RCS VoLTE Interoperability Event 2012

Multivendor testing in global
RCS/VoLTE Networks

Host Sites

Operator Sponsor

Event Sponsor

Silver Sponsor

Participants

Abstract

This white paper provides a summary of the RCS (Rich Communications Suite) VoLTE (Voice over LTE) Interoperability event 2012 which took place from September 24th – October 12th 2012. The event was jointly organised by the Multi-Service Forum (MSF), European Telecoms Standards Institute (ETSI) and the GSM Association (GSMA).

In order to facilitate the deployment of NGN technology, it is important to identify and understand the level of interoperability of commercially available equipment for both backwards incompatibility and non-compliancy, from both a Vendors' perspective and an Operators' perspective. Vendors' gain from the benefit of identifying issues and improving products to become more commercially viable, and Operators need to be aware of any backwards incompatibility aspects to take into account for vendor selection and deployment strategy. Public multi-vendor interoperability events such as the RCS VoLTE IOT event help to detect and fix these issues at an early stage

The event builds on the success of previous MSF VoLTE Interoperability events and ETSI IMS Plugtests. It reflects the industry's drive to continue to deliver major carrier driven events that benefit all its members in their quest to keep pace with an ever faster moving industry.

The RCS VoLTE Interoperability event 2012 focused on validating key network and application interfaces to ensure multi-vendor deployment strategies for LTE/EPC/IMS technology for RCS and VoLTE. The main objective was to validate the work of the GSMA as part of its global VoLTE initiative, focusing on the validation of a number of GSMA's technical recommendations, namely PRD IR.92 ("IMS Profile for Voice and SMS"), PRD IR.65 ("IMS Roaming and Interworking Guidelines"), PRD IR.88 ("LTE Roaming Guidelines"), PRD IR.90 ("RCS Interworking Guidelines"), PRD IR.67 ("DNS/ENUM Guidelines for Service Providers and GRX/IPX"), PRD IR.58 ("IMS Profile for Voice over HSPA") and PRD IR.94 ("IMS Profile for Conversation Video Service"). Different versions of RCS Services and Client Specifications were valid to be tested in the event, namely "RCS-e – Advanced Communications: Services and Client Specification: Version 1.2.1" and "Rich Communication Suite 5.0 Advanced Communications: Services and Client Specification".

The GSMA technical recommendations are based on The Third Generation Partnership Project (3GPP) standards. 3GPP introduced the Evolved Packet Core to support LTE access with the IMS core network providing the application layer for which services (e.g. voice) may be deployed. The EPC and IMS core interact with the Policy and Charging Control (PCC) framework to enable Quality of Service for the bearers supporting voice and RCS services.

ETSI, as one of the partners of the Third Generation Partnership Project (3GPP), has played a key role towards the deployment of IMS via its Technical Committee dedicated to IMS Network Testing: TC INT.

RCS VoLTE IOT 2012 Test Plans were developed and sourced from each of the partner organisations:-

- ETSI contributed to with the following TC INT Test Specifications: TS 186 011 "IMS Network to Network Interface Interoperability", TS 102 901 "IMS Network to Network Interface Interoperability for RCS" and TS 103 029 "IMS & EPC Interoperability".
- GSMA contributed with a sub-set of its RCS IOT RCS-e v1.2 test cases.
- MSF contributed the VoLTE test cases.

The event was conducted in two host sites at the Sintesio facility in Kranj, Slovenia and the China Mobile Research Institute Laboratory in Beijing, China. Telekom Slovenia was a joint host at the Sintesio site.

The event demonstrated that the GSMA technical recommendations, based on the 3GPP specifications, for providing end to end communications services based on IMS infrastructure were mature and interoperable.

Highlights of the event included:-

- Multi-vendor interoperability of UEs/clients, network infrastructure and services.
- Full IP interconnect between the two host sites via IPX was demonstrated,
- VoLTE and multimedia (voice/video) calls demonstrated together with multi-media telephony services as well as configuration of these services,
- Voice and video calls were established with the appropriate QOS (quality of service) utilizing the policy framework. DIAMETER Routing Agents (DRAs) successfully provided the capability to simplify the routing within the PLMN and between PLMNs when subscribers were roaming. The usage of DRA's greatly reduced network connections and were also shown to provide interworking functionality.
- RCS services were demonstrated

In parallel with the IOT, a workshop on the topic "Next Generation Services: RCS, VoLTE and beyond" was organized by ETSI. The workshop covered a good range of presentations and raised a spectrum of issues, from device clients, provisioning, media management and integration to network interconnections. With positive results out of the event, the general conclusion is that RCS and VoLTE are now well on their way to mass implementation with a good basis of clear standards, interoperability guidelines and carriers' cooperation.

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EXECUTIVE SUMMARY

INTRODUCTION

The RCS VoLTE Interoperability Event 2012 was designed to test standards compliance of Long Term Evolution (LTE) and IMS network scenarios in support of the provision of Rich Communication Suite (RCS) and Voice over LTE (VoLTE). Such network scenarios are of interest to major Service Providers, and the event is intended to gauge vendor support for this technology. This event builds on the previous MSF VoLTE Interoperability Event and ETSI IMS Plugtests. It seeks to validate a number of GSMA technical recommendations, namely:

- RCS-e – Advanced Communications: Services and Client Specification: Version 1.2.1
- Rich Communication Suite 5.0 Advanced Communications: Services and Client Specification
- PRD IR.65 - IMS Roaming and Interworking Guidelines,
- PRD IR.88 - LTE Roaming Guidelines,
- PRD IR.92 - IMS Profile for Voice and SMS,
- PRD IR.90 – RCS Interworking Guidelines,
- PRD IR.67 – DNS/ENUM Guidelines for Service Providers and GRX/IPX,
- PRD IR.58 – IMS Profile for Voice over HSPA,
- PRD IR.94 – IMS Profile for Conversation Video Service.

Interoperability testing was conducted in 2 labs; the Sintesio facility in Kranj and the CMCC Research Lab in Beijing. The two labs were interconnected via an IPX. Conducting the tests in two interconnected labs made it possible to test more vendor combinations, and also allowed realistic testing of important roaming and interconnect scenarios.

A total of 210 test cases were written across 2 test scenarios:

- RCS VoLTE in a single/home network,
- RCS VoLTE for Roaming & Interconnect.

During the event, there was also a background activity to perform SIP / DIAMETER conformance criteria checking on the trace files generated during the RCS VoLTE scenarios and validating a number of ETSI Interoperability Test Specifications.

Finally, an inter-RAT call transfer from LTE/IMS to GERAN/MSC Server was demonstrated.

ARCHITECTURE

The RCS VoLTE architecture allows users to connect to the network via the LTE high-speed wireless access and access voice, video and RCS services provided by MultiMedia Telephony and RCS Application Servers on an IMS framework. This way, access to the applications and services requested by today's sophisticated users, benefits from the necessary Quality of Service management and mobility functions.

The basic RCS VoLTE architecture is shown in Figure 1 below:

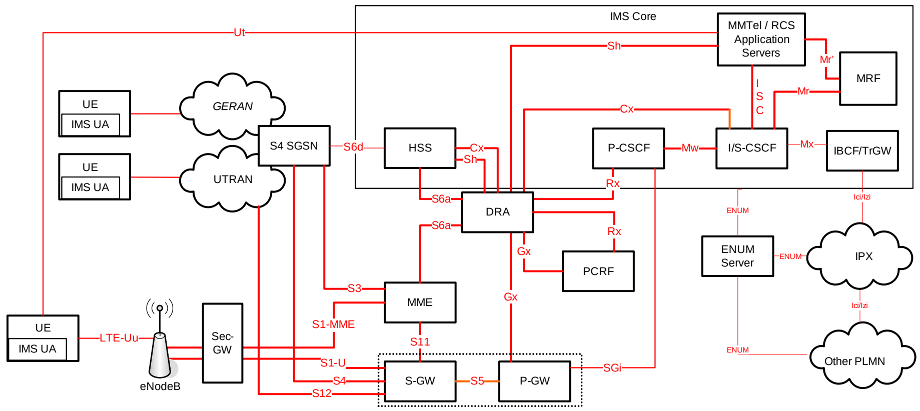

FIGURE 1 – BASIC RCS VOLTE ARCHITECTURE

NOTE: The Gm interface (UE to P-CSCF) is a focus for testing although not explicitly shown in the above figure.

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.

- **eNodeB.** The evolved RAN (E-UTRAN) consists of a single node, the eNodeB 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 S-GW (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. The S-GW and P-GW functions could 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 P-GW 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. The S-GW and P-GW functions could 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 (P-GW 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 and IMS core during UE attach and IMS registration.

- **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.

- **P-CSCF (Proxy Call Session Control Function).** The P-CSCF is the initial point of contact for session signaling for the IMS-enabled VoLTE UE. The P-CSCF behaves as a SIP proxy by forwarding SIP messages between the UE and the IMS Core Network, maintains the security associations between itself and the VoLTE UE, and incorporates the Application Function aspect of PCC to enable binding of the IMS session with the bearer for applying dynamic policy and receiving notifications of bearer level events.

- **I/S-CSCF (Interrogating/Serving Call Session Control Function).** The I-CSCF is the contact point within an operator's network for all connections destined to a user of that network. On IMS Registration, it interrogates the HSS to determine which suitable S-CSCF to route the request for registration. For Mobile Terminating calls, it interrogates the HSS to determine which S-CSCF the user is registered on.

The S-CSCF provides session set-up, session tear-down, session control and routing functions. It generates records for billing purposes for all sessions under its control, and invokes applications in the Application Servers. The S-CSCF acts as SIP registrar for VoLTE UE's that the HSS and I-CSCF assign to it. It queries the HSS for the applicable subscriber profiles and handles calls involving these end points once they have been registered. The S-CSCF uses subscription information to determine the appropriate onward routing for calls originating through it.

- **MMTel AS (Multimedia Telephony Application Server).** The MMTel AS is an IMS Application Server providing support for multimedia telephony services as defined by 3GPP e.g. supplementary service functionality.

- **MRF (Media Resource Function).** The MRF is a common media resource function, for use by IMS Application Servers and I/S-CSCFs, to provide media plane processing independent of application types. Eg. The MRF provides multimedia transcoding, video share/calling, multiparty multimedia conferencing, network announcements/tones, interactive voice/video services, etc. under the control of IMS Application Servers (MMtel AS or RCS Video Servers) as well as basic media processing functions to CSCFs. The control plane interfaces to MRFs are defined by the 3GPP references Mr, Mr', and Cr interfaces (SIP/SDP and XML encoded media service requests) while the media plane interfaces to MRFs are defined by 3GPP reference Mb for RTP/RTCP and MSRP multimedia transport.

- **IBCF/TrGW (Interconnection Border Control Function / Transition Gateway).** The IBCF/TrGW is responsible for the control/media plan at the network interconnect point to other PLMNs.

- **RCS ASs.** The RCS Application Servers provide support for RCS related services and comprise the following elements :-
  - Presence Server & XDM Server,
  - IM / Chat Server,
  - Video Share Application Server.
  - File Transfer,
  - Image Transfer

- **Sec-GW (Security Gateway).** The Sec-GW is used to originate and terminate secure associations between the eNodeB and the Evolved Packet Core network. IPsec tunnels are established with pre-shared security keys, which can take a number of different formats. IPsec tunnels enforce traffic encryption, for added protection, according to the parameters exchanged between the two parties during tunnel setup. This enables secure communications between the eNodeB and EPC across the S1-MME, S1-U and X2 interfaces.

- **DRA (Diameter Routing Agent).** The Diameter Routing Agent defined by 3GPP and GSMA, is a new network element that controls Diameter signalling, enabling the seamless communication and control of information between network elements within LTE or IMS networks and across LTE network borders. A DRA reduces the mesh of Diameter connections that negatively impacts network performance, capacity and management. For roaming cases, the DRA may also act as a DEA (Diameter Edge Agent).

- **ENUM Server**. This element provides a database functionality to enable translation of E164 numbers to domain names to enable message routing of IMS sessions. In the above figure, a single ENUM Server is shown that is accessible from either PLMN as well as IPX.

- **IPX.** This is the IP-Exchange transit network providing an interconnect capability between PLMNs.

