Qualcomm Wireless Academy

VOLTE TROUBLESHOOTING & PERFORMANCE WORKSHOP

STUDENT GUIDE
80-W3072-1 REV A

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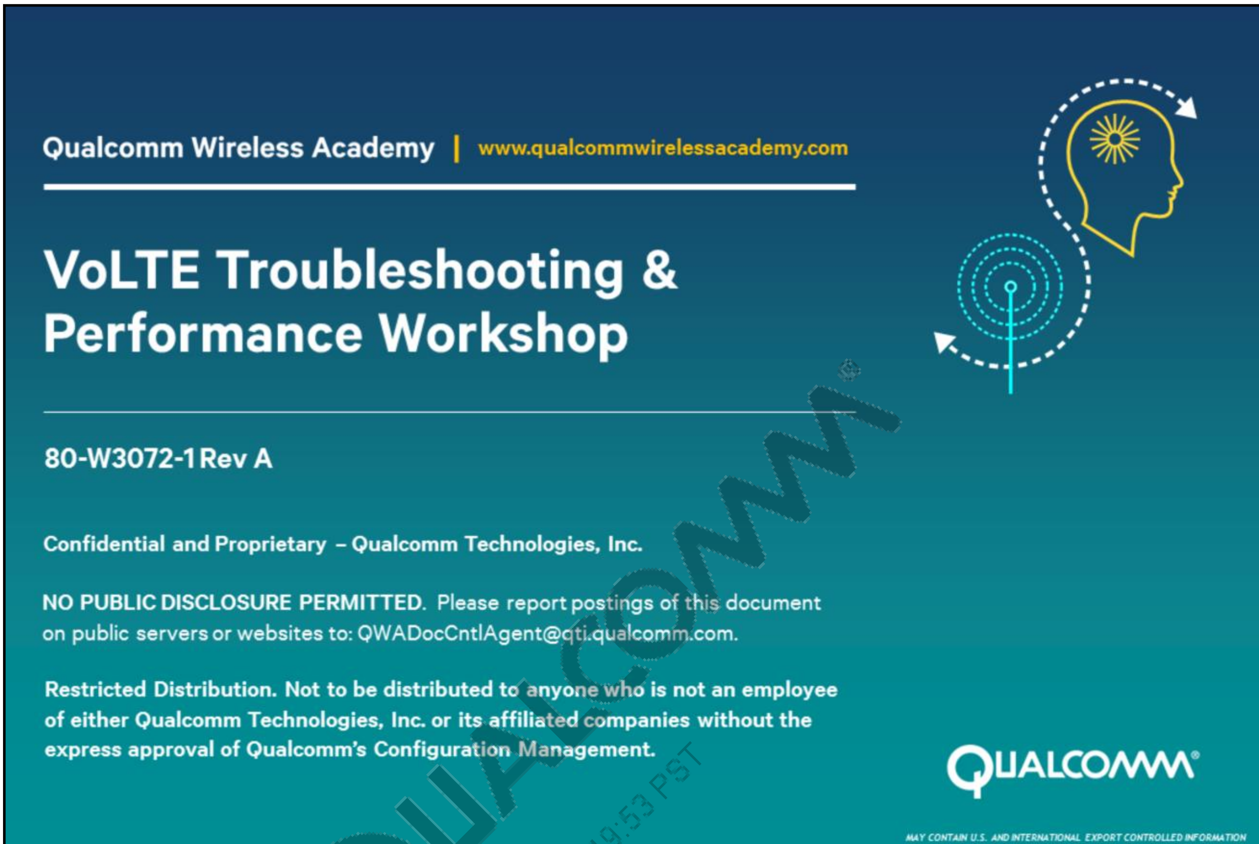

