable UE accessing EPS via the LTE-Uu radio interface.
- **ENB (eNodeB).** The evolved RAN (E-UTRAN) consists of a single node, the eNodeB (ENB) that interfaces with the UE. The eNodeB hosts the Physical (PHY), Medium Access Control (MAC), Radio Link Control (RLC), and Packet Data Convergence Protocol (PDCP) layers that include the functionality of user-plane header-compression and encryption. It also offers Radio Resource Control (RRC) functionality corresponding to the control plane. It performs many functions including radio resource management, admission control, scheduling, enforcement of negotiated UL QoS, cell information broadcast, ciphering/deciphering of user and control plane data, and compression/decompression of DL/UL user plane packed headers.
- **MME (Mobility Management Entity).** The Mobility Management Entity (MME) is the key control-node for the LTE access-network. It is responsible for idle mode UE tracking and paging procedures including retransmissions. It is involved in the bearer activation / deactivation process and is also responsible for choosing the SGW (see below) for the UE at the initial attach and at time of intra-LTE handover involving Core Network node relocation. It is responsible for authenticating the user (in conjunction with the HSS). The NAS (Non-Access Stratum) signalling terminates at the MME which is also responsible for the generation and allocation of temporary identities to the UEs. The MME validates the permission of the UE to camp on the service provider's PLMN (Public Land Mobile Network) and enforces UE roaming restrictions. The MME is the termination point in the network for ciphering/integrity protection for NAS signalling and handles security key management. Lawful interception of signalling is also a function provided by the MME. The MME provides the control plane

function for mobility between LTE and 2G/3G access networks and interfaces with the home HSS for roaming UEs.

- **S-GW (Serving Gateway).** The S-GW routes and forwards user data packets, while also acting as the mobility anchor for the user plane during inter-eNodeB handovers and as the anchor for mobility between LTE and other 3GPP technologies (terminating S4 interface and relaying the traffic between 2G/3G systems and PDN GW). For idle state UE, the S-GW terminates the DL data path and triggers paging when the DL data arrives for the UE. It manages and stores UE contexts and performs replication of the user traffic in case of lawful interception. It is likely that the S-GW and P-GW functions would be realized as a single network element.
- **P-GW (Packet Data network GateWay).** The P-GW provides connectivity between the UE and external packet data networks, it provides the entry and exit point of traffic for the UE. A UE may have simultaneous connectivity with more than one P-GW for accessing multiple Packet Data Networks. The PGW performs policy enforcement, packet filtering for each user, charging support, lawful interception and packet screening. The P-GW also acts as the anchor for mobility between 3GPP and non-3GPP technologies such as WiMAX or DSL. It is likely that the S-GW and P-GW functions would be realized as a single network element.
- **PCRF (Policy Charging and Rules Function).** The PCRF provides policy control decisions and flow based charging controls. The PCRF determines how a service data flow shall be treated in the enforcement function (PGW in this case) and ensure that the user plane traffic mapping and treatment is in accordance with the user's profile.
- **HSS (Home Subscriber Server).** The HSS is a network database that holds both static and dynamic data elements related to subscribers. The HSS provides user profile information to the MME during user authentication.
- **S4-SGSN (Serving GPRS Support Node).** The SGSN supports the legacy access for UTRAN and GERAN. In the EPS architecture (3GPP release 8) the SGSN is enhanced to support the S4 and S3 interfaces (hence referred to as the S4 SGSN). The S4 interface provides control and mobility support between GPRS Core and the 3GPP Anchor function of the Serving GW. The S3 interface enables user and bearer information exchange for inter 3GPP access network mobility.

The main interfaces of the Architecture are described below.

- **LTE-Uu.** The radio interface between the eNodeB and the User Equipment. Interoperability of this interface is out of scope for the scenarios described in this document and is covered by the work of other organizations, principally LTSL.
- **S1-MME.** The control plane interface between EUTRAN and MME. The protocols used over this interface are the Non-access stratum protocols (NAS).
- **S1-U.** The interface between EUTRAN and the SGW for per-bearer user plane tunnelling and inter-eNB path switching during handover. The transport protocol over this interface is GPRS Tunnelling Protocol-User plane (GTPv1-U).
- **S3.** The interface between the S4-SGSN and the MME enabling user and bearer information exchange for inter 3GPP access network mobility. The protocol used on the S3 interface is GPRS Tunnelling Protocol-Control plane (GTPv2-C).
- **S4.** The interface between the S4-SGSN and the SGW providing user plane and related control and mobility support. The protocols used on the S4 interface are GPRS Tunnelling Protocol-Control plane (GTPv2-C) and is GPRS Tunnelling Protocol-User plane (GTPv1-U).

- **S5.** The interface provides user plane tunnelling and tunnel management between SGW and PGW. It is envisaged that the SGW and PGW may be realized as single network element in which case the S5 interface is not exposed. The protocol used on the S5 interface is either GTPv1-U/GTPv2-C or PMIPv6.
- **S6a.** The interface enables the transfer of subscription and authentication data for authenticating/authorizing user access. The protocol used on the S6a interface is Diameter.
- **S10.** The interface provides for MME – MME information transfer and is used to enable MME relocation. The protocol used on the S10 interface is GPRS Tunnelling Protocol-Control plane (GTPv2-C).
- **S11.** The interface between the MME and SGW. The protocol used on the S11 interface is GPRS Tunnelling Protocol-Control plane (GTPv2-C).
- **S12.** The interface between the legacy UTRAN and the SGW for user plane tunnelling when direct tunnel is established. The protocol used on the S12 interface is GPRS Tunnelling Protocol-User plane (GTPv1-U). Usage of the S12 interface is an operator configuration option.
- **Gx.** The interface between the PCRF and the PGW, allowing the PCRF direct control over the policy enforcement functions of the PGW. The protocol used on the Gx interface is Diameter.
- **Gxc.** The interface between the PCRF and the SGW, allowing the PCRF direct control over the bearer binding and event reporting functions (BBERF) of the SGW when PMIPv6 is used as a S5/S8 protocol. The protocol used on the Gxc interface is Diameter.
- **Rx.** The interface between the appropriate Application Function (the P-CSCF in the case of IMS) and the PCRF allowing the Application Function to request the application of an appropriate policy for a session.
- **SGi.** The interface between the PGW and the Packet Data Network which can be an operator external public or private packet data network or an intra operator packet data network (e.g. for provision of IMS services).