Key Objectives

It is vital that operators have confidence in the multi-vendor interoperability of LTE and IMS components as a solid basis for RCS VoLTE before volume deployment can begin. Demonstrating this capability in action was a key overarching objective of the RCS VoLTE Interoperability Event 2012. The following equipment types (and associated vendor instances) participated in the event:

- In Slovenia, the equipment types included LTE UE (1), Voice Client (2), RCS Client (1), eNodeB (1), EPC (MME/S-GW/PGW) (1), PCRF (1), HSS (1), IMS Core (I/S-CSCF) (2), P-CSCF (3), MRF (1), MMTEL AS (2), RCS Chat Server (1), RCS Video Server (1), DRA (1), IBCF (2), ENUM (1),IPX (1) and monitoring equipment (1).

- In China, the equipment types included LTE UE (1), Voice Client (1), eNodeB (1), EPC (MME/S-GW/PGW) (1), PCRF (1), HSS (1), IMS Core (I/S-CSCF) (1), P-CSCF (1), MMTEL AS (2), DRA (2), IBCF (1), ENUM (1), IPX (1) and monitoring equipment (1).

NB – there was no Security GW in the event.

NB – In some cases, a single vendor brought multiple instances of a given equipment to facilitate additional parallel testing configurations.

In addition, the RCS VoLTE Interoperability Event 2012 was designed to:

- Validate the maturity of LTE network interfaces to enable multi-vendor support.
- Demonstrate that an LTE network can manage session control with an applied Quality of Service for default and dedicated bearers for voice, video telephony and RCS services.
- Validate the maturity of IMS network interfaces to enable multi-vendor support,
- Demonstrate the support for user roaming between different networks.
- Validate VoLTE, MMTel and RCS services for both home registered and roaming UEs,
- Validate VoLTE, MMTel and RCS services over interconnected IMS networks,
- Demonstrate the use of DRAs to simplify DIAMETER routing within the PLMN and between PLMNs when subscribers were roaming.
- Demonstrate the use of an IPX to provide interconnection between several PLMNs,
- Demonstrate the use of ENUM to enable inter-domain call routing.

Key Statistics

The RCS VoLTE Interoperability Event 2012 was held from September 24th to October 12th 2012 at two host sites; China Mobile Research Institute Laboratory in Beijing, China and the Sintesio facility in Kranj, Slovenia.

Over 50 network components from 12 participating companies were tested by 51 test engineers using approximately 1200 pages of test plans during this 3 week event.

The two test scenarios incorporated a total of 210 test cases. Of the 210 defined tests, a total of 48 were executed of which 46 tests were successfully completed and 2 failed. Overall, across both host sites, a total of 98 test cases were recorded in the event recording tool. In those cases where defined tests were not run, it was due to a combination of lab configuration limitations, equipment limitations or lack of time. Appendix A gives a detailed summary of the test results.

Key Results

- Multi-vendor interoperability of UE, eNodeB, EPC, IMS Core, AS, DRA and PCC.
- Interaction with service layer (e.g. IMS) was successfully demonstrated, with binding of Quality of Service to EPC bearers utilising Policy and Charging Control (PCC), providing relevant QoS for signalling and voice/video/RCS Services on the default bearer and dedicated bearers respectively.
- Voice calls established using dedicated bearer (QCI=1),
- Usage of a number of services was demonstrated via MMTEL AS.
- Voice / Video calls established using dedicated bearers (QCI=1 & QCI=2), inclusive of video being added/removed to/from an existing voice session.
- GTP is stable. As in the previous VoLTE IOT event in 2011, there were no issues with GTP,
- There were very few issues with DIAMETER, which was observed to be much more stable than in the previous VoLTE IOT event in 2011. The use of a DRA reduced connections and simplified Diameter message routing. DRAs were also shown to provide interworking between different transport layer protocols and DIAMETER application implementations.
- MMTEL Service configuration via Ut was demonstrated for a number of services.
- Transcoding, transrating and DTMF collection demonstrated via MMTEL AS and MRF.
- RCS Chat & FT (File Transfer) were demonstrated,
- Voice calls over a network interconnect were demonstrated via an IPX with SIP/RTP traversing the IPX Gateway and the IBCF/TrGWs in each PLMN.
- DIAMETER message routing was demonstrated for remote attachment of a roaming UE where the DIAMETER messaging traversed the DRA in the IPX and the DEAs in each PLMN.
- IMS (VoLTE and RCS) soft clients interworked with a number of 3rd party LTE data dongles for LTE Attach and, additionally, with different IMS Core Network and MMTel/RCS AS to provide IMS services to the end user.
- Commercial test tools used provided uncompromising visibility to all End2End procedures allowing rapid analysis.

INTRODUCTION

The RCS VoLTE Interoperability Event 2012 test environment was based on:

1. Proving multivendor interoperability of RCS VoLTE Architecture for single/home network and Roaming & Interconnect scenarios;
2. QoS control as an essential underpinning for services using PCC architecture and binding to the application layer in IMS;
3. Proving VoLTE and Video Telephony, including MMTel services via EPC and IMS, as well as interaction with the PCC architecture;
4. Proving RCS services via LTE and IMS, including interaction with the PCC architecture;
5. Roaming between LTE capable networks, including the proving of VoLTE, Video Telephony (MMTel) and RCS Services for the roaming UE;
6. Proving VoLTE, Video Telephony (MMTel) and RCS Services via the interconnect between IMS networks over an IPX;
7. Proving interaction with an ENUM Server for inter-domain call routing between IMS networks via an IPX.

Operators and Equipment Vendors that participate in Interoperability Events such as RCS VoLTE 2012 learn how multivendor next-generation products and networks will interoperate in the real world. This insight translates into a number of benefits:-

- For vendors, a reduced time to market for deployment of interoperable solutions and decreased costs and resources to resolve interoperability issues as well as an opportunity to demonstrate their competence in a given technology.
- For Operators, a better understanding of the maturity of a technology and an insight into "best in class" products.
- For the industry as a whole, a thoroughly evaluated architectural framework for cooperatively designing end-to-end networking solutions consistent with real world deployment scenarios.

In addition, publishing the results of the RCS VoLTE Interoperability Event 2012 provides valuable feedback to the industry in general, including specific feedback to the Standards Development Organizations (SDOs) when issues are encountered in the tested standards. This leads to improved protocol documentation through clarifications and / or corrections of errors.

This white paper is organized into three parts and six appendices:

Part I, describes the planning of the RCS VoLTE Interoperability Event 2012.

- Part II explains how the three-week event was run,

- Part III presents the key results obtained from the RCS VoLTE Interoperability 2012 Event.-

Appendix A provides details on the main test scenarios;

Appendix B describes additional testing during the event;

Appendix C highlights the interfaces that were tested,

Appendix D provides a brief resume of the organisers,

Appendix E provides a brief resume of the hosts,

Appendix F provides a brief resume of the participating companies.

Part I: Participants and Planning

The RCS VoLTE Interoperability Event 2012 was organised by a joint Task Force comprising members from the three partner organisations of MSF, ETSI and GSMA. Its goal was to test the current capabilities of LTE and IMS products operating in real world Service Provider environments. In particular, the event focussed on validating RCS and VoLTE services (Rich Communications Suite and Voice over LTE) based upon GSMA technical recommendations utilizing 3GPP LTE access technology. The Task Force developed a number of testing scenarios to validate core network interfaces to ensure multi-vendor deployment strategies for RCS VoLTE.

This testing allowed vendors to improve their products, Service Providers to accelerate their service deployment strategies, and any standards shortfalls to be highlighted to the appropriate SDO's.

The event comprised 3 weeks of testing preceded by a mandatory 1 week set-up and involved two lab sites interconnected via an IPX network, 12 participant companies, 51 engineers, 55 network components and 1200 pages of test plans.

Planning for the RCS VoLTE Interoperability Event 2012 began in November 2011 by identifying scenarios and tests for the event. The scope of the event is defined in the Testing Scenarios document which is publicly available at the event web site http://www.msforum.org/interoperability/RCSVoLTE.shtml. A total of 5 scenarios were initially defined :_

- RCS VoLTE in a single/home network,
- RCS VoLTE for Roaming & Interconnect,
- non-LTE access to EPC,
- Handover (intra-LTE and LTE <->2G/3G) and
- Priority Call Handover (LTE/IMS <-> Other RAN/CS).

Each of the 5 main scenarios included a number of sub-scenarios. Test plans were developed for all of the identified sub-scenarios and were sourced from each of the partner organisations.

During the event planning, it became clear that commercial equipment was unlikely to be available with the functionality required for all test scenarios. In addition, a test case survey was conducted among registered participants to identify their main point of interest in the test scenarios. Considering that there were a large number of test cases to be run given the planned timescale, the effort was focussed on the highest priority scenarios and the numbers of tests to be run in those scenarios reduced and prioritized to a more realistic overall total. This White Paper will therefore only detail the test scenarios that were executed during the RCS VoLTE Interoperability Event 2012.

Inter-lab testing was a key objective of the RCS VoLTE Interoperability Event 2012 with special attention put to provide inter-lab connectivity reflecting real world deployment scenarios (i.e. roaming and interconnect). In that regard, the two sites were interconnected via an intermediate IPX network with a limited number of network elements (i.e. DRA/IBCF) being exposed to it .

The initial activity focused on limiting (where possible) multi-vendor interoperability testing to those interfaces that reflect realistic deployment scenarios – i.e. it was intended to test configurations involving typical single vendor blocks of network elements and thereby limiting the number of observed interfaces to those between such blocks. The following equipment groups were identified:-

- UE,
- eNodeB
- EPC (MME, S-GW, P-GW),

- IMS core (P/I/S-CSCF, HSS),
- Application Servers,
- MRF
- Border Gateway elements (IBCF/TrGW and P-CSCF/IMS-AGW),

To facilitate participation, vendor equipment was permitted to be located remotely from the host site(s) subject to certain constraints (i.e. UE, eNodeB and monitoring equipment had to be located in the host lab and all relevant interfaces needed to be observable by the monitoring equipment). Remotely located kit was connected into the host site via VPNs based on the L2TP protocol.

Given the complexity of the event and to help prioritize demand, the event Task Force developed a test schedule to maximise inter-vendor testing and vendor participation for all sessions. In particular, due to the amount of equipment in the Sintesio site, it was decided to split the equipment between two logical halves which enabled maximum use of the available equipment at the Sintesio site (albeit within a single PLMN) and also defining a number of different such configurations in response to participant input to ensure that all permutations of multi-vendor testing were covered on the key interfaces.

Test traces were captured by the participating test tool company (JDSU). A proprietary ETSI sourced tool was used as a results recording tool.

In addition to test planning, host site selection, preparation and network interconnectivity needed to be completed before the start of testing. A number of Task Force meetings were held and a number of vendor participation calls kept the participants informed of the preparation progress and their needed inputs and activities. The 3 week event was preceded by a mandatory set-up week to ensure that the components were installed so that testing could commence on time in the event proper.

Host Sites

Sintesio and CMCC provided host sites in Slovenia and China respectively, thereby allowing the various tests and scenarios to be deployed in an environment that replicates a live global network. Testing was structured to enable both intra-site and inter-site testing and a test schedule was devised to enable structured testing to be performed at each site as well as co-ordinating the activity between the two sites for the roaming and interconnect scenarios.

The two host sites were:

SINTESIO TelekomSlovenije

Sintesio provided the host site at their facility in Kranj, Slovenia. This site was jointly hosted by Telekom Slovenia.

中国移动通信 CHINA MOBILE
移 动 信 息 专 家

China Mobile provided the host site at the CMCC Research Lab in Beijing, China.

PARTICIPANTS

Twelve companies participated in the RCS VoLTE Interoperability Event 2012.

The network equipment vendors were:

The network infrastructure providers of IPX and ENUM were:

The Network protocol and call-flow analysis test equipment vendor was:-

Tables 1 and 2 show the RCS VoLTE components provided by the vendor participants at the Sintesio and Beijing sites respectively. In some cases, elements are tagged as Telecom Slovenia or CMCC, indicating elements procured by those hosts and supplied by vendor companies not officially signed up to the event. Also note that Wi-Fi UEs, whilst not a focus of the event, were also permitted to be used in order to provide additional end points and increase the level of parallel testing.