STUDENT GUIDE

80-W3072-1 REV A

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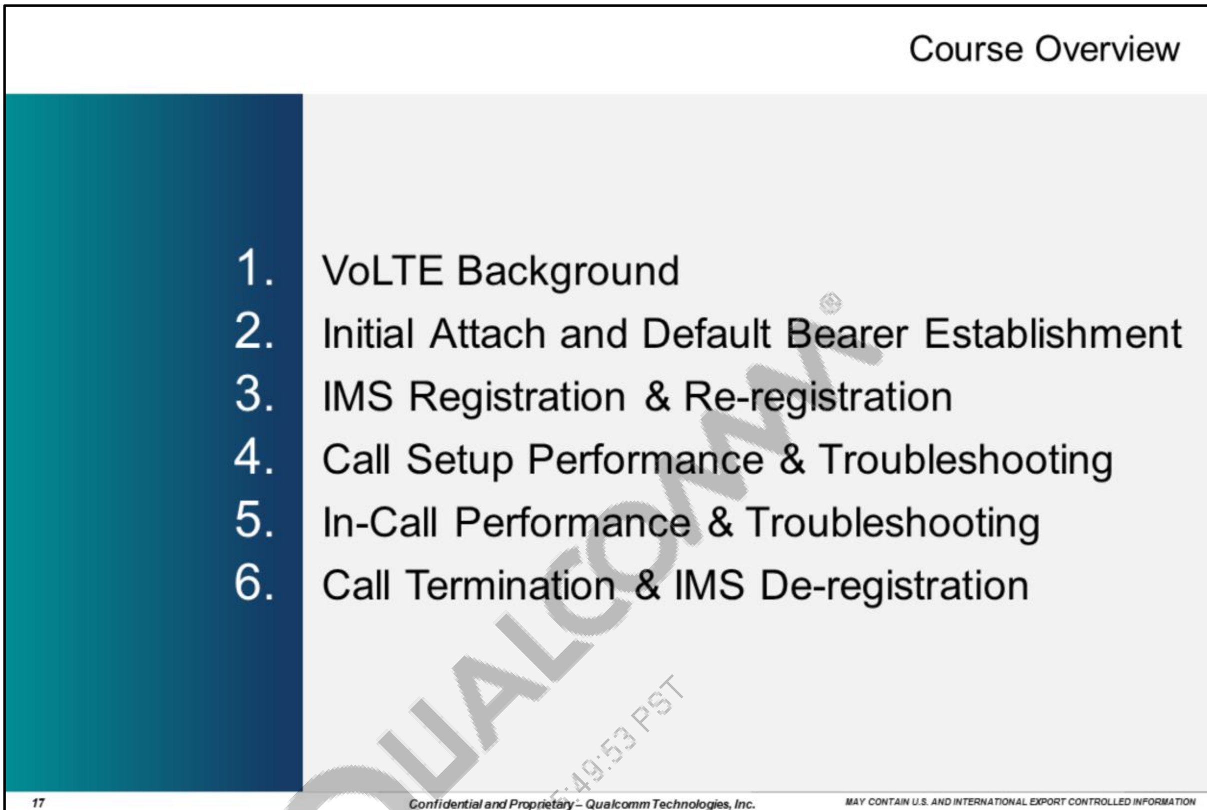
Acronyms and Abbreviations

1xRTT	1 times Radio Transmission Technology
3GPP	3rd Generation Partnership Project
ACK	Acknowledge/Acknowledgement
AMBR	Aggregate Maximum Bit Rate
AMR	Adaptive Multi-Rate
AMR-WB	Adaptive Multi-Rate Wideband
APN	Access Point Name
ARP	Allocation/Retention Priority
AS	Access Stratum
ATCF	Access Transfer Control Function
ATGW	Access Transfer Gateway
AVP	Audio Video Profile
BCQI	Best Channel Quality Indicator
BE	Best Effort
BLER	Block Error Rate
BW	Bandwidth
C-DRX	RRC Connected Discontinuous Reception
CDMA	Code Division Multiple Access
CQI	Channel Quality Indicator
CS	Circuit Switched
CSCF	Call Session Control Function
CSFB	CS Fallback
DCCH	Dedicated Control Channel
DHCP	Dynamic Host Configuration Protocol
DL	Downlink
DRB	Data Radio Bearer
DRX	Discontinuous Reception
DTMF	Data Tone Multiple Frequency
E2E	End-to-End
eNB	E-UTRAN NodeB
EPC	Evolved Packet Core
EPS	Evolved Packet System
ESM	EPS Session Management
eSRVCC	enhanced Single Radio Voice Continuity Control
EUTRA	Evolved Universal Terrestrial Radio Access
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
FGI	Feature Group Indicator
FO	First Order
GBR	Guaranteed Bit Rate
GERAN	GSM EDGE Radio Access Network
GSM	Global System for Mobile communications
GSMA	GSM Association
GW	Gateway
HARQ	Hybrid ARQ
HO	Handoff
HSS	Home Subscriber Server
I-CSCF	Interrogating CSCF
IE	Information Element