1.1 Test Scenarios

This document describes four test scenarios that will be used to exercise interoperability of the key interfaces of the EPS architecture these being:-

Basic Interoperability. In this scenario a single instance of the EPS architecture will be created using components from different vendors. Testing will include attachment and detachment from the network, Tracking Area Update, IP-CAN session establishment, SIP registration (to IMS), SIP session establishment, MME pooling and SGW Selection.

Roaming. In this scenario the different roaming scenarios are tested including the home routed traffic model and the local breakout model with both home and visited operator applications. The test set will be the same as for the Basic Interoperability case (with the exception of MME pooling).

Non-LTE Access. In this scenario, the ‘legacy’ 3G access types of UMTS (UTRAN) and EDGE (GERAN) are used to interface to the EPC along with non-3G access such as DSL or WIMAX. The test set will be the same as for the Basic Interoperability case (with the exception of MME pooling).

Handover. In this test case the different handover scenarios are tested, this will include handover between eNBs, MME/SGW relocation and handover between LTE and legacy 3G (UMTS, EDGE) access.

2 Testing Scenarios

2.1 Scenario 1 – Basic Interoperability

The architecture for the Basic Interoperability test case is shown in the figure below. The interfaces for which interoperability will be tested are shown in red (viz S1-MME, S1-U, S-11, S6a, Gx and Rx). In some circumstances it may be necessary to interoperate multiple of the interfaces together rather than in isolation.

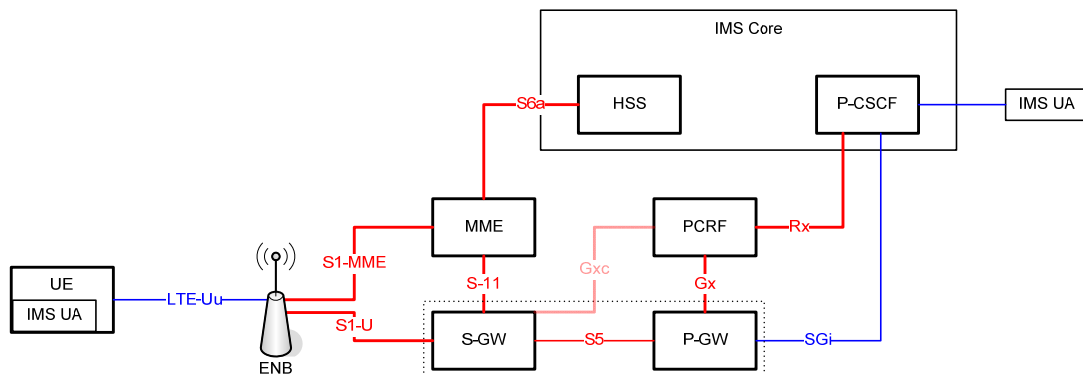


Figure 2 - Scenario 1a Physical Architecture – Basic Configuration

Additionally an extension scenario 1b (shown below) extends the basic architecture in order to demonstrate MME ‘pooling’ and test the interoperability of the pooling function.

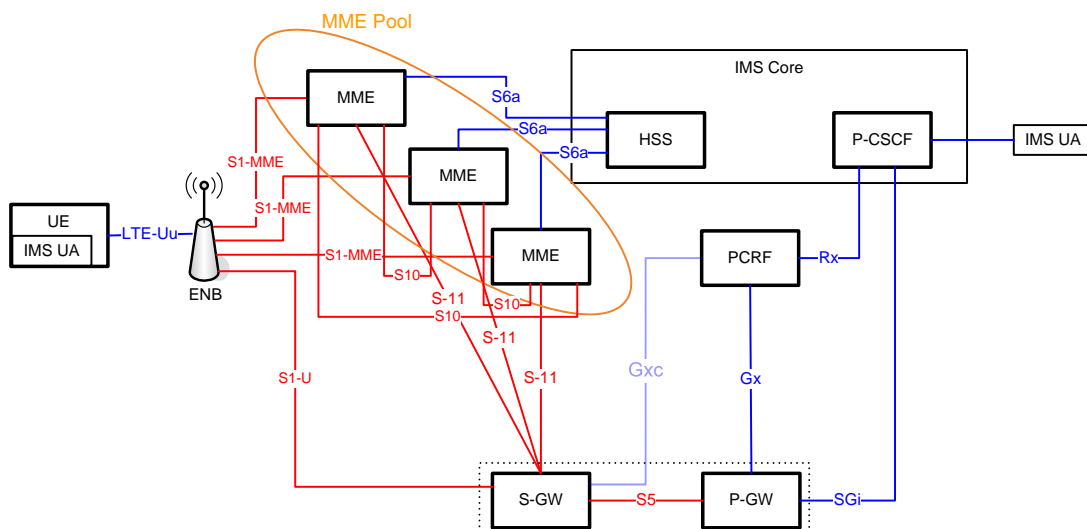


Figure 3 - Scenario 1b Physical Architecture – MME Pooling

Additionally an extension scenario 1c (shown below) extends the basic architecture in order to demonstrate S-GW Selection and test the interoperability of the selection function.