Element Type	Vendor(s)		
LTE UE	Telecom Slovenia	D2Tech	
Wi-Fi UE	Radisys	D2Tech	
VoLTE Client	Radisys	D2Tech	
RCS Client		D2Tech	
eNodeB	Telekom Slovenia		
EPC (MME+SGW+PGW)	Cisco		
HSS		Iskratel	
PCRF	Tekelec		
P-CSCF/IMS-ALG	Cisco	Iskratel	Metaswitch
I/S-CSCF	Cisco	Iskratel	
MMTel AS	Genband	Iskratel	
MRF	Radisys	Iskratel	
RCS Video Share AS	Genband		
RCS IM/Chat Server	Genband		
IBCF-TrGW	Iskratel	Metaswitch	
DRA	Ulticom		
ENUM	Neustar		
IPX	Aicent		
Monitoring Equipment	JDSU		

Table 1. The RCS VoLTE Interoperability vendor participants in the Sintesio host-site in Kranj, Slovenia

	CMCC	
LTE UE	**CMCC**	
VoLTE Client	**CMCC**	
RCS Client		
eNodeB	**CMCC**	
EPC (MME+SGW+PGW)	**CMCC**	
HSS	**CMCC**	
PCRF	**CMCC**	**Tekelec**
P-CSCF/IMS-ALG	**Acme Packet**	
I/S-CSCF	**Acme Packet**	
MMTel AS	**CMCC**	**Genband**
MRF		
RCS Video Share AS		**Genband**
RCS IM/Chat Server		**Genband**
IBCF-TrGW	**Acme Packet**	
DRA	**Acme Packet**	**Tekelec**
ENUM	**Neustar**	
Monitoring Equipment	**JDSU**	

Table 2. The RCS VoLTE Interoperability vendor participants in the China Mobile host-site in Beijing, China.

OBSERVING COMPANIES / ORGANIZATIONS

Non-vendor companies were permitted to attend RCS VoLTE Interoperability Event 2012 as observers. Invitations were extended to MSF/ETSI/GSMA non-vendor members and partner fora/organizations. The following companies/organisations attended the event as observers:-

PART II: THE RCS VOLTE INTEROPERABILITY EVENT 2012 EXECUTION

The RCS VoLTE Interoperability Event 2012 involved two host sites, the Sintesio site in Kranj, Slovenia and the China Mobile Research Institute Laboratory site in Beijing, China. The two labs were interconnected via an IPX network. Both sites were connected to the IPX via an IP Security (IPSec) Virtual Private Network (VPN). All inter-site connectivity thus traversed the IPX and mimicked real-world deployment whereby PLMNs interconnect via an intermediate IPX network.

Vendor equipment was permitted to be located remotely from the host site(s) subject to certain constraints, namely that the UEs, eNodeBs and monitoring equipment needed to be located in the host lab. Remotely located equipment was connected into the host site via VPNs based on the L2TPv3 protocol. Traffic on remote observed interfaces was routed through a central observation point at the host sites in order to allow monitoring equipment to capture and analyze it.

Additional VPN connections enabled participants to have remote management access to any equipment located in the host site, thereby enabling vendors to complement onsite staff with personnel at home locations. The use of remotely located equipment enhanced flexibility and reduced participation costs for vendors.

Figure 6 presents a high-level diagram of the test environment used for the Sintesio/Telekom Slovenia host-site.

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Figure 6. Test environment used for the Sintesio/Telekom Slovenia host-site

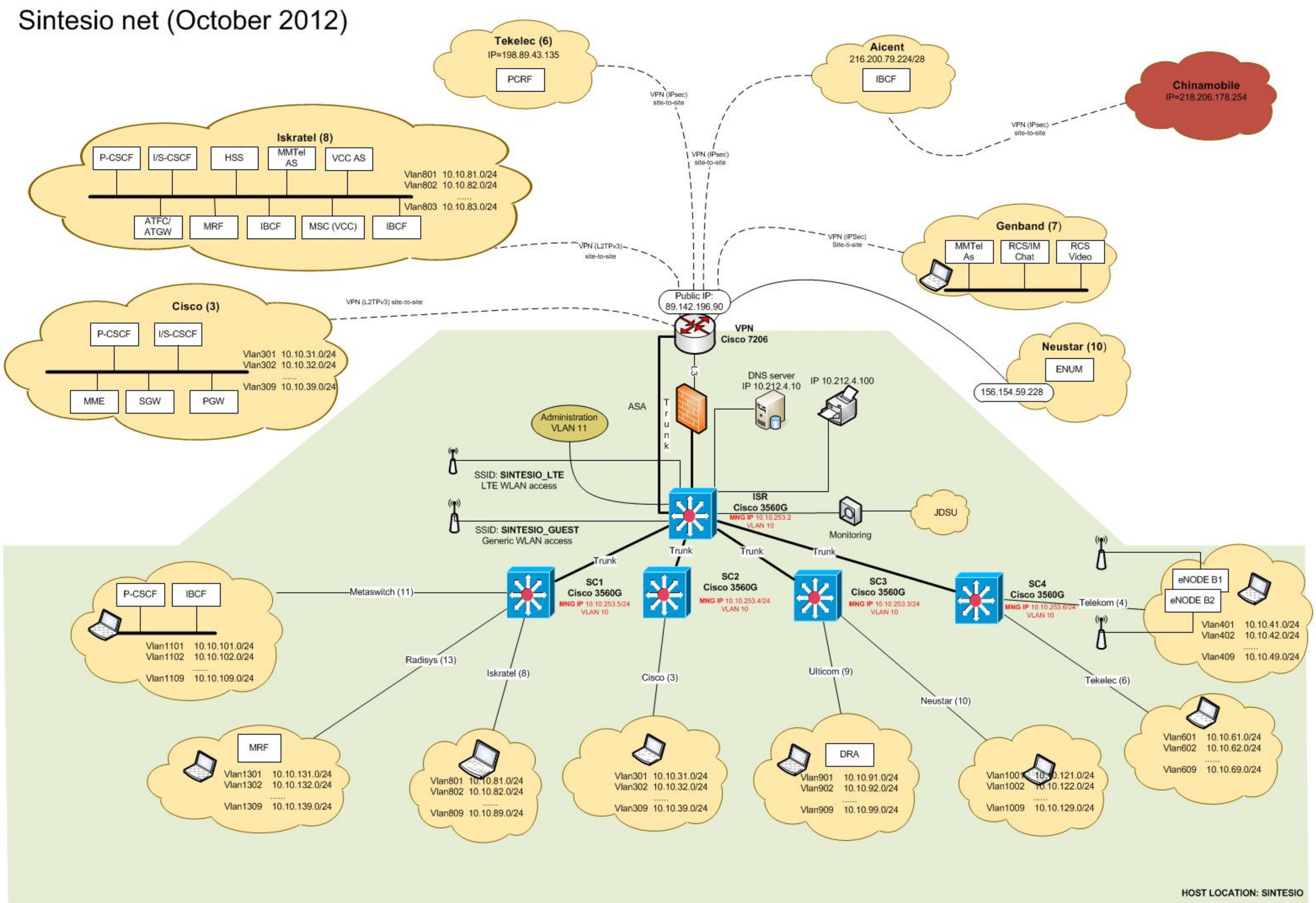
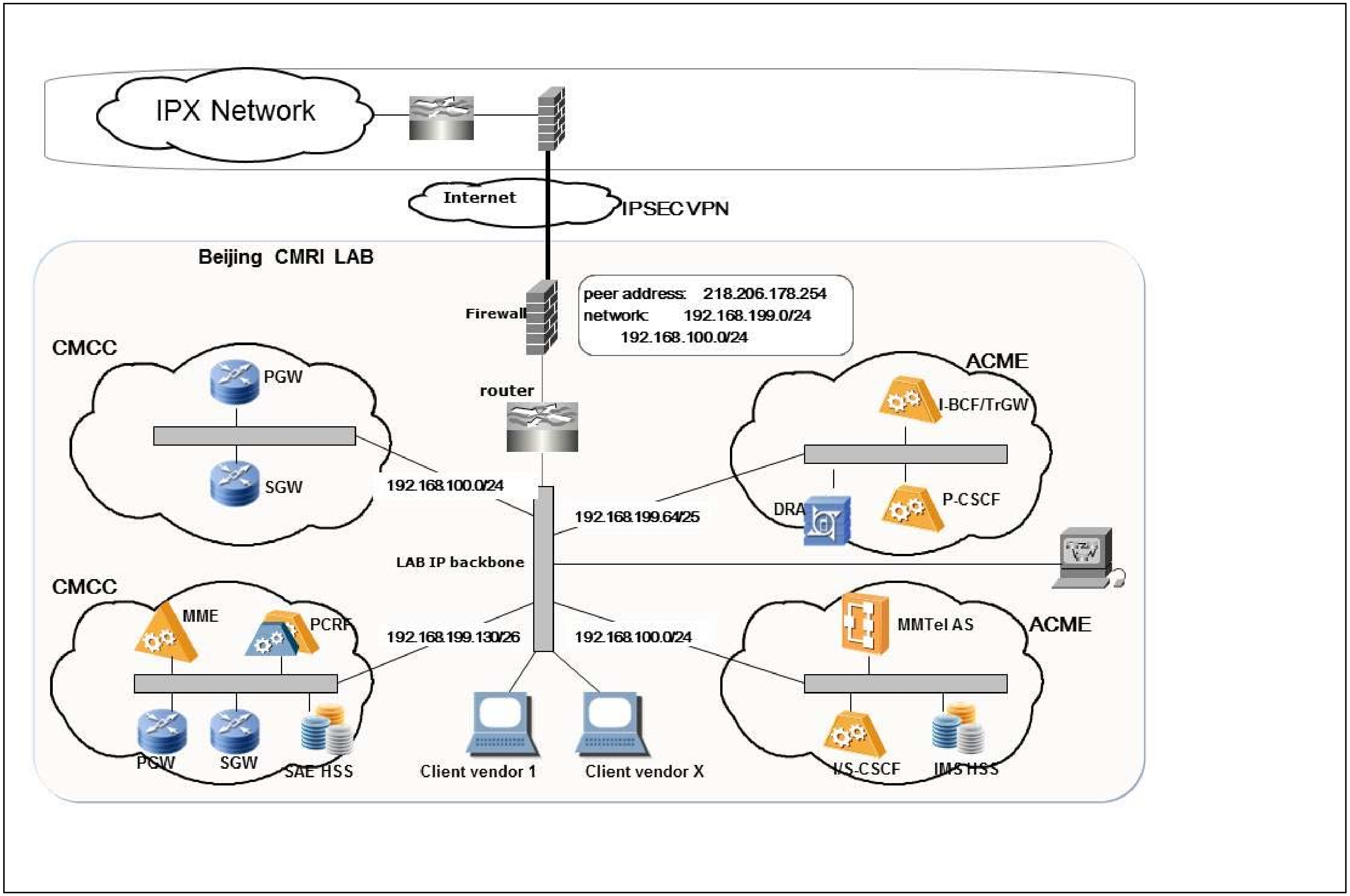


Figure 7 presents a high-level diagram of the test environment used for the China Mobile, Beijing host-site.



The Network Test Scenarios

Figure 8 is a high-level view of the EPC framework. The EPC network provides capabilities to attach multiple access technologies into a single core network infrastructure. These include LTE, legacy wireless access technologies (2G/3G), non-3GPP wireless access and fixed access. The common infrastructure provides a converged way to access a common service layer (e.g. Internet, IMS) and apply a consistent method of Quality of Service management and mobility management.