IETF	Internet Engineering Task Force
IMS	IP Multimedia Subsystem
IMSI	International Mobile Subscriber Identity
IP	Internet Protocol
IPv4	Internet Protocol Version 4
IPv6	Internet Protocol Version 6
IR	Initialization & Refresh
IRAT	Inter-Radio Access Technology
ISIM	IM Services Identity Module
ITU	International Telecommunications Union
KPI	Key Performance Indicator
KPN	In full Koninklijke KPN N.V., also Royal KPN N.V. A Dutch landline and mobile telecommunications company
LQO	Line Quality Operation
LTE	Long Term Evolution
M2M	Machine-to-Machine
MAC	Medium Access Control
MCS	Modulation Coding Scheme
MME	Mobility Management Entity
MO	Managed Object
MOS	Mean Opinion Score
MRM	Measurement Report Message
MT	Mobile Terminated
NACK	No or Negative Acknowledgment
NAS	Non-Access Stratum
NW	Network
OMTS	Optimization Model for Telecommunication Systems
OTA	Over-the-Air
PCI	Physical Cell Identity
PCO	Protocol Configuration Options
PCRF	Policy and Charging Rules Function
P-CSCF	Proxy - Call Session Control Function
PDCCH	Physical Downlink Control Channel
PDCP	Packet Data Convergence Protocol
PDN	Packet Data Network
PDSCH	Physical Downlink Shared Channel
PDU	Protocol Data Unit
PESQ	Perceptual Evaluation Speech Quality
P-GW	Packet Gateway
PHICH	Physical Hybrid ARQ Indicator Channel
POLQA	Perceptual Objective Listening Quality Assessment
PRACK	Provisional Response ACK
PRB	Physical Resource Block
PS	Packet Switched
PUSCH	Physical Uplink Shared Channel
QAM	Quadrature Amplitude Modulation
QCI	Quality of Service Class Indicator
QoP	Quality of Protection
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying