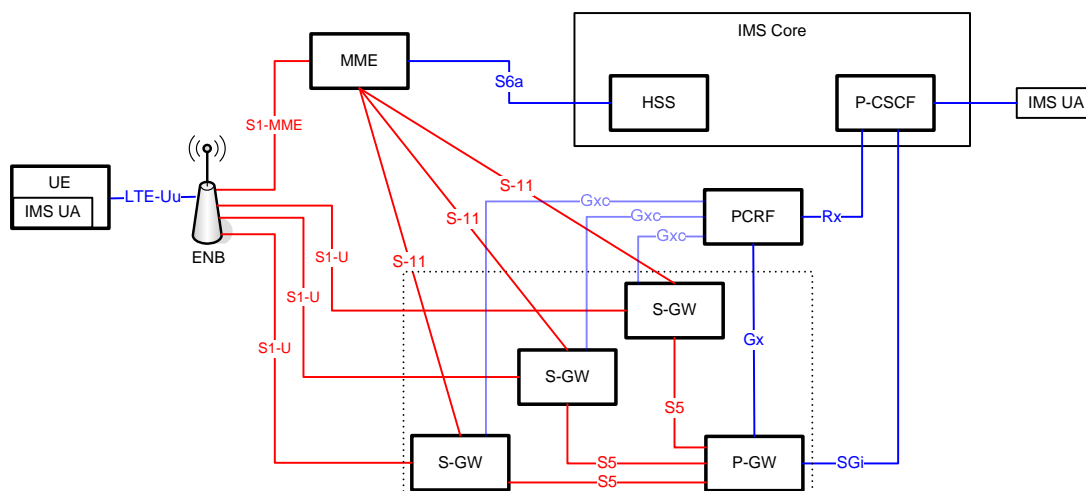


Figure 4 - Scenario 1c Physical Architecture – S-GW Selection

2.1.1 Network Components

2.1.1.1 Scenario 1a

The following components are required for this scenario.

- One LTE UE (likely a data dongle on a laptop).
- One IMS UA to run on the LTE UE (likely a soft client on a laptop).
- One eNB
- One MME
- One S-GW
- One P-GW
- One PCRF
- An IMS Core with the P-CSCF exposing the Rx interface and the HSS exposing the S6a interface.
- An IMS UA registered with the IMS Core.

2.1.1.2 Scenario 1b

The following components are required for this scenario.

- At least one LTE UE (likely a data dongle on a laptop) per MME instance.
- One IMS UA per LTE UE (likely a soft client on a laptop).
- One eNB
- Two or more MME's configured in a pool.
- One S-GW
- One P-GW
- One PCRF
- An IMS Core with the P-CSCF exposing the Rx interface and the HSS exposing the S6a interface.
- An IMS UA registered with the IMS Core.

2.1.1.3 Scenario 1c

The following components are required for this scenario.

- At least one LTE UE (likely a data dongle on a laptop) per MME instance.

- One IMS UA per LTE UE (likely a soft client on a laptop).
- One eNB
- One MME.
- Two or more S-GW's
- One P-GW
- One PCRF
- An IMS Core with the P-CSCF exposing the Rx interface and the HSS exposing the S6a interface.
- An IMS UA registered with the IMS Core.

2.1.2 Protocols and Reference Points

The following reference points will be interoperated in this scenario.

Interface	Protocol	Sub Scenario
S1-MME	NAS	1a, 1b, 1c
S1-U	GTPv1-U	1a, 1b, 1c
S5	GTPv1-U/GTPv2-C or PMIPv6	1a, 1b, 1c
S10	GTPv2-C	1b
S11	GTPv2-C	1a, 1b, 1c
S6a	Diameter	1a
Gx	Diameter	1a
Gxc	Diameter	1a
Rx	Diameter	1a

2.1.3 Test Cases

2.1.3.1 Scenario 1a

The following tests will be executed in order to verify interoperability of the indicated interfaces between different vendors.

- LTE UE Attach (IP-CAN Session Establishment)
- Tracking Area Update
- LTE UE Detach (IP-CAN Session Tear Down)
- IMS UA Registration (via LTE UE)
- IMS Session Establishment (from IMS UA on LTE UE)
- IMS Session Establishment (from IMS UA directly connected to IMS Core)
- IMS Session Termination (from IMS UA on LTE UE)
- IMS Session Termination (from IMS UA directly connected to IMS Core)

2.1.3.2 Scenario 1b

The following tests will be executed in order to verify interoperability of the indicated interfaces between different vendors.

With a single vendor pool (all MME from same vendor)

- LTE UE Attach (IP-CAN Session Establishment) with load balancing across pool.
- LTE UE Detach (IP-CAN Session Tear Down)
- IMS UA Registration (via LTE UE)

With a multi-vendor pool (pool of MME instances from different vendors)

- LTE UE Attach (IP-CAN Session Establishment) with load balancing across pool.
- LTE UE Detach (IP-CAN Session Tear Down)
- IMS UA Registration (via LTE UE)

2.1.3.3 Scenario 1c

The following tests will be executed in order to verify interoperability of the indicated interfaces between different vendors.

With a single vendor (all S-GW from same vendor)

- LTE UE Attach (IP-CAN Session Establishment) with S-GW Selection across multiple S-GW's.
- LTE UE Detach (IP-CAN Session Tear Down)
- IMS UA Registration (via LTE UE)

With a multi-vendor (S-GW instances from different vendors)

- LTE UE Attach (IP-CAN Session Establishment) with S-GW Selection across multiple S-GW's.
- LTE UE Detach (IP-CAN Session Tear Down)
- IMS UA Registration (via LTE UE)

2.2 Scenario 2 – Roaming

The Roaming test case actually represents three different test architectures (Roaming with home routed traffic, Roaming with local breakout and home IP services and Roaming with local breakout and visited IP services) as depicted in the figures below.