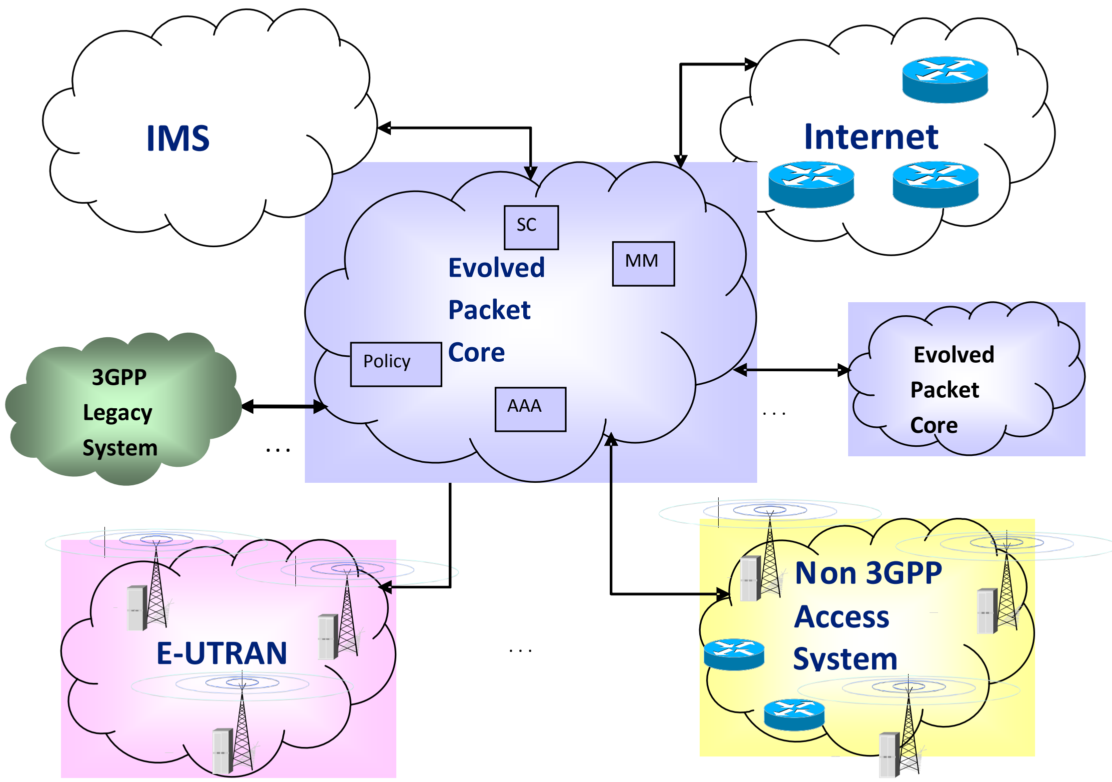


Figure 8. The Evolved Packet Core

The Evolved Packet Core can be accessed using all mainstream wireline and wireless access technologies, for connection to the application/service layer (e.g. IMS, Internet).

This high-level architecture formed the basis of the scenarios for the RCS VoLTE Interoperability Event 2012. These scenarios focused on RCS VoLTE in the following cases:-

Home/Single Network. In this scenario a single instance of the RCS VoLTE architecture was created using components from different vendors. Testing included attachment and detachment from the network, IPCAN session establishment, SIP registration (to IMS), SIP session establishment, interaction with IMS Multimedia Telephony, IMS Conversational Video Services and RCS services. This scenario focused on testing interoperability of the functionality as profiled by GSMA PRDs IR.92, IR.94, IR.90, IR.67 and the RCS Services and Client Specification.

The test cases for this scenario were extracted from ETSI TS 103 029 “IMS & EPC Interoperability”, a number of MSF Test Plans and a sub-set of GSMA test plans for RCS client accreditation.

Roaming & Interconnect. In this scenario, the local breakout model with visited P-CSCF and home operator applications was tested. The test set was the same as for the home/single network case, plus some roaming specific tests to demonstrate the transfer of Policy Rules between home/visited networks, the usage of Diameter Routing Agents, Session Border Controllers and use of ENUM. This scenario focused on testing interoperability of the functionality as profiled by GSMA PRDs IR.65, IR 88, IR.92, IR.94, IR.90, IR.67 and the RCS Services and Client Specification The test cases for this scenario were extracted from ETSI TS 186 011 "IMS Network to Network Interface Interoperability", TS 102 901 "IMS Network to Network Interface Interoperability for RCS" and a number of MSF Test Plans.

Outside of the two main scenarios, there were two additional testing activities:-

- a background activity to perform SIP / DIAMETER conformance criteria checking on the trace files generated during the RCS/VoLTE scenarios following ETSI Interoperability Test Specifications:

- an inter-RAT call transfer from LTE/IMS to GERAN/MSC Server was demonstrated.

The main scenarios are described in more detail in Appendix A and the additional testing activities are described in more detail in Appendix B.

TEST SCENARIO VALIDATION

JDSU

The JDSU Signaling Analyzer solution, in a multi-user setup, was used to validate the completed test scenarios at both the Sintesio and China Mobile Research Institute sites. This multi-user setup provided the participants of the Interoperability Event a real-time end to end view of the test scenarios as they were being executed.

The Signaling Analyzer provides full support for all the requirements outlined in the major GSMA technical recommendations for delivering Voice, Video services over LTE (V2oLTE) and Rich Communications Suite (RCS) services as specified in 5.0 release.

The Signaling Analyzer provided a number of key capabilities:-

- End to End EPC, Policy and Charging Control, IMS Core Network Sub-System, MMTel/RCS Application Servers Visibility
- Real-Time Multiple Interface end to end Call Session Correlation and Measurements
- Real-time control-plane and user-plane correlation
- Access to common data source (probe) with the ability to perform independent functions/operations
- LTE/SAE security - EPS real time NAS Encryption deciphering
- Generic file sharing of the test scenarios results (both in JDSU proprietary format and Wireshark .pcap format)

The Signaling Analyzer supports an extensive set of LTE/EPC/2G/3G/PCC/IMS Core network interfaces and is able to validate the outcome of the test cases in real-time. After the validation of each individual test scenario the trace file was saved for possible future reference and traceability.

TTCN-3 Automatic Conformance Review

ETSI has developed an automatic tool to check recorded traces on conformance towards the base standards. For this purpose recorded trace files were analyzed off-line in accordance with the conformance criteria defined in the test specifications. The test tool specifically implemented for this interoperability event is based on the standardized testing language TTCN-3 (Testing and Test Control Notation Version 3) and allowed automatic assignment of conformance test verdicts for message flows containing SIP and Diameter messages. The results have been filled into the test session reports by ETSI representatives that had been present at the event for the purpose of running the TTCN-3 tool.

PART III: RESULTS AND OBSERVATIONS

The event demonstrated that the GSMA technical recommendations, based on the 3GPP specifications, were mature and interoperable for the provision of VoLTE, Video Telephony and RCS services over LTE access technology. Multi-vendor interoperability of UE, eNodeB, EPC, IMS Core, AS, DRA and PCC was demonstrated.

The two host sites were successfully interconnected via an IPX. Visibility of the IPX was limited to the border elements – i.e. IBCF/TrGW and DRA. DIAMETER, SIP and RTP traffic was successfully routed between the host sites over the IPX.

VoLTE was also demonstrated for interconnect via an IPX network with the SIP/RTP traversing the IBCF/TrGW in each site and the IPX Gateway.

Third party registration of ASs was demonstrated.

MMTEL Service configuration and usage was demonstrated for VoLTE calls.

Transcoding, transrating and DTMF digit collection were demonstrated via an AS and MRF.

RCS FT (File Transfer) and RCS Chat were successfully demonstrated. However, these test cases did not use a dedicated bearer due to issues encountered on Rx by a P-CSCF.

Roaming was limited to the testing of Slovenian UEs roaming in the Beijing site. This was due to the availability of appropriate SIM cards in the Sintesio site. Whilst there were HSS configuration issues encountered during the attachment phase, the relevant S6a DIAMETER messages were correctly routed from the CMCC MME via local DRA via IPX DRA to the Sintesio DRA and onto the Sintesio HSS.

GTP was stable with no issues encountered.

The utilisation of Diameter Routing Agents provided optimisation of diameter routing within each core network/site and across the IPX between the two sites. Whilst most DRA clients supported SCTP, some only supported TCP in which case the DRA provided the necessary inter-working. Whilst some implementations were encountered that were not completely standards compliant, the DRA was able to modify/delete AVPs to enable interoperability in most cases. The net result was that DIAMETER was generally stable and caused much fewer problems than had been the case in the VoLTE IOT in 2011.

Interaction with the PCC/EPC was successfully demonstrated both for application binding to the default bearer on IMS registration and for the creation of dedicated bearers. Dedicated bearers were created with the appropriate QCI value for voice and video telephony sessions.

The approach of defining stable configurations and limiting testing to typical deployment groupings of single vendor network nodes (e.g. single vendor EPC), resulted in configuration problems being minimized. In any case, such issues are not seen as a problem for network deployments.

VoLTE soft clients interworked with a number of 3rd party LTE data dongles.

The ENUM Server was configured to support the allocated MSISDNs used in the event but no external ENUM queries were generated by IBCFs or IPX.

The Sh interface was not supported by all ASs.

Whilst the use of remotely located equipment facilitated participation, there was an impact on session set-up times and media quality due to the increased latency in the test network.

As in the VoLTE IOT event in 2011, the vast majority of implementations in this event were based on 3GPP Release 8.

RCS/VoLTE in a Single/Home Network:

In this scenario, intra-network testing utilised a single RCS VoLTE architecture created using components from different vendors. Testing included LTE attachment and detachment from the network, SIP registration/deregistration (to/from IMS), SIP voice session establishment, SIP multi-media session establishment, SIP session teardown, MMTel Service Configuration, MMTel Service usage and RCS services (both stand-alone and associated with a voice call) as specified by GSMA IR.90, IR.92, IR.94 and RCS services and client specification.

This test scenario demonstrated that VoLTE / Video Telephony calls and supplementary services, based on GSMA IR.92 and IR.94, are a viable solution for providing voice/video services for LTE access. Multi-vendor interoperability of UE, eNodeB, EPC, IMS Core, AS, DRA and PCC was demonstrated. Dedicated bearers with appropriate QCI were set up for voice and video telephony calls.

RCS File Transfer and RCS Chat were also demonstrated although with no dedicated bearer. The lack of a dedicated bearer was due to an Rx issue on one of the P-CSCFs.

MMTEL services were configured and used. Some of the ASs did not support the Sh interface.

Transcoding, transrating and DTMF collection was demonstrated via an AS and MRF. The DTMF collection was used to enable authentication of a priority call attempt and to set the SIP Resource Priority Header (RPH).

IMS Soft Clients interworked successfully with 3rd party LTE data dongles for LTE Attach and additionally with the IMS Core Network and MMTel AS to provide IMS services to the end user.

The use of a DRA simplified Diameter routing within the PLMN and reduced the number of required connections. DRA's were also shown to provide interworking between different transport layer protocols (i.e. SCTP to TCP) and also to be able to act as DIAMETER “firewalls”. Overall, DIAMETER was stable and caused very few issues.

In some cases, SIP fragmentation issues were encountered when the MTU exceeded 1500 bytes. These were resolved by a combination of reducing the offered codecs form the UE and /or use of TCP instead of UDP transport.

Issues with 3rd party registration of ASs were encountered due to IFCs, but these were all resolved. Subsequently, there were issues encountered on the SUB/NOTIFY exchange for the registration event package – but these were also subsequently resolved.

SIP syntax errors were encountered on some implementations for certain SIP headers. Related to this, it was noted that different implementations behaved differently on receipt of such syntax errors- i.e. some were relatively tolerant in some cases.

Appendix A provides more details on the test results.

Roaming & Interconnect:

The Roaming test scenario represents the test architecture where two subscribers of the same Operator, perform an end to end call whilst one subscriber is in the HPLMN and the other is roaming in a VPLMN. The roaming subscriber attaches in the visited network where local breakout is applied, a Visited P-CSCF and home IMS services as defined in GSMA IR.65 and IR.88.

The Interconnect test scenario is where two subscribers, of different operators, perform an end to end call whilst in their respective PLMN's as defined in GSMA IR.65.

Roaming

This test scenario was designed as an inter-site test with the subscriber roaming in a 'visited network'. The LTE UE, eNodeB, MME, SGW, PGW and V-PCRF were physically in the visited network whilst the H-PCRF and HSS were physically located in the Home Network. Whilst the IMS Core was configured in the home network, the P-CSCF was configured in the Visited Network. This roaming model aligns with GSMA specifications IR.65 and IR.88. Two variants of the Roaming scenario were tested to reflect test plans sourced from MSF & ETSI – both variants being equally valid.

The focus of these tests was to verify the interfaces between the H-PLMN and V-PLMN required for roaming with VoLTE/RCS. Specifically the utilisation of a DRA for routing Diameter messages between the MME in the visited network and the HSS in the home network with S6a and between the visited PCRF to home PCRF interaction across the S9 interface – both via IPX. Additional roaming aspects are the PCC interaction in the visited network (Rx and Gx interfaces) and the SIP interconnect between the P-CSCF in the visited network to the Session Border Controller in the home network (via IPX).

This scenario tests LTE attachment and detachment of the visiting UE as well as IMS registration, IMS session establishment & teardown MMTel Service Configuration, MMTel Service usage and RCS service usage; as specified in GSMA IR.90, IR.92, IR.94, IR.65, IR.88 and RCS services and client specification.

Due to a limitation of SIM cards, roaming was only able to be tested in one direction, namely for a Slovenian UE roaming in the Beijing lab. HSS configuration issues were encountered during the attachment phase, although the relevant S6a DIAMETER messages were correctly routed from the CMCC MME via local DRA via IPX DRA to the Sintesio DRA and onto the Sintesio HSS. Unfortunately, this issue was unable to be resolved in the time available. In the meantime, a simulator was also used to test the routing of SIP Register messages from the CMCC lab over IPX to the IMS Core and HSS in Sintesio. Once again, the underlying infrastructure successfully delivered the message but issues were encountered with the authentication which were not resolved during the event.