RACH	Random Access Channel
RAN	Radio Access Network
RAT	Resource Allocation Type; Radio Access Technology
RF	Radio Frequency
RFC	Radio Frequency Control
RLC	Radio Link Control
RLF	Radio Link Failure
RoHC	Robust Header Compression
RR	Round Robin
RRC	Radio Resource Control
RSRP	Reference Signal Received Power
RSRQ	Reference Signal Received Quality
RTP	Real Time Protocol
S-CSCF	Serving CSCF
SDP	Session Description Protocol
SFN	Single Frequency Network
S-GW	Serving Gateway
SI	System Information
SIB	System Information Block
SINR	Signal-to-Interference-plus-Noise Ratio
SIP	Session Initiation Protocol
SMS	Short Message Service
SN	Sequence Number
SO	Second Order
SPR	Subscriber Profile Repository
SPS	Semi-Persistent Scheduling
SRB	Signaling Radio Bearer
SRVCC	Single Radio Voice Call Continuity
STN	Session Transfer Number
SVLTE	Simultaneous Voice and LTE data
TAU	Tracking Area Update
TNO	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Netherlands Organization for Applied Scientific Research)
TTI	Transmission Time Interval
TTT	Time-to-Trigger
U	Unidirectional mode
UDP	User Datagram Protocol
UE	User Equipment
UL	Uplink
UM	Unacknowledged Mode
UMTS	Universal Mobile Telecommunications Systems
URI	Uniform Resource Identifier
USB	Universal Serial Bus
UTRAN	UMTS Terrestrial Radio Access Network
VCC	Voice Continuity Control
VoIP	Voice Over IP
VoLTE	Voice over LTE