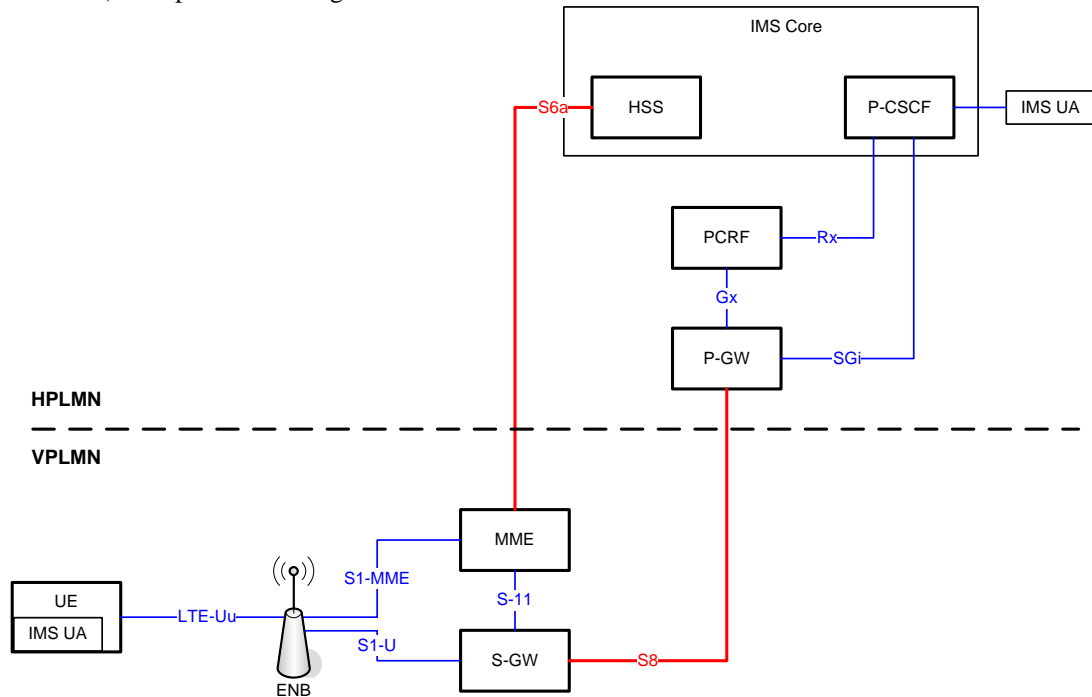


Figure 5 - Scenario 2a Roaming with home routed traffic.

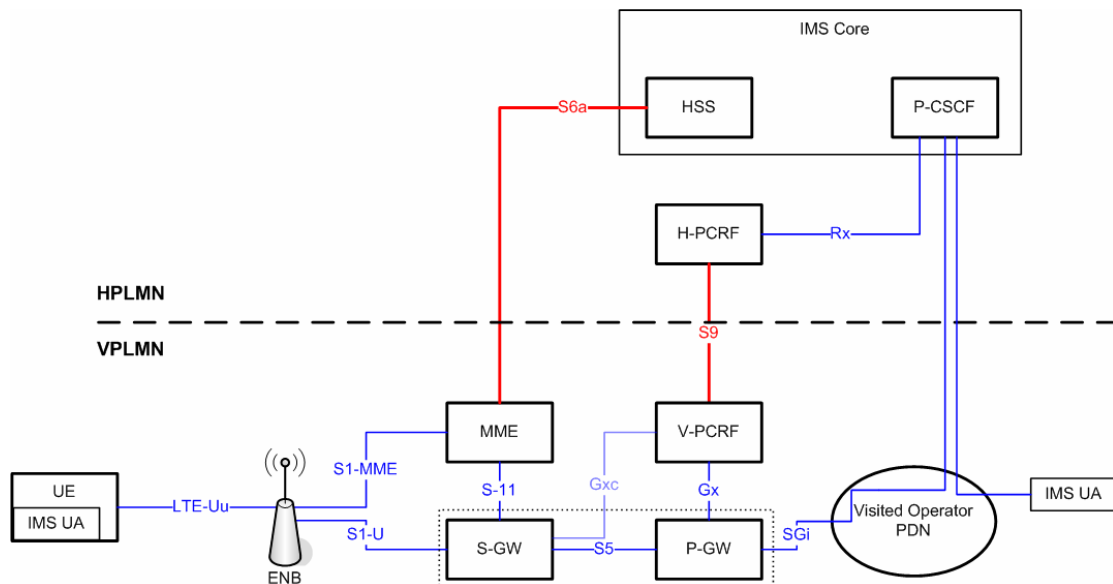


Figure 6 - Scenario 2b Roaming with local breakout (home operator application functions)