In summary, whilst the roaming scenario did not result in a successful attachment and registration, these were due to HSS configuration issues. On the positive side, the underlying RCS VoLTE roaming architecture was provided by a multi-vendor configuration and enabled DIAMETER and SIP messages to be passed from then V-PLMN to the H-PLMN via IPX. Therefore, the RCS VoLTE roaming architecture is a viable solution for providing voice, multi-media and RCS services for LTE access for a user whilst in a roaming network.

Appendix A provides more details on the test results.

Interconnect

This test scenario tests IMS session establishment (voice & multi-media), IMS session teardown plus MMTel Service Configuration, MMTel Service usage and RCS Service usage for LTE UEs registered in their respective home PLMNs and interacting across the Ici/Izi reference points. Compliance against GSMA PRD IR.65 and RCS services and client specification is tested.

This test scenario demonstrated that the VoLTE architecture is a viable solution for providing voice and RCS services for LTE access between users on different PLMN's. The setting consisted of equipment from different infrastructure vendors in each site being interconnected via IPX over the applicable 3GPP standardized interfaces.

The two host sites were successfully interconnected via an IPX and voice calls were successfully established with SIP/RTP messages traversing the IBCF/TrGW in each site and the intermediate IPX Gateway. MMTel services and video telephony were not tested due to a lack of time.

RCS tests were not able to be run due to there being no RCS client in the Beijing site.

Appendix A provides more details on the test results.

FUTURE WORK

Interest has been expressed on continuing work in this area by way of a future RCS VoLTE related Interoperability Event.

The focus of such an event may initially be on the test cases that were not able to be executed in this event. These are as follows:-

- RCS Presence
- ENUM Interaction
- Non-LTE Access via S4-SGSN
- Non-LTE Access via legacy SGSN
- 2G/3G PS (Packet Switched) handover via S4-SGSN
- 2G/3G PS (Packet Switched) handover via legacy SGSN
- Priority (MPS) Call Handover (LTE/IMS <-> Other RAN/CS)

In addition, there are additional potential features that could also be part of a future IOT event:-

- Further testing of RCS services aligned with the evolution of the RCS specifications.
- RCS for enterprise networks,
- Quality measurements (MOS score, jitter, latency etc) for voice, video and real time services,
- SRVCC,
- Emergency Call,
- LTE-Wi-Fi interworking.

The timeframe of any future IOT event would be dependent on availability of UEs and network nodes supporting the required functionality as well as Service Provider interest in seeing such functionality tested in a multi-vendor environment.

Appendix A: The Test Scenarios

This appendix provides a detailed description of each of the test scenarios and presents the test results on a per-lab, per-scenario basis. When presenting the results, the following category types are defined to define the results of the test cases in the RCS VoLTE Interoperability Event:-

- **Passed –** Test case was scheduled to be run and Passed the criteria defined within the Test Plan
- **Failed –** Test case was scheduled to be run and Failed the criteria defined within the Test Plan
- **Not Run –** Test Case was scheduled to be run, however due to lack of time this was not possible
- **N/A –** Test Case was identified to be not applicable to be scheduled (e.g. duplication of test case functionality)
- **Restricted –** Test Case was scheduled to be run, however due to issues with configuration or other limitations (UE and equipment restrictions) it was not possible.

RCS VoLTE in a Home/Single Network

This test scenario demonstrated the attachment and detachment from the network, IP-CAN session establishment, SIP registration (to IMS), SIP voice session establishment/termination, SIP Multi-Media session establishment/teardown, invocation/configuration of MMTel Services and RCS Services (both stand-alone and in combination with a voice session). .

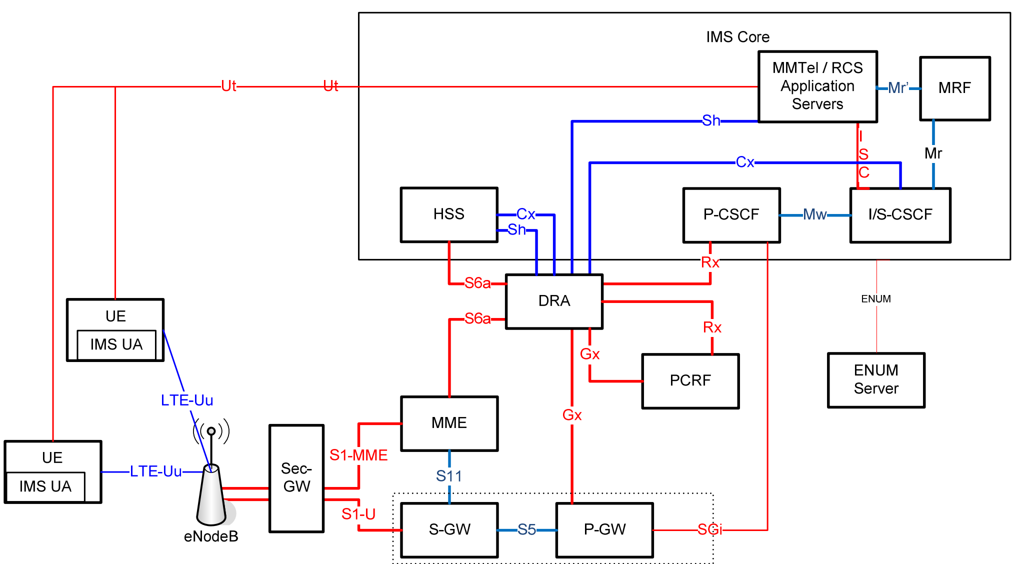


Figure 9 Scenario 1 - RCS VoLTE in a Home/Single Network.

NOTE: The Gm interface (UE to P-CSCF) is a focus for testing although not shown in the above figure.

The network architecture for VoLTE Basic Interoperability is shown in Figure 5 above. The interfaces for which interoperability were tested are shown in red (i.e. S1-MME, S1-U, S5, S11, S6a, Gx, Rx, Gm, Mw, ISC, and Ut).

Test Objectives

1. To demonstrate the ability to perform UE Attach (IP-CAN Session Establishment) and UE Detach (IP-CAN Session Tear Down). This covers inter-working between eNodeB-EPC, between the EPC elements, MME-HSS and P-GW-PCRF for creation of a default bearer for IMS Signalling.

2. To demonstrate the ability to perform UE IMS Registration as a common basis for accessing IMS based voice/multi-media/RCS services.

3. To demonstrate IMS Voice Session Establishment, IMS Voice Session Termination as defined by GSMA IR.92. This covers inter-working between UE, IMS Core Network, MMTel AS and PCC for creation of a dedicated bearer for voice.

4. To demonstrate IMS multi-media (voice/video) Session Establishment, IMS multi-media Session Termination as defined by GSMA IR.94. This covers inter-working between UE, IMS Core Network, MMTel AS and PCC for creation of dedicated bearers for voice/video.

5. To demonstrate the ability to perform MMTel Service Configuration over the Ut reference point for an attached UE.

6. To demonstrate inter-working between the UE, IMS Core and IMS-AS for MMTel Service usage as defined by GSMA IR.92.

7. To demonstrate inter-working between the UE, IMS Core and RCS-ASs for RCS Service usage as defined by GSMA IR.90, including interaction with the PCC for creation of dedicated bearers for RCS services (e.g. file transfer).

8. To demonstrate the ability to provide an optimised solution for routing of Diameter messages within the core network utilising the DRA functionality.

Test Results and Observations

The Scenario 1 test plan included 4 sub-scenarios namely:-

- 1a - Attachment & IMS Registration,
- 1b - IMS voice session establishment/teardown and configuration/usage of MMTEL services,
- 1c- RCS Services (both stand-alone and in combination with a voice session).
- 1d - IMS multi-media session establishment/teardown and configuration/usage of MMTEL services,

There were a total of 102 defined test cases across the 4 sub-scenarios. Test case results were as follows:-

Of the tests that were run, they were sometimes run multiple times (e.g. parallel testing or change of configuration). The following table summarizes the Scenario 1 test coverage.

Scen.	No Run	Passed	N/A	Failed	Restricted	Total	Lab
1a	0	5	0	0	1	6	Kranj
	0	4	0	0	2		Beijing
1b	3	19	0	2	4	28	Kranj
	5	14	0	0	9		Beijing
1c	38	2	0	1	12	53	Kranj
	0	0	0	0	53		Beijing
1d	9	4	0	0	2	15	Kranj
	0	10	0	0	5		Beijing

Table 3. RCS/VoLTE Scenario 1 Test Results

The “No run” test cases were mostly due to lack of time to execute those test cases.

The “Restricted” test cases were due to missing functionality that prevented the test case to be executed and include a combination of lack of equipment (e.g. Presence Server), issues with handling SIP OPTIONS in the core and the maturity of the RCS client.

The “Failed” test cases were largely due to :-

- Failure of an IMS core to handle SIP OPTIONS message for RCS Capability Exchange,
- A HSS configuration issue for Call Forwarding Not Logged In,
- An IMS core issue resulting in a triggering response (408, 500, 503) not being received by the AS for Call Forwarding Not Reachable Service.

The Scenario 1 test results demonstrated that :-

- Multi-vendor interoperability of UE, eNodeB, EPC, IMS/MMTEL, RCS AS, DRA and PCC technology.
- VoLTE calls and supplementary services, based on GSMA IR.92, are a viable solution for providing voice services for LTE access.
- Multimedia (voice/video) calls, based on GSMA IR.94, were demonstrated. This included voice & video bearers established at the start of the session as well as the addition and deletion of a video bearer to / from an existing session. A number of MMTEL services were also demonstrated for multimedia calls.
- Dedicated bearers with appropriate QCI (1 for voice, 2 for video telephony) were established.
- Application binding to the default bearer was demonstrated at IMS registration.
- Ut configuration of a number of MMTEL services was demonstrated between the UE and HSS.

- RCS FT and RCS Chat were demonstrated. However, a dedicated bearer was not used for the MSRP/TCP sessions as there was an issue with the P-CSCF for those tests (see below).
- Transcoding, transrating and DTMF collection was demonstrated via an AS and MRF. The DTMF collection was used to enable authentication of a priority call attempt and to set the SIP Resource Priority Header (RPH).
- The IMS Soft Clients interworked successfully with the LTE data dongle for LTE Attach and additionally with the IMS Core Network and MMTel AS to provide IMS services to the end user.
- GTP protocol proved to be mature and stable with no issues identified.
- Diameter routing within the PLMN was greatly simplified by utilizing Diameter Routing Agents. DRA's were also shown to provide interworking between different transport layer protocols and to be able to act as a "DIAMETER firewall" to facilitate interoperability (e.g. changing or deleting AVPs). DIAMETER was generally very stable.

Several issues were encountered during the test execution of Scenario 1:

- PCC Issues
  - On Rx interfaces, one P-CSCF was not compliant.
  - Some AVPs were incorrectly present or incorrectly tagged as mandatory. The DRA largely fixed these issues by acting as a "DIAMETER firewall".
- IMS Issues
  - The Sh interface was not supported on all implementations of Application Servers. Instead, the user service information was set up/ stored locally on the AS.
  - The Ut interface was not supported on all MMTel AS's in order to provide supplementary service configuration. Note that this is mandatory within GSMA PRD IR.92.
  - Issues were encountered on 3rd Party Registration requests due to the IFCs being passed down from the HSS. These were resolved during the event.
  - RCS Capability Exchange failed due to an IMS core not transiting the SIP OPTIONs message. This was fixed during the event but time ran out before it could be re-tested.
  - SIP syntax errors on some headers were encountered and it was also noted that some implementations were more tolerant than others of these errors.
  - Issues with parsing SIP URIs was observed on some ASs.
  - Different P-CSCFs were observed to have different TFT (Traffic Flow Template) filter implementations in terms of strict/lenient definition of the source host/port .
- Transport Issues
  - SCTP was not supported all DRA clients. Instead, TCP was the transport protocol supported. The DRA provided transport layer interworking. It is noted that 3GPP Diameter interfaces are based on SCTP for the transport protocol.
  - Fragmentation issues were seen when the MTU size exceeded that specified by 3GPP for e.g. 1500 octets in the transport network. This was solved by reducing the size of the SIP INVITE's by e.g. reducing the number of codecs being offered and (as a more permanent solution) using TCP in place of UDP transport.