VoPS	Voice over Postscript
WB	Wideband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3. IMS Registration & Re-registration
4. Call Setup Performance & Troubleshooting
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6. Call Termination & IMS De-registration
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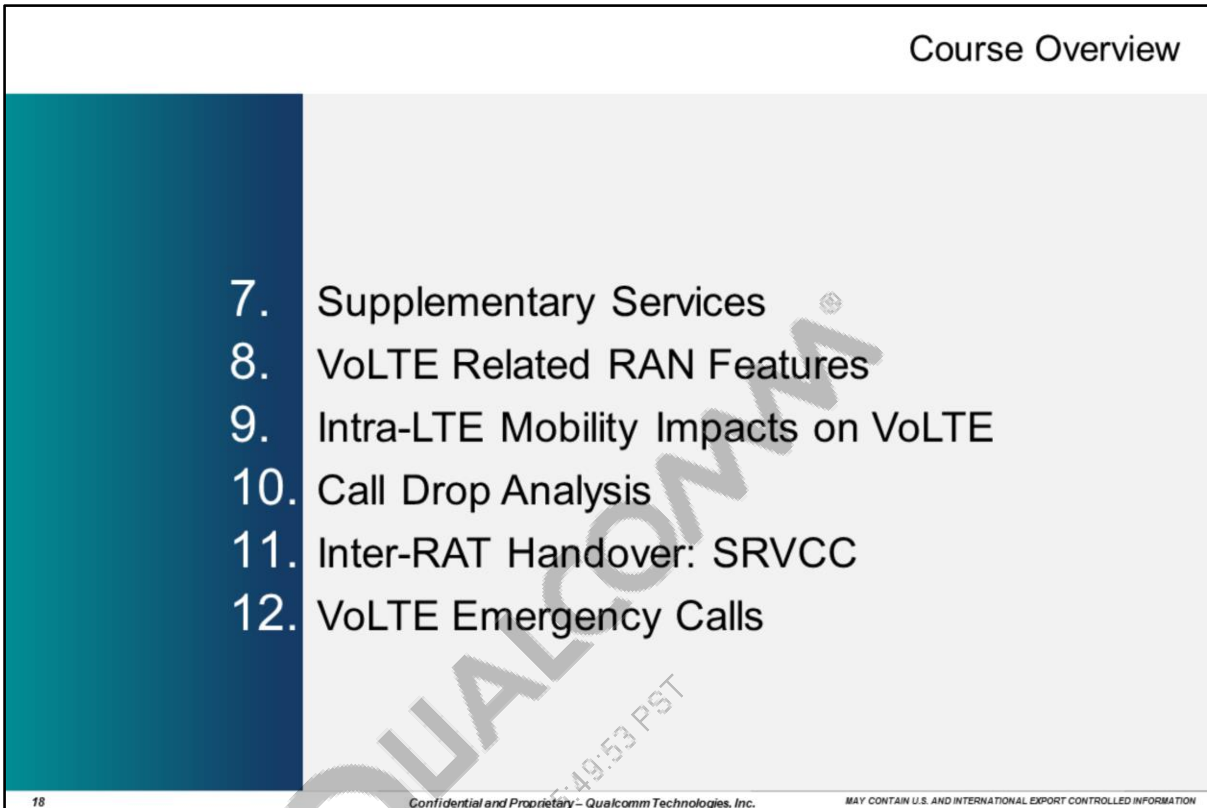
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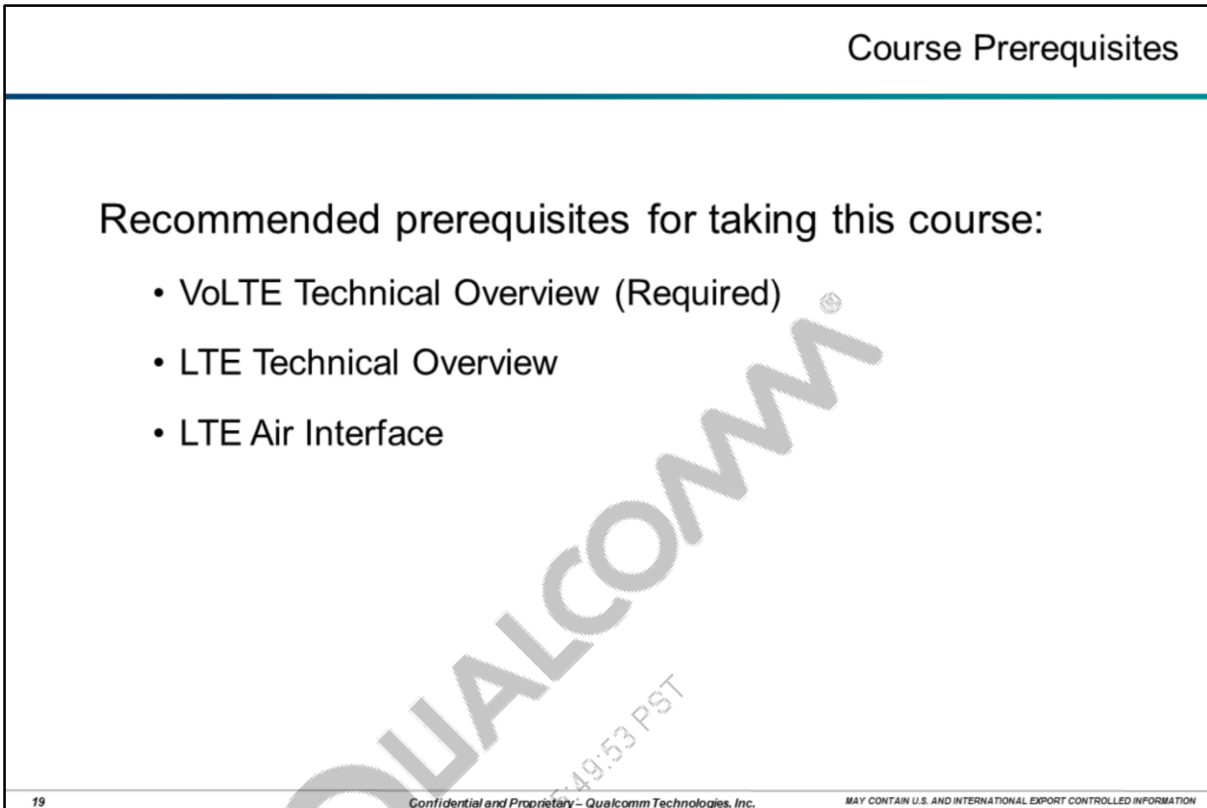
Course Prerequisites
Recommended prerequisites for taking this course:
• VoLTE Technical Overview (Required)
• LTE Technical Overview
• LTE Air Interface
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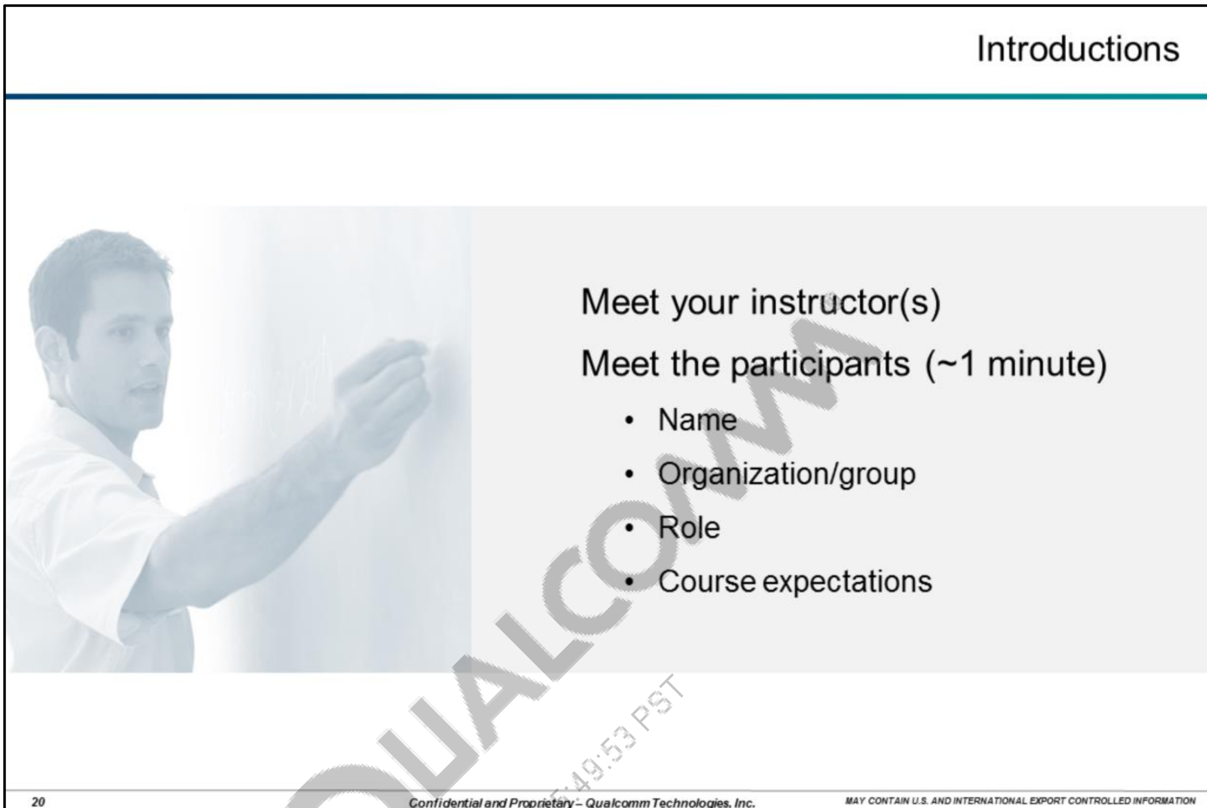