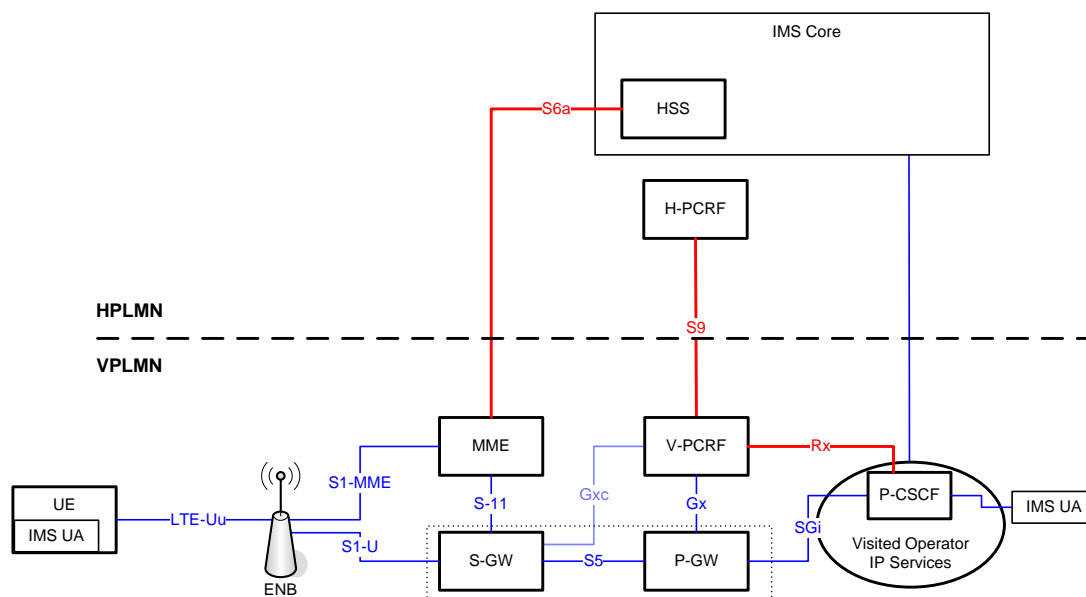


Figure 7 - Scenario 2c Roaming with local breakout (Visited Operator Application Functions / Visited P-CSCF Model)

2.2.1 Network Components

2.2.1.1 Scenario 2a

In the Visited Network

- One LTE UE (likely a data dongle on a laptop).
- One IMS UA to run on the LTE UE (likely a soft client on a laptop).
- One eNB
- One MME
- One S-GW

In the Home Network

- One P-GW
- One PCRF
- An IMS Core with the P-CSCF exposing the Rx interface and the HSS exposing the S6a interface.
- An IMS UA registered with the IMS Core.

2.2.1.2 Scenario 2b

In the Visited Network

- One LTE UE (likely a data dongle on a laptop).
- One IMS UA to run on the LTE UE (likely a soft client on a laptop).
- One eNB
- One MME
- One S-GW
- One P-GW
- One PCRF
- Visited IP network (router)

- An IMS UA registered with the IMS Core in the Home Network via the Visited IP network.

In the Home Network

- One PCRF
- An IMS Core with the P-CSCF exposing the Rx interface and the HSS exposing the S6a interface.

2.2.1.3 Scenario 2c

In the Visited Network

- One LTE UE (likely a data dongle on a laptop).
- One IMS UA to run on the LTE UE (likely a soft client on a laptop).
- One eNB
- One MME
- One S-GW
- One P-GW
- One PCRF
- Visited IP network (router)
- One P-CSCF (Visited P-CSCF model of IMS roaming)
- One IMS UA registered with the Home Network IMS core via the P-CSCF in the Visited Network (or directly with a P-CSCF in the Home Network IMS core).

In the Home Network

- One PCRF
- An IMS Core with the HSS exposing the S6a interface.
- An IMS UA registered with the IMS Core via the Visited IP network.

2.2.2 Protocols and Reference Points

The following reference points will be interoperated in this scenario.

Interface	Protocol	Sub-Scenarios
S6a	Diameter	2a, 2b, 2c
S8	GTPv2-C (control plane) / GTPv1-U (user plane) or PMIPv6.	2a
S9	Diameter	2a, 2b, 2c
Rx	Diameter	2c

2.2.3 Test Cases

- LTE UE Attach (IP-CAN Session Establishment)
- LTE UE Detach (IP-CAN Session Tear Down)
- IMS UA Registration (via LTE UE)
- IMS Session Establishment (from IMS UA on LTE UE)
- IMS Session Establishment (from IMS UA directly connected to IMS Core)
- IMS Session Termination (from IMS UA on LTE UE)
- IMS Session Termination (from IMS UA directly connected to IMS Core)