- There was some difficultly experienced when re-configuring the network components for testing the different multi-vendor configurations. However, this was minimized during the event due to configurations being mostly stable and unchanged and it is not seen as a major issue for network deployments.

RCS/VoLTE for Roaming & Interconnect

This test scenario demonstrated the following:-

For Roaming:-

- IP-CAN session establishment / dis-establishment,
- SIP registration (to IMS) when roaming,
- SIP voice session establishment/termination and configuration/usage of MMTel Services,
- RCS Services (both stand-alone and in combination with a voice session), and
- SIP Multi-Media session establishment/teardown and configuration/usage of MMTel Services.

For Interconnect :-

- SIP voice session establishment/termination and usage of MMTel Services,
- RCS Services (both stand-alone and in combination with a voice session),and
- SIP Multi-Media session establishment/teardown and usage of MMTel Services.

As in Scenario 1, this scenario was broken down into four similar sub-scenarios .In addition, 3 different configurations were defined of which 2 were related to roaming and one for interconnect. The reason for having 2 different roaming configurations was related to the roaming test plan documents that were written by MSF and ETSI respectively which were equally valid but covered different call configurations.

Further details are provided below.

Roaming

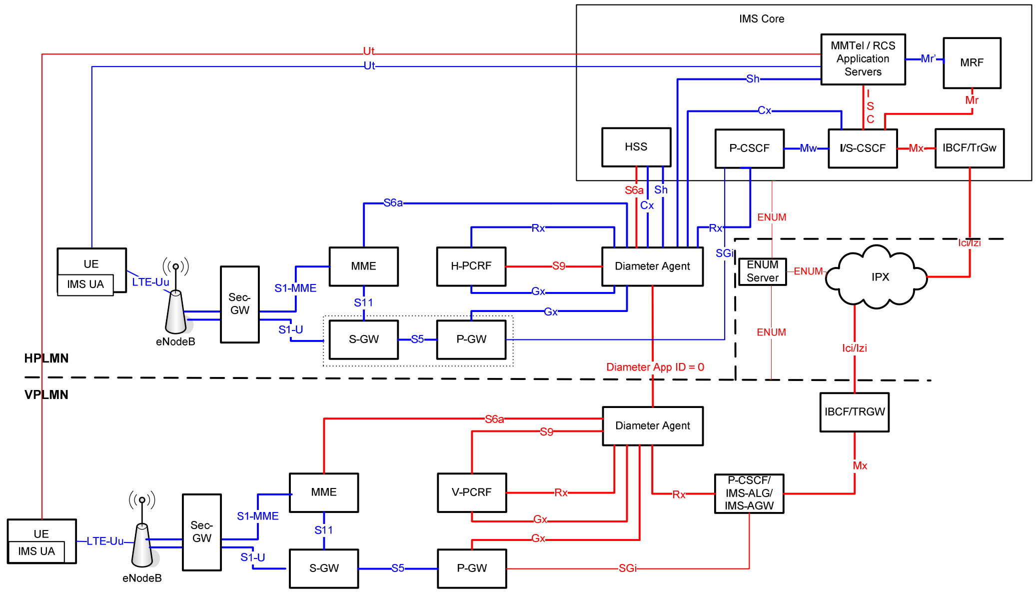


FIGURE 10. ***SCENARIO 2*** **- CONFIG I - ROAMING (SAME HOME PLMN)**

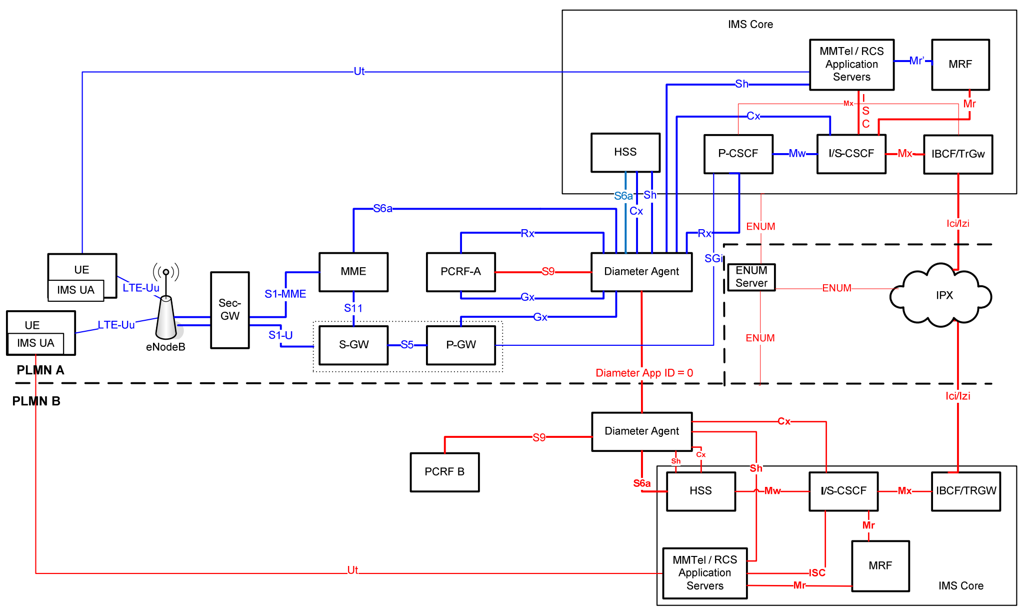


FIGURE 11 ***SCENARIO 2*** **- CONFIG II - ROAMING (DIFFERENT HOME PLMNS)**

NOTE: The Gm interface (UE to P-CSCF) is a focus for testing although not shown in the above figures.

The network architecture for the Roaming test scenario is shown in Figures 10 and 11 above. The interfaces for which interoperability were tested are shown in red (i.e. S6a, S9, Rx, Gx, Mw, Gm, Ut and ISC).

<u>Objectives</u>

1. To demonstrate roaming with the UE in a Visited Network (i.e. eNodeB, MME, S-GW, P-GW, V-PCRF and P-CSCF in the VPLMN and the HSS, H-PCRF and IMS core in the HPLMN). Specifically, the ability to perform interworking between the MME and PCRF in the VPLMN with the HSS and PCRF in the HPLMN respectively, and the PCRF and P-CSCF in the visited network by performing UE Attach (IP-CAN Session Establishment) and UE Detach (IP-CAN Session Tear Down) to validate the Diameter roaming interfaces and DRA functionality for S6a and S9 as defined by GSMA IR.88.

2. To demonstrate UE IMS Registration to the home PLMN whilst roaming in a visited network.

3. To demonstrate IMS Voice Session Establishment, IMS Voice Session Termination as defined by GSMA IR.92 whilst roaming in a visited network, including interaction with the PCC for creation of a dedicated bearer for voice.

4. To demonstrate IMS multi-media (voice/video) Session Establishment, IMS multi-media Session Termination as defined by GSMA IR.94 whilst roaming in a visited network, including interaction with the PCC for creation of dedicated bearers for voice/video.

5. To demonstrates the ability to perform MMTel Service Configuration over the Ut reference point for an attached UE, whilst roaming in a visited network..

6. To demonstrate inter-working between the UE, IMS Core and IMS-AS for MMTel Service usage as defined by GSMA IR.92, whilst roaming in a visited network.

7. To demonstrate inter-working between the UE, IMS Core and RCS-ASs for RCS Service usage as defined by GSMA IR.90, whilst roaming in a visited network, including interaction with the PCC for creation of dedicated bearers for RCS services (e.g. file transfer).

Testing Results and Observations

The Roaming test plan included 4 sub-scenarios (for Config I & II) namely:-

- 2a - Attachment & IMS Registration,
- 2b- IMS voice session establishment/teardown and configuration/usage of MMTEL services,
- 2c - RCS Services (both stand-alone and in combination with a voice session).
- 2d - IMS multi-media session establishment/teardown and configuration/usage of MMTEL services,

Due to SIM card issues, it was only possible to test roaming from the Beijing lab (i.e. Slovenian SIM in China).

There were a total of 85 defined test cases across the 4 sub-scenarios. Test case coverage was as follows:-

Scen.	No Run	Passed	N/A	Failed	Restricted	Total	Lab
2a	**0**	**0**	**0**	**1**	**7**	**8**	**Both**
2b	**0**	**0**	**0**	**0**	**22**	**22**	**Both**
2c	**0**	**0**	**0**	**0**	**41**	**41**	**Both**

2d	**0**	**0**	**0**	**0**	**14**	**14**	**Both**

Table 4. RCS/VoLTE Scenario 2 Roaming Test Results

The "No run" test cases were due to the failure to perform a network attach and subsequent running out of time which then restricted further test cases.

The "Restricted" test cases were essentially due to the attachment failure – although there was also some missing functionality that would have further restricted some tests in the event of a successful attachment (e.g. Presence Server).

The "Failed" test case was caused by a configuration issue in the HSS. When the roaming UE attached in the visited network, the AIR/AIA interchange over S6a worked but the subsequent ULR/ULA interchange failed.

Roaming demonstrated:-

- Despite the attachment failure, the S6a DIAMETER messages were successfully routed from the MME in the V-PLMN via the DRA in Beijing, the DRA in the IPX network, the DRA in Sintesio and onto the HSS in the H-PLMN. This showed that the underlying architecture and infrastructure was able to support the routing of DIAMETER messages between the 2 PLMNs. It is also noted that the IPX configuration was done in a matter of days due to that element joining the event during the second week.

Issues were encountered during the test execution of Roaming:

- Configuration issue on the HSS which cause the ULR/ULA exchange to fail.
- Whilst topology hiding is not a mandatory functionality, it was also tested as part of the IOT event for the roaming scenario. Diameter routing was performed on a hop-by-hop basis between DEA's on the edge of the Visited and Home Networks. It should be noted that the Origin-Host and the Origin Realm of the MME in the visited network were stored in the HSS, to enable messages initiated by the HSS to be routed to the correct MME in the visited network. If full topology hiding was implemented (Origin-Host masked across the interconnect by the visited DEA), the visited DEA would be required to perform a mapping of the received User-Name to the relevant MME in order to be able to route the incoming Diameter request from the HSS. This mapping is seen as an intensive functionality that is not recommended, furthermore additional security can be provided utilising IPSec is recommended..)

Interconnect

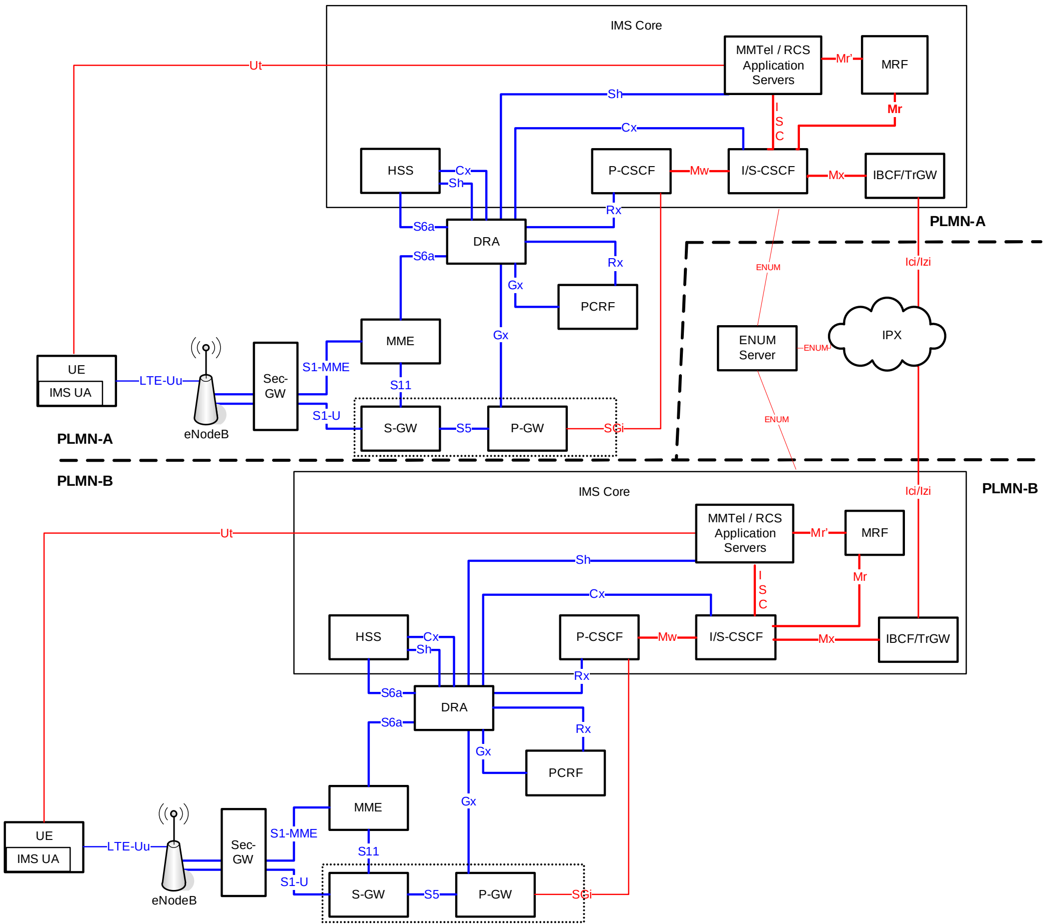


Figure 12. Scenario 2 Config III (Interconnect)

NOTE: The Gm interface (UE to P-CSCF) is a focus for testing although not shown in the above figure.