Introductions
Meet your instructor(s)
Meet the participants (~1 minute)
• Name
• Organization/group
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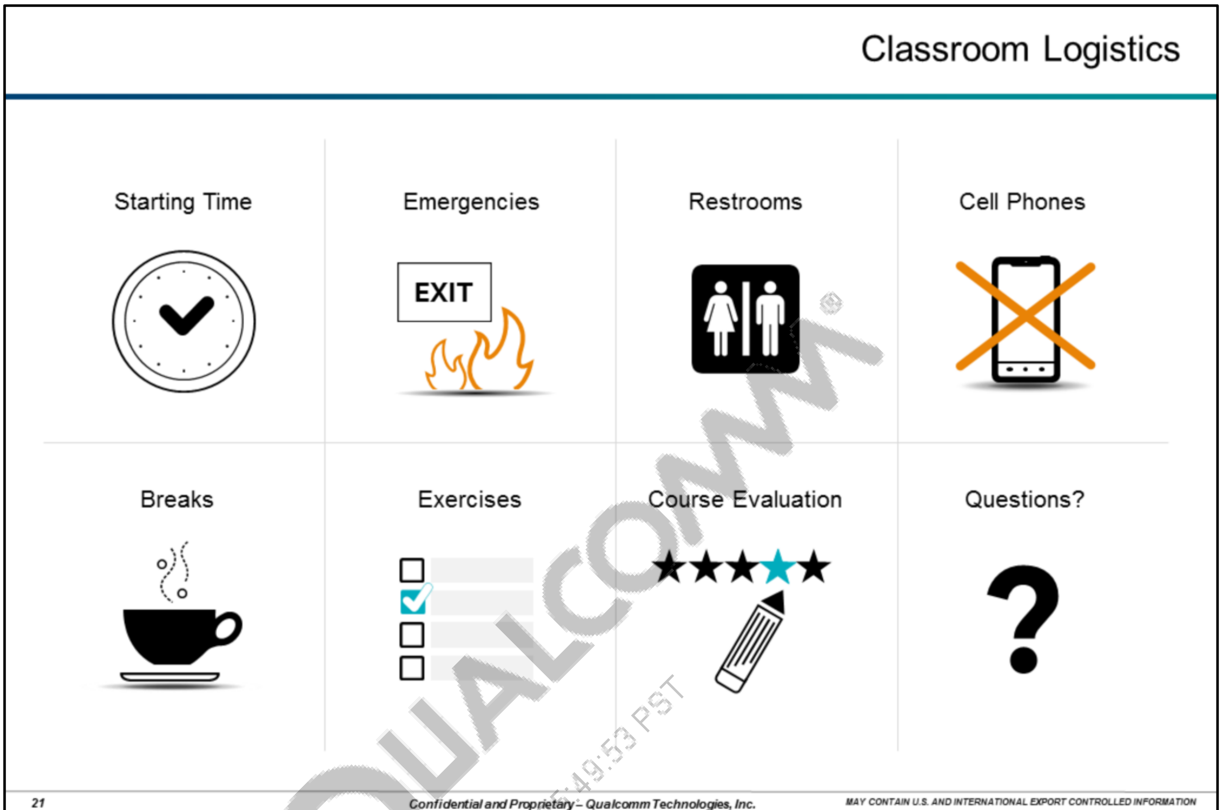
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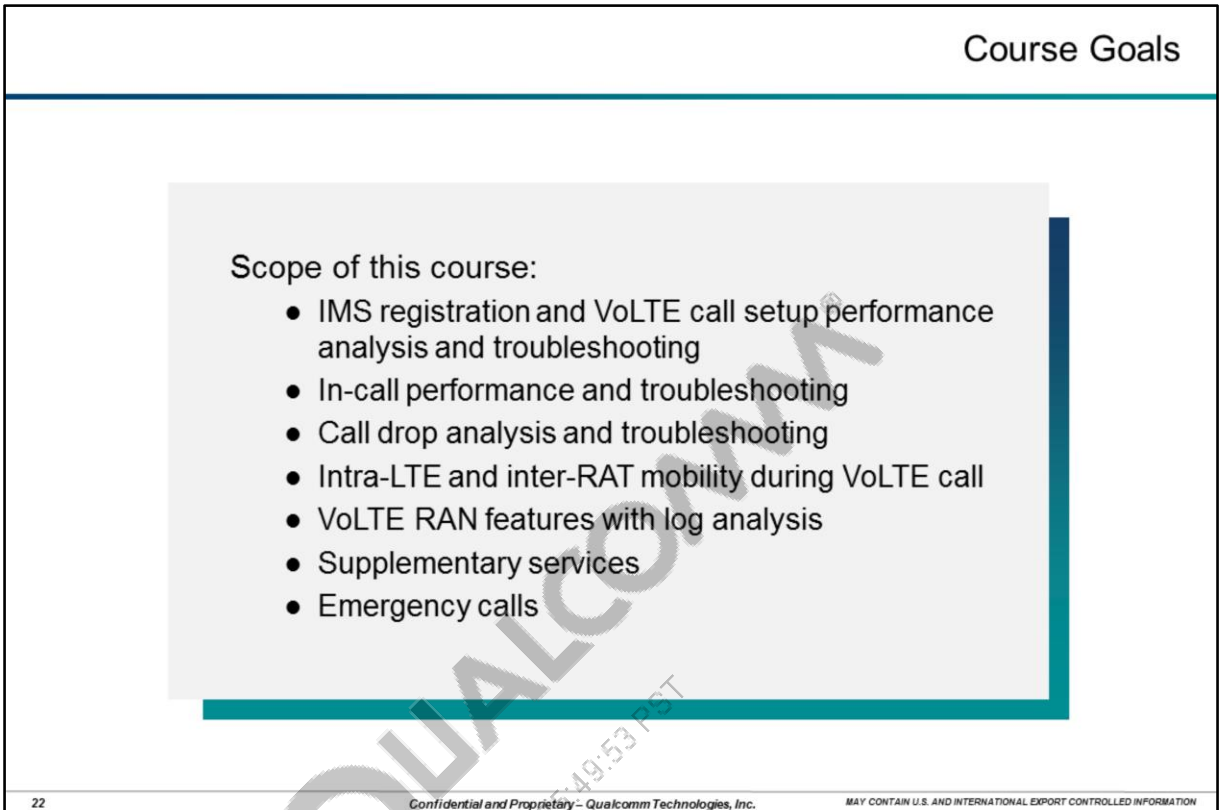
Course Goals
Scope of this course:
• IMS registration and VoLTE call setup performance analysis and troubleshooting
• In-call performance and troubleshooting
• Call drop analysis and troubleshooting
• Intra-LTE and inter-RAT mobility during VoLTE call
• VoLTE RAN features with log analysis
• Supplementary services
• Emergency calls
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Notes