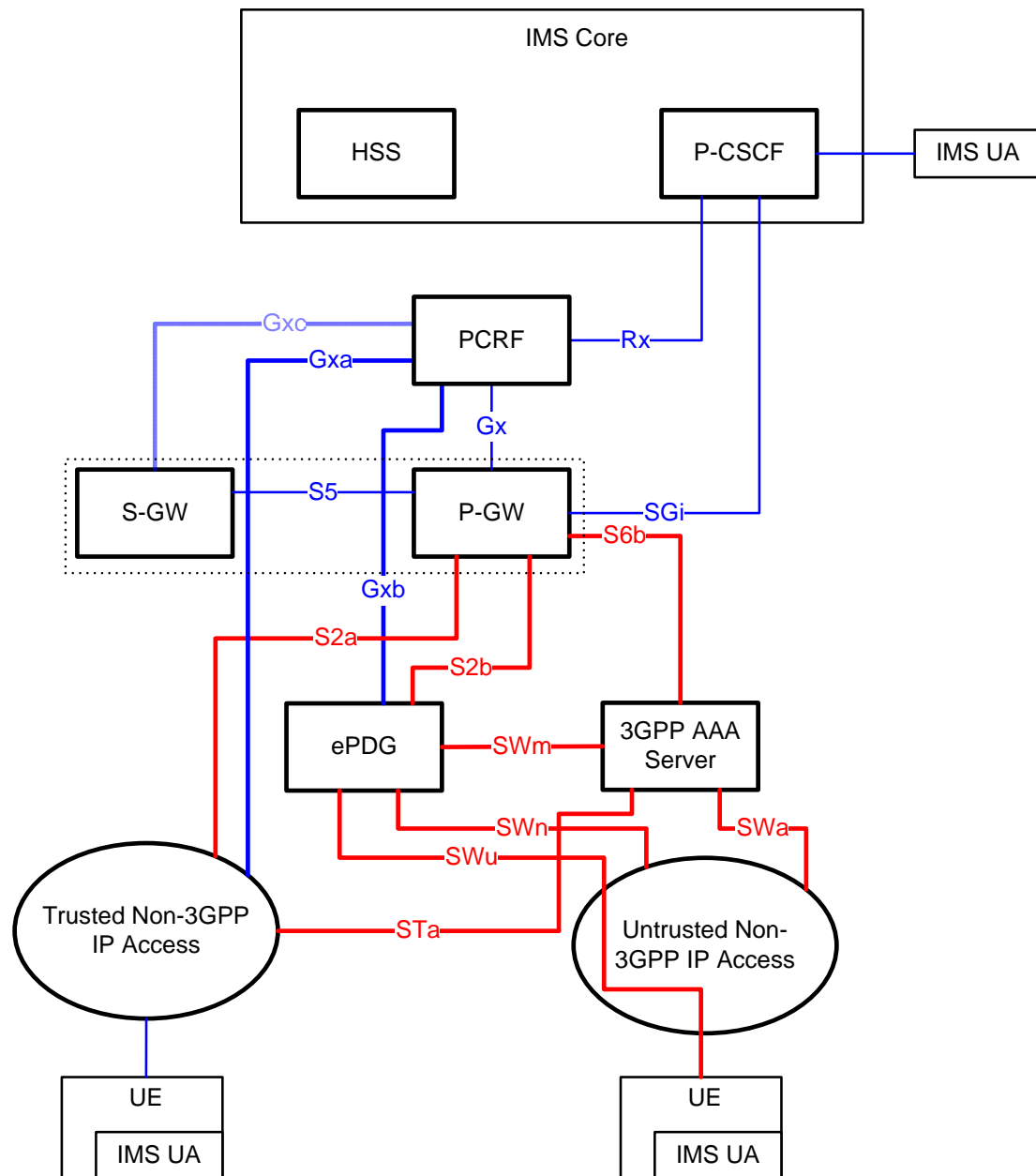


Figure 10 - Scenario 3c. Non-3G Access.

The next version of this document will include a scenario 3d showing CDMA2000 / 1xEV-DO Rev A access to the EPC.

2.3.1 Network Components

2.3.1.1 Scenario 3a

- One UTRAN / GERAN UE (likely a data dongle on a laptop).
- One IMS UA to run on the UTRAN / GERAN UE (likely a soft client on a laptop).
- UTRAN / GERAN access infrastructure.
- One S4 SGSN

- One MME
- One S-GW
- One P-GW
- One PCRF
- One IMS Core with the HSS exporting the S6a and S6d interfaces and a P-CSCF exporting the Rx interface.
- One IMS UA registered directly with the IMS Core

2.3.1.2 Scenario 3b

- One UTRAN / GERAN UE (likely a data dongle on a laptop).
- One IMS UA to run on the UTRAN / GERAN UE (likely a soft client on a laptop).
- UTRAN / GERAN access infrastructure.
- One SGSN (pre Rel 8)
- One MME
- One S-GW
- One P-GW
- One PCRF
- One IMS Core with the HSS exporting the S6a and Gr interfaces and a P-CSCF exporting the Rx interface.

2.3.1.3 Scenario 3c

- One S-GW
- One P-GW
- One ePDG (evolved Packet Data Gateway).
- One PCRF
- One 3GPP AAA Server.
- Trusted non-3GPP Access (could be any access type e.g. DSL).
- Untrusted non-3GPP Access (could be any access type e.g. DSL).
- UE + IMS UA for trusted access.
- UE + IMS UA for un-trusted access.
- One IMS Core with the a P-CSCF exporting the Rx interface.

2.3.2 Protocols and Reference Points

The following reference points will be interoperated in this scenario.

Interface	Protocol	Sub-Scenarios
S2a	PMIPv6	3c
S2b	PMIPv6	3c
S3	GTPv2-C	3a
S4	GTPv2-C (control plane) / GTPv1-U (user plane)	3a
S6b	Diameter.	3c
S12	GTPv1-U	3a
S6d	Diameter	3a
Gr	MAP	3b
Gn	GTPv1	3b
Gp	GTPv1	3b
STa	Diameter	3c
SWa	Diameter	3c
SWm	Diameter	3c
SWn	Unspecified	3c
SWu	Unspecified	3c

2.3.3 Test Cases

For all three sub-scenarios

- UE Attach (IP-CAN Session Establishment)
- UE Detach (IP-CAN Session Tear Down)
- IMS UA Registration (via UTRAN/GERAN UE)
- IMS Session Establishment (from IMS UA on UTRAN/GERAN UE)
- IMS Session Establishment (from IMS UA directly connected to IMS Core)
- IMS Session Termination (from IMS UA on UTRAN/GERAN UE)
- IMS Session Termination (from IMS UA directly connected to IMS Core)

2.4 Scenario 4 – Handovers

This scenario tests the different handover conditions both with registered terminals and with active sessions. There are two sub-test cases for this scenario, 4a in which an S4-SGSN is used and 4b in which an earlier version of the SGSN is used. The architectures for these scenarios are shown in the figures below.