The network architecture for Interconnect is shown in Figure 11 above. The interfaces for which interoperability were tested are shown in red (i.e. Mw, Mx, Gm, Ut, ISC and Ici/Izi).

<u>Objectives</u>

1. To demonstrate interconnect between two UE's registered in their respective home PLMN's. Specifically, the ability to perform interworking between the IBCF/TrGW's in the respective PLMN's validating the Ici/Izi interfaces and GSMA IR.65.

2. To demonstrate IMS Voice Session Establishment and IMS Voice Session Termination as defined by GSMA IR.92 and IR.65, with voice sessions established with a subscriber in a different PLMN.

3. To demonstrate IMS Multi-media (voice/video) Session Establishment and IMS Multi-media Session Termination as defined by GSMA IR.94 and IR.65, with multi-media sessions established with a subscriber in a different PLMN.

4. To demonstrate the usage of MMTel Services as defined by GSMA IR.92, across a network-to-network-interconnect validating Ici/Izi.

5. To demonstrate the usage of RCS Services as defined by GSMA IR.90, across a network-to-network-interconnect validating Ici/Izi.

Testing Results and Observations

The Interconnect test plan included 3 sub-scenarios (for Config III) namely:-

- 2b- IMS voice session establishment/teardown and configuration/usage of MMTEL services,
- 2c - RCS Services (both stand-alone and in combination with a voice session).
- 2d - IMS multi-media session establishment/teardown and configuration/usage of MMTEL services,

There were a total of 64 defined test cases across the 3 sub-scenarios. Test case coverage was as follows:-

Scen.	**No Run**	**Passed**	**N/A**	**Failed**	**Restricted**	**Total**	**Lab**
2b	**8**	**2**	**0**	**0**	**1**	**11**	**Both**
2c	**0**	**0**	**0**	**0**	**41**	**41**	**Both**
2d	**11**	**0**	**0**	**0**	**1**	**12**	**Both**

Table5. RCS/VoLTE Scenario 2 Interconnect Test Results

The "No run" test cases were largely due to lack of time to execute those test cases.

The "Restricted" test cases were due to missing functionality that did not enable the test case to be executed (lack of equipment and/or missing functionality on an AS).

Interconnect demonstrated:-

- VoLTE calls, based on GSMA IR.92 and IR.65, are a viable solution for providing voice services for LTE access between Mobile Network Operators.
- The two host sites were successfully connected via an IPX with SIP/RTP traversing the IBCF/TrGW in each site and the intermediate IPX Gateway.
- Multi-vendor interoperability of IBCF/TrGW's and IPX was achieved. It is also noted that the IPX configuration was done in a matter of days due to that element joining the event during the second week.

Issues were encountered during the test execution of Interconnect:

- RCS tests were not run due to there being no RCS client in the Beijing lab.
- MMTel services were not tested due to a lack of time.
- Multi-media calls were not tested due to a lack of time.
- The external ENUM Server was not used by any of the IBCFs nor IPX.

Appendix B: Additional Testing

This appendix provides details of additional testing that was carried out (in addition to that described in Appendix A) in the RCS VoLTE Interoperability Event 2012.

Inter RAT Call Transfer

This test was related to the original Scenario 5b which demonstrated inter-RAT handover of a priority call between LTE and GERAN/UTRAN with a legacy MSC. The architecture for this test case is shown in figure 13 below:-

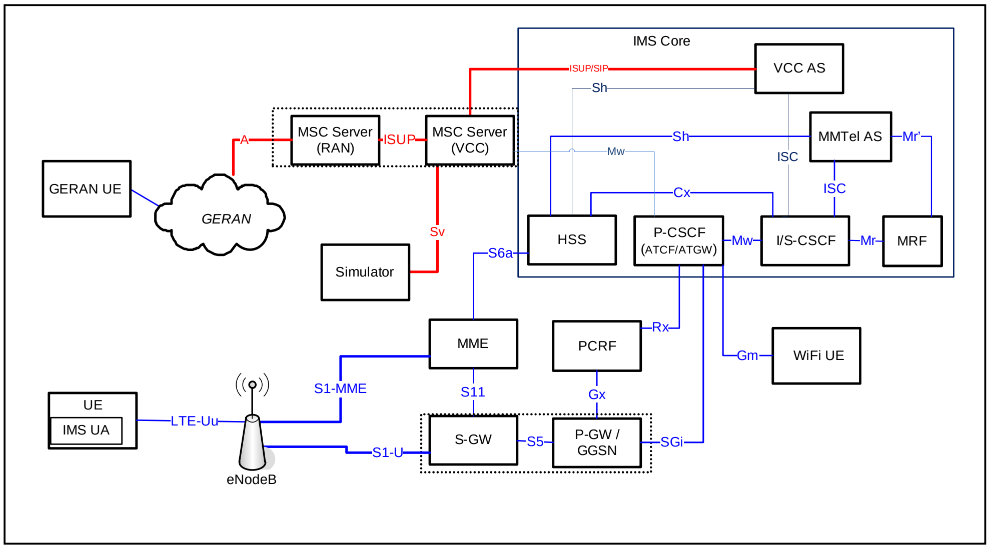


FIGURE 13–INTER-RAT CALL TRANSFER (LTE TO GERAN)

In the event proper, there was no MME supporting the required Sv reference point. Instead, a simulator was used. The remaining required elements for SRVCC were supplied as shown in table 6 below.

Element Type	Vendor
MSC Server (RAN)	Telekom Slovenia
GERAN	Telekom Slovenia
MSC Server (VCC)	Iskratel
ATCF/ATGW	Iskratel
VCC AS	Iskratel
I/S CSCF	Iskratel

Table 6. Inter-RAT Call Transfer Related Equipment

Initially, a call was established between a LTE UE and a Wi-Fi UE. The simulator then invoked the Sv reference point and the call was transferred to a real mobile phone attached to the MSC Server in the CS-domain and via GERAN. The final connection was between the Wi-Fi UE and the CS attached mobile phone, thus demonstrating transfer of a voice call between LTE and GERAN RATs.

Conformance Criteria Checking

This was a background activity during the event to perform SIP / DIAMETER conformance criteria checking on trace files captured while following the ETSI TS during the RCS VoLTE testing.

This activity builds on the work of ETSI STF450 to validate ETSI Conformance Test Suites TS 101 580-3 (Rx) & TS 101 601-3 (Gx). The STF developed tools to enable automatic conformance checking of traces taken during the IOT.

As a further activity, tools previously developed by other STFs were also used to enable automatic conformance checking of SIP messages.

Two STF experts were in attendance at the event to check conformance on :-

- SIP (Mw, Ici, ISC) for test cases in TS 186 011
- DIAMETER (Rx) for test cases in TS 103 029

Trace captures of the manual interoperability test executions were recorded independently. For the offline analysis of these trace captures two conformance criteria verification test tool instances were used in parallel. Each test tool instance was first configured with IP address and port information of all participating network equipment and user equipment. Then recorded trace captures were analyzed by executing the corresponding test case. The trace was accepted in case the final verdict was a pass. In the case of a fail verdict, each test execution was checked in order to determine if the reason for the failure was indeed caused by non-conformant behaviour or if it was caused by a problem in the test system. The test engineers used the same TTCN-3 test suite but executed it with two different commercial TTCN-3 tools.

Here, the “Pass” verdict has been given in cases that the analysis of the test execution trace shows that all components participating in a test fulfilled all of the verdict criteria specified in the test specification for that test. The “Fail” verdict has been given in cases that the analysis of the test execution trace show that at least one entity participating in a test violated one or more of the verdict criteria specified in the test specification for that test. The “Inconclusive” verdict was assigned in cases were some non-conformant condition had been observed which was either not part of the verdict criteria, e.g., the test never got to through its preamble, or could not be performed in its totality, e.g., a user equipment was not able to add and drop media streams to an existing SIP dialogue. So in both cases the verdict criteria cannot be checked – therefore the test is assigned an “Inconclusive” verdict.

The results showed several syntax errors in SIP headers exchanged between different equipment such as missing “<” and “>” characters in P-Associated-URI headers and the use of superfluous space characters at the end of SIP message lines. Those results were reported to the vendors involved.

Diameter signalling messages turned out to be syntactically correct and no coding errors caused the conformance review software to assign Fail-verdicts based on the analysis of the exchanged Diameter messages. Only the Diameter procedures that are relevant to the interoperability tests covering UE attachment, de-attachment, registration and deregistration were considered as the ETSI test specification TS 103 029 focuses on those procedures.

Appendix C: Interface References

LTE-Uu (UE – eNodeB)

3GPP TS 36.300 (E-UTRAN protocol)

S1-MME (UE – MME)

3GPP TS 24.301 (Non Access Stratum)

S1AP (eNodeB-MME)

3GPP TS 36.413 (S1 Application Protocol)

S1-U (eNodeB - S-GW)

3GPP TS 29.281 (GTPv1-U)

X2 (eNodeB – eNodeB)

Signaling 3GPP TS 36.423 (X2 Application Protocol).

User Plane 3GPP TS 29.281 (GTPv1-U)

S3 (S4 SGSN – MME)

3GPP TS 29.274 (GTPv2-C)

S4 (S4 SGSN – S-GW)

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

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

S5 (S-GW - P-GW)

User Plane 3GPP TS 29.281 (GTPv1-U)

Control Plane 3GPP TS 29.274 (GTPv2-C)

S6a (HSS – MME)

3GPP TS 29.272 (Diameter)

S6b (P-GW – 3GPP AAA)

3GPP TS 29.273 (Diameter)

S6d (HSS – S4 SGSN)

3GPP TS 29.272 (Diameter)

S8 (S-GW – P-GW)

User Plane 3GPP TS 29.281 (GTPv1-U)

Control Plane 3GPP TS 29.274 (GTPv2-C)

S9 (PCRF – PCRF)

3GPP TS 29.215 (Diameter).

S10 (MME – MME)

3GPP TS 29.274 (GTPv2-C).

S11 (MME – S-GW)

3GPP TS 29.274 (GTPv2-C)

S12 (UTRAN – S-GW)

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

Gx (PCRF – P-GW)

3GPP TS 29.212 (Diameter).

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

3GPP TS 29.214 (Diameter).

Gr (SGSN – HSS)

3GPP TS 29.002 (MAP)

Gn (SGSN – MME / SGSN – P-GW)

Control Plane 3GPP TS 29.060 (GTPv1-C)

User Plane 3GPP TS 29.281 (GTPv1-U)

Gm (UE – P-CSCF)

3GPP TS 24.229 (IMS SIP)

Mw (x-CSCF – x-CSCF)

3GPP TS 24.229 (IMS SIP)

Mx (x-CSCF – IBCF)

3GPP TS 24.229 (IMS SIP)

ISC (S-CSCF – AS)

3GPP TS 24.229 (IMS SIP)

Mr (CSCF – MRF)

3GPP TS 24.229 (IMS SIP)

Mr' (AS – MRF)

3GPP TS 24.229 (IMS SIP)

Cr (AS – MRF)

3GPP TS 24.229, 24.147, 27.247 (IMS SIP)

Ut (UE – AS)

3GPP TS 24.623 (XCAP)

SGi (EPC based PLMN and another packet data network)

3GPP TS 29.061 (IP)

ENUM

IETF RFC 6116 (ENUM)

S102 (MME – 1xCS IWS)

3GPP 29.277 (3GPP2 A21)

Ici (IBCF-IBCF)

3GPP 29.165 (IMS SIP)

Izi (TrGW-TrGW)

3GPP 29.165 (RTP/MSRP)

Mb (MRF - UE)

3GPP 23.002, 29.163 (RTP)

Sv (MME - MSC)

3GPP 29.280 (GTPv2-C)

Appendix D: The Organisers

About the MSF

The MultiService Forum (www.msforum.org) is a global association of service providers, system suppliers and test equipment vendors committed to developing and promoting open-architecture, multiservice Next Generation Networks. 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 of network elements, and encouraging input to appropriate national and international standards bodies.

About GSMA

The GSMA represents the interests of mobile operators worldwide. Spanning more than 220 countries, the GSMA unites nearly 800 of the world's mobile operators, as well as more than 200 companies in the broader mobile ecosystem, including handset makers, software companies, equipment providers, Internet companies, and media and entertainment organizations. The GSMA also produces industry-leading events such as the Mobile World Congress and Mobile Asia Expo. For more information, please visit the GSMA corporate website at www.gsma.com or Mobile World Live, the online portal for the mobile communications industry, at www.mobileworldlive.com.

About ETSI

ETSI produces globally-applicable standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, aeronautical, broadcast and internet technologies and is officially recognized by the European Union as a European Standards Organization. ETSI is an independent, not-for-profit association whose more than 700 member companies and organizations, drawn from 62 countries across 5 continents worldwide, determine its work programme and participate directly in its work. For more information please visit: www.etsi.org ETSI Plugtests are interoperability test events that cover a wide range of telecommunications, Internet, broadcasting and multimedia converging standards. For more information, please visit: www.etsi.org/plugtests

APPENDIX E: THE HOSTS

About CMCC

China Mobile Communications Corporation (" China Mobile "), established on April 20, 2000, is a GSM/TD-SCDMA/TD-LTE mobile communication operator with the world's largest network scale and almost 650 million customers. The business of China Mobile includes mobile voice, mobile data, enterprise, multimedia services and Internet global interworking. In addition China Mobile also provide various value-added services such as fax, data and IP telephony. In 2011, China Mobile ranked 87 on Fortune magazine's world top 500, with outstanding brand value among the forefront of the global telecom brands. It was also listed among the world's top 50 most innovative enterprises.

For more information, please visit: www.chainamobileltd.com.

About Sintesio

Sintesio is an open, not-for-profit foundation, co-founded by the European Telecommunications Standards Institute (ETSI), Slovenian Institute for Standardization (SIST), and Iskratel, a Slovenian telecommunication vendor. The aim of the Foundation is to promote open standards, interoperability in multi-vendor/multioperator environments, to support standardization efforts and to facilitate vendors' collaboration in the area of NGN telecommunication technologies and standardization. The Foundation set up the interoperability test lab, located in Kranj, Slovenia, with the purpose to test and validate interoperability of multi-vendor ICT products, as well as to validate the quality of open ICT standards, especially in the NGN and IMS domain. For more information, please visit: www.sintesio.org.

About Telekom Slovenia

The Telekom Slovenije Group is Slovenia`s leading and most advanced telecommunications operator in all key segments of the well-developed and highly competitive Slovenian market, delivering a comprehensive portfolio of fixed, mobile, Internet and state-of-the-art integrated telecommunication solutions via its modern proprietary network. Beyond its clear number of presence in Slovenia, Telekom Slovenije Group is present in several high growth markets in Southeast Europe, in Macedonia, Bosnia and Herzegovina, Kosovo and Albania. The Group's acquisition of 50% stake in Gibtelecom, Gibraltar's dominant fixed, mobile and Internet operator, represents further steps in the strategy to extend Telekom Slovenije's geographic footprint into selected Southeast European and Mediterranean markets.

APPENDIX F: THE PARTICIPANTS

This appendix provides a brief resume of the participant companies in the LTE Interoperability Event:-

Aicent

Serving more than three billion mobile users around the world, Aicent, Inc. is a leading IPX provider of data network services and solutions for global mobile operators. To enable interoperability between Aicent customers and other networks, Aicent operates one of the world's largest mobile IPX network exchanges connecting to over 200 operators, including nine of the world's ten largest. Through extensive peering arrangements and Diameter Routing Platforms located in NA, Europe, and Asia, Aicent's network reaches nearly all 3G and 4G LTE operators around the world. The company's global IPX network operates an integrated mobile messaging exchange, value added data roaming and global reach infrastructure services, including the world's first and largest multimedia messaging exchange, designed to help carriers maximize revenue opportunities. For more information, visit www.aicent.com.

Acme Packet

Acme Packet, the leader in session delivery network solutions, enables the trusted, first-class delivery of next-generation voice, video, data and unified communications services and applications across IP networks. Our Net-Net product family fulfills demanding security, service assurance and regulatory requirements in service provider, enterprise and contact center networks. Based in Bedford, Massachusetts, Acme Packet designs and manufactures its products primarily in the USA, selling them through over 309 reseller partners worldwide. More than 1,850 customers in 109 countries have deployed over 20,000 Acme Packet systems, including 89 of the top 100 service providers and 48 of the Fortune 100.

These solutions enable new services such as VoLTE, RCS and SIP trunking and reduce total cost of ownership with simplified IMS, Diameter routing and SIP interconnects. Acme Packet experience, expertise and solution portfolio enables service providers and enterprises to successfully transform their business and succeed in the all-IP world.

For more information visit www.acmepacket.com.

Cisco

The Next Generation of Mobile Voice and Video

Mobile operators have begun migrating to fourth-generation (4G) architectures based on the Long-Term Evolution (LTE) standard; including the Evolved Packet Core (EPC) architecture defined by the 3rd Generation Partnership Project (3GPP). To offer voice and video over an LTE-standard network, operators must migrate from circuit-switched voice to packet voice. This requires an architectural vision that supports voice and short message service (SMS) using the existing third-generation (3G) network, while providing a clear path to networks based on Session Initiation Protocol (SIP). This architecture enables newer services, such as optimized conversational video, presence, and instant messaging. Cisco's V^2oLTE solution meets 3GPP standards, provides seamless continuity within the IMS and circuit domains, and is cost-optimized for performance. Because video is the fastest-growing component of mobile traffic, Cisco has made video a central part of the initial IMS offering.

Voice and Video over LTE and IMS: One Voice Solution

Cisco provides a complete solution for V^2oLTE based on the 3GPP IMS solution meeting the One Voice Initiative's profile requirements. The Cisco ASR 5000 Series supports a high-performance IMS CSCF core (P/I/S/E-CSCF, PCRF, and BGCF). This functionality can be provided as a set of standalone functions or can be integrated with EPC functions to provide a lower total cost of ownership (TCO) for system operators. Additional benefits of the solution include high availability, support for both RFC 3261- and IMS-based SIP endpoints, full regulatory support (such as local number portability, emergency calling, and lawful intercept), the highest performance in the industry, and IP mobility.

For more information on the CISCO V^{2}oLTE solution, please refer to this page: http://www.cisco.com/en/US/solutions/collateral/ns341/ns973/solution_overview_c22-643109.html

D2 Technologies

D2 is a recognized leader in VoIP and converged IP communications software for devices used in 4G and next-generation networks that deliver advanced communication services, such as VoIP and video over LTE (VoLTE) and IMS-based Rich Communications Suite (RCS). Manufacturers and service providers rely on D2 software to deliver carrier-grade IP communications across any network (LTE, WiMAX, cellular, WiFi, broadband, PSTN), service (voice, video, IM chat, SMS, presence/status, etc.) and system (carrier, IPPBX, UC, OTT, social network, etc.) for a broad range of fixed and mobile devices. From processing billions of VoIP minutes each month to adding enhanced IP communications for Android™, learn how D2 software is converging communications at www.d2tech.com or follow the company on Twitter @D2Tech.

Genband

GENBAND is a global leader of IP infrastructure solutions, enabling service providers and enterprises around the world to evolve communications networks through IP innovation. The Company offers market-leading Switching, Applications, Networking and Service solutions, with products deployed in over 600 customer networks spanning more than 80 countries. GENBAND is headquartered in Frisco, Texas, and has vast resources in R&D, sales and support spanning more than 50 countries. To learn more, visit us on the web at www.GENBAND.com .

Iskratel

With 60 years of experience in telecommunications, Iskratel belongs to the leading high-tech companies in the world, and develops integrated telecommunications solutions for the future information society. The company provides integrated telecommunications solutions for fixed and mobile telephony, for next generation networks, and for telecommunications network management. Linking experience and intellectual capital with creativity and innovation is demonstrated in Iskratel's ability to successfully build telecommunications and next generation networks, and implement advanced products, applications and solutions that are based on the emerging IMS/Tispan technology. The company has over 1100 employees, with 300 more working in affiliated companies in 20 countries. The direct presence of Iskratel's employees in foreign countries ensures full harmonization of network solutions that we provide with the national telecommunications requirements as well as our partners' needs.
www.iskratel.com

JDSU

JDSU is the world's leading network and service enablement company, transitioning from traditional test and measurement to provide an integrated portfolio that helps our customers deal with soaring growth of traffic, devices and applications. With 2400 employees, 30 sales and R&D sites, 4300 customers globally, and $800M in annual revenue, JDSU communications test and measurement solutions set a new standard for network and service enablement. By reducing operating costs and deployment time, we offer value-based solutions that create new revenue opportunities as well as service differentiation. JDSU Mobility solutions ensure agile operation by employing intelligent probes

and products that can be fully integrated to fit a variety of applications from R&D through network monitoring, from the core to access devices, and in laboratory settings or live networks. Only JDSU is uniquely qualified to address your wireless challenges in such a comprehensive fashion.
www.jdsu.com.

Metaswitch Networks

Metaswitch Networks powers over 600 network operators worldwide and is a leading provider of the technologies and solutions that are empowering the migration of communications networks to open, next-generation architectures. For over 30 years, Metaswitch has been innovating solutions to simplify communications, add next-gen functionality and services, while addressing the challenges of converging networks and devices.
http://www.metaswitch.com/

Neustar

Neustar, Inc., (NYSE: NSR) is a trusted, neutral provider of real-time information and analysis to the Internet, telecommunications, entertainment and marketing industries throughout the world. Neustar applies its advanced, secure technologies in routing, addressing and authentication to its customers' data to help them identify new revenue opportunities and network efficiencies, and institute cybersecurity and fraud protection measures.

Neustar is responsible for operating of the GSMA's PathFinder service, providing Carrier ENUM to support addressing for IPX interconnect, global service provider discovery and number portability resolution.

http://www.neustar.biz

Radisys

Radisys is a leading provider of embedded wireless infrastructure solutions for telecom, aerospace, defense and public safety applications. Radisys' market-leading ATCA, IP Media Server (MRF) and COM Express platforms coupled with world-renowned Trillium software, services and market expertise enable customers to bring high-value products and services to market faster with lower investment and risk. For 4G/LTE mobile deployments, Radisys media servers provide the MRF in a 3GPP IMS architecture, delivering scalable IP media processing required for Voice over LTE (VoLTE) with HD audio, video streaming, mobile HD video conferencing, IP-to-IP transcoding, multimedia value-added services (VAS) and other revenue-generating LTE mobile services. Additional Radisys solutions include a wide variety of 3G & 4G / LTE mobile network applications including: Radio Access Networks (RAN) solutions from Femtocells to Picocells and Macrocells, wireless core network applications, WiFi & LTE Security Gateway, Deep Packet Inspection (DPI) and policy management. http://www.radisys.com.

Tekelec

Tekelec's intelligent mobile broadband solutions enable service providers to manage and monetize mobile data and evolve to LTE and IMS. We are the architects of the new Diameter network, the foundation for session, policy and subscriber data management. More than 300 service providers use our market-leading solutions to deliver cloud, machine-to-machine and personalized services to consumers and enterprises. For more information visit www.tekelec.com.

Ulticom

Ulticom, a Platinum Equity Company, is a leader in high performance mission critical products that evolve information delivery. With over 6,000 deployments worldwide, the company's flagship product, Signalware, is the premier platform for the deployment of applications and services within wireless, IP, and wireline networks.

For over 35 years, Ulticom has delivered carrier-grade solutions that are robust and reliable, all backed by the company's unmatched service and support.

Mobile Network Operators (MNO), Signaling Hub Providers (IPX, GRX), Telecom Equipment Manufacturers (TEM) and Systems Integrators (SI) trust Ulticom solutions to optimize information and application delivery with increased efficiency and security.

For more information, please visit www.ulticom.com.