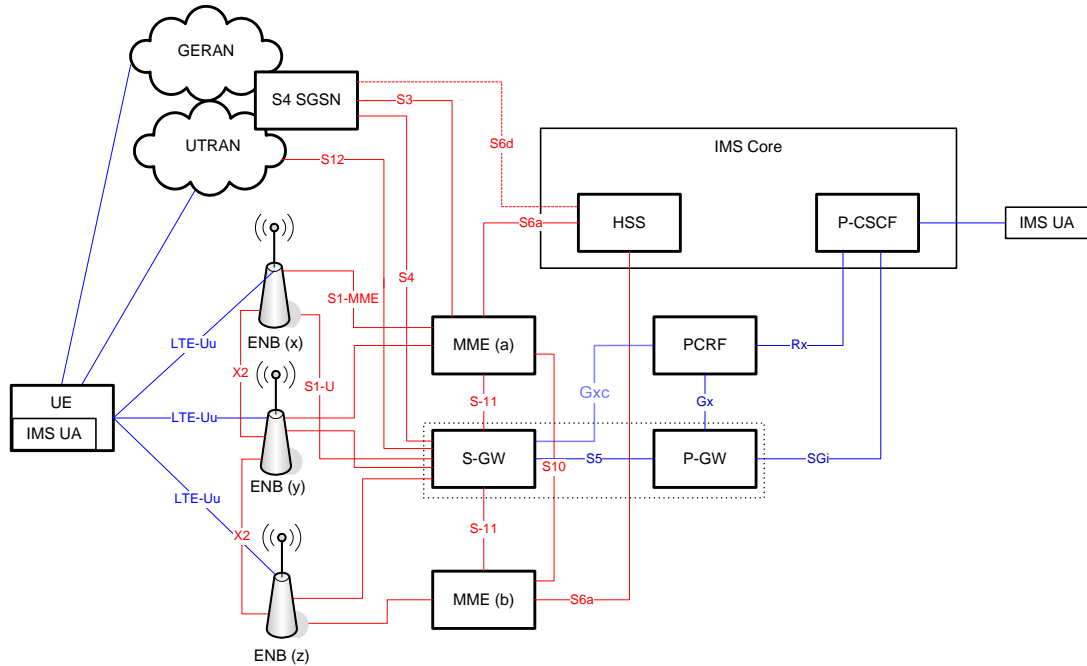


Figure 11 – Scenario 4a. Handovers with S4 SGSN

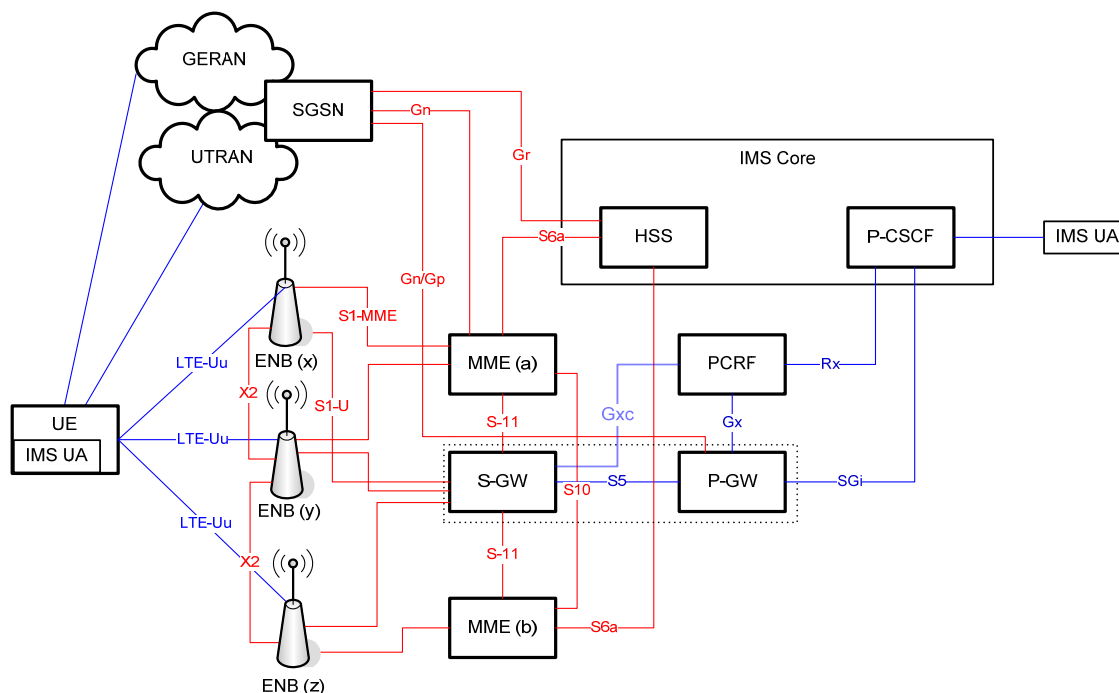


Figure 12 - Scenario 4b. Handovers with legacy SGSN

The next version of this document will include a scenario 4c for handover between CDMA2000 / 1xEV-DO Rev A and LTE.

2.4.1 Network Components

2.4.1.1 Scenario 4a

- One Multi-mode (LTE – UTRAN/GERAN) UE (likely a data dongle on a laptop).
- One IMS UA on the Multi-mode UE (likely a soft client on a laptop).
- Three eNB
- Two MME
- One SGW
- One S4 SGSN
- GERAN/UTRAN access infrastructure.
- One P-GW.
- One PCRF.
- One IMS Core with the HSS exposing the S6a and S6d interfaces and the P-CSCF exposing the Rx interface.
- One IMS UA directly registered to the IMS Core.

2.4.1.2 Scenario 4b

- One Multi-mode (LTE – UTRAN/GERAN) UE (likely a data dongle on a laptop).
- One IMS UA on the Multi-mode UE (likely a soft client on a laptop).
- Three eNB
- Two MME

- One SGW
- One SGSN (pre release 8).
- GERAN/UTRAN access infrastructure.
- One P-GW.
- One PCRF.
- One IMS Core with the HSS exposing the S6a and S6d interfaces and the P-CSCF exposing the Rx interface.
- One IMS UA directly registered to the IMS Core.

2.4.2 Protocols and Reference Points

Interface	Protocol	Sub Scenarios
S1-MME	NAS	4a, 4b
S1-U	GTPv1-U	4a, 4b
X2	X2 AP (signalling) / GTPv1-U (user plane)	4a, 4b
S3	GTPv2-C	4a
S4	GTPv2-C (control plane) / GTPv1-U (user plane) or PMIPv6.	4a
S10	GTPv2-C	4a, 4b
S11	GTPv2-C	4a, 4b
S12	GTPv1-U	4a
S6a	Diameter	4a, 4b
S6d	Diameter	4a
Gn	GTP	4b
Gr	MAP	4b
Gp	GTP	4b

2.4.3 Test Cases

The handover scenarios will be tested both for registered terminals and with established (IMS) sessions.

Basic Attachment.

- The UE attaches to ENB (y) and hands over to ENB(x), the UE remains attached.
- The UE attaches to ENB(y) and hands over to ENB(z), moving from MME(a) to MME(b), the UE remains attached.
- The UE attaches to ENB(y) and hands over to ENB(z), moving from SGW(a) to SGW(b), the UE remains attached.
- The UE attaches to ENB (x) and hands over to UTRAN/GERAN, the UE remains attached.
- The UE attaches to UTRAN/GERAN and hands over to ENB(x), the UE remains attached.

IMS Registration.

- The UE attached to ENB (y) and the UA registers with the IMS Core. The UE hands over to ENB(x), the UA remains registered with the IMS Core.
- The UE attaches to ENB(y) and the UA registers with the IMS Core. The UE hands over to ENB(z), moving from MME(a) to MME(b), the UA remains registered with the IMS Core.
- The UE attaches to ENB(y) and the UA registers with the IMS Core. The UE hands over to ENB(z), moving from SGW(a) to SGW(b), the UA remains registered with the IMS Core.

- The UE attaches to ENB (x) and the UA registers with the IMS Core. The UE hands over to UTRAN/GERAN, the UA remains registered with the IMS Core.
- The UE attaches to UTRAN/GERAN and the UA registers with the IMS Core. The UE hands over to ENB(x), the UA remains registered with the IMS Core.

IMS Session.

- The UE attaches to ENB (y) , the UA registers with the IMS Core and establishes a session with the directly connected IMS UA. The UE hands over to ENB(x), the IMS session remains active.
- The UE attaches to ENB(y), the UA registers with the IMS Core and establishes a session with the directly connected IMS UA. The UE hands over to ENB(z), moving from MME(a) to MME(b), the IMS session remains active.
- The UE attaches to ENB(y), the UA registers with the IMS Core and establishes a session with the directly connected IMS UA. The UE hands over to ENB(z), moving from SGW(a) to SGW(b), the IMS session remains active.
- The UE attaches to ENB (x), the UA registers with the IMS Core and establishes a session with the directly connected IMS UA. The UE hands over to UTRAN/GERAN, the IMS session remains active.
- The UE attaches to UTRAN/GERAN, the UA registers with the IMS Core and establishes a session with the directly connected IMS UA. The UE hands over to ENB(x), the IMS session remains active.

3 Interface Specifications

The following is a set of references for the interfaces tested in these scenarios.

3.1 S1-MME (eNB – MME)

3GPP TS 24.301(NAS)

3.2 S1-U (eNB-SGW)

3GPP TS 29.281 (GTPv1-U)

3.3 S2a

3GPP TS 29.275 (PMIPv6)

3.4 S2b

3GPP TS 29.275 (PMIPv6)

3.5 X2 (eNB – eNB)

Signaling 3GPP TS 36.423 (X2 Application Protocol).

User Plane 3GPP TS 29.281 (GTPv1-U)

3.6 S3 (S4 SGSN – MME)

3GPP TS 29.274 (GTPv2-C)

3.7 S4 (S4 SGSN – SGW)

Control Plane 3GPP TS 29.274 (GTPv2-C).

User Plane 3GPP TS 29.281 (GTPv1-U).

3.8 S5 (SGW-PGW)

User Plane 3GPP TS 29.281 (GTPv1-U)

Control Plane 3GPP TS 29.274 (GTPv2-C)

or

3GPP TS 29.275 (PMIPv6)

3.9 S6a (HSS – MME)

3GPP TS 29.272 (Diameter)

3.10 S6b (PGW – 3GPP AAA)

3GPP TS 29.273 (Diameter)

3.11 S6d (HSS – S4 SGSN)

3GPP TS 29.273 (Diameter)

3.12 S8 (SGW – PGW)

User Plane 3GPP TS 29.281 (GTPv1-U)

Control Plane 3GPP TS 29.274 (GTPv2-C)

or

3GPP TS 29.275 (PMIPv6)

3.13 S9 (PCRF – PCRF)

3GPP TS 29.215 (Diameter).

3.14 S10 (MME – MME)

3GPP TS 29.274 (GTPv2-C).

3.15 S11 (MME – SGW)

3GPP TS 29.274 (GTPv2-C)

3.16 S12 (UTRAN – SGW)

3GPP TS 29.281 (GTPv1-U, utilized for direct tunnel model).

3.17 Gx (PCRF – PGW)

3GPP TS 29.212 (Diameter).

3.18 Gxc (PCRF-SGW)

3GPP TS 29.212 (Diameter)

3.19 Rx (PCRF - IP Application [P-CSCF for IMS])

3GPP TS 29.214 (Diameter).

3.20 Gr (SGSN – HSS)

3GPP TS 29.002 (MAP)

3.21 Gn (SGSN – MME / SGSN – PGW)

3GPP TS 29.060 (GTP)

3.22 Gp (SGSN – PGW)

3GPP TS 29.060 (GTP)

3.23 STa

3GPP TS 29.273 (Diameter)

3.24 SWa

3GPP TS 29.273 (Diameter)

3.25 SWm

3GPP TS 29.273 (Diameter)