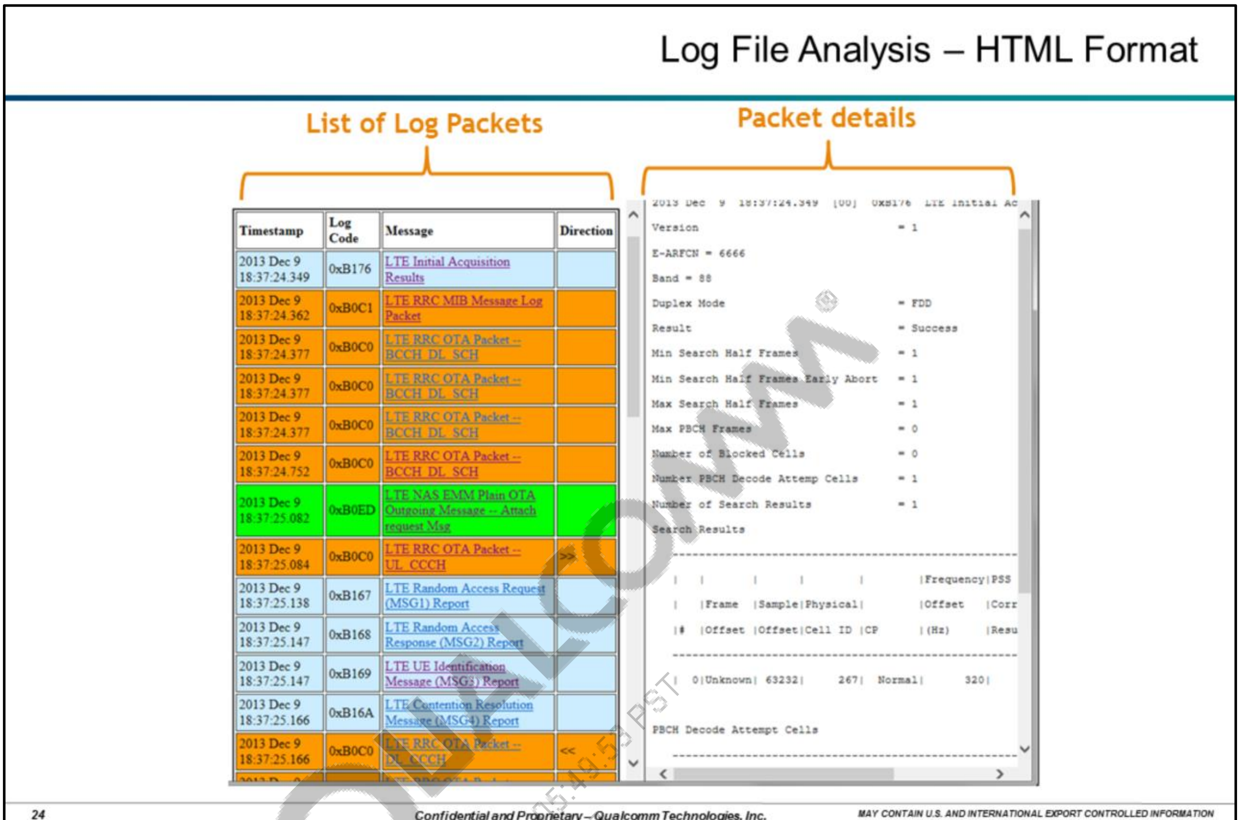
Log File Analysis

- For each scenario, the exchange of signaling messages is captured and explained using **log files**
- Hands-on exercises are provided, identifying key messages in typical LTE and VoLTE scenarios
- Post-processing is tool-independent
  - ✓ **Log files are presented in HTML files**
- The guidelines and processes covered in the workshop can be applied to standard analysis tools

Important notes:

- **Internet Explorer is the only supported browser to view the log files.**
- Logs and configurations included in this workshop are for demonstration purposes only.

Notes

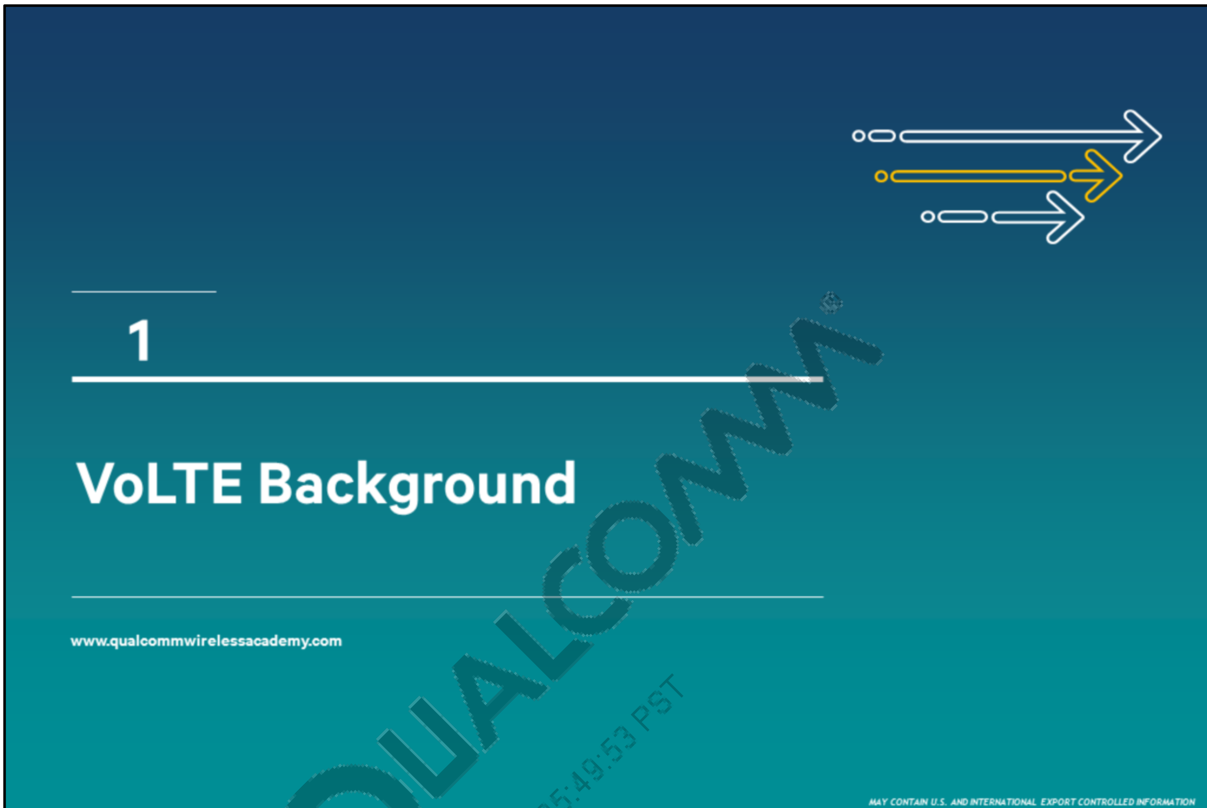


Log File Analysis – HTML Format

The HTML files included with this workshop file provide a summary of the key messages associated with each case being studied.

Each individual color shaded row differentiates protocol layers.

Clicking on a specific message displays the log packet content in the panel on the right side of the web page.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VoLTE Background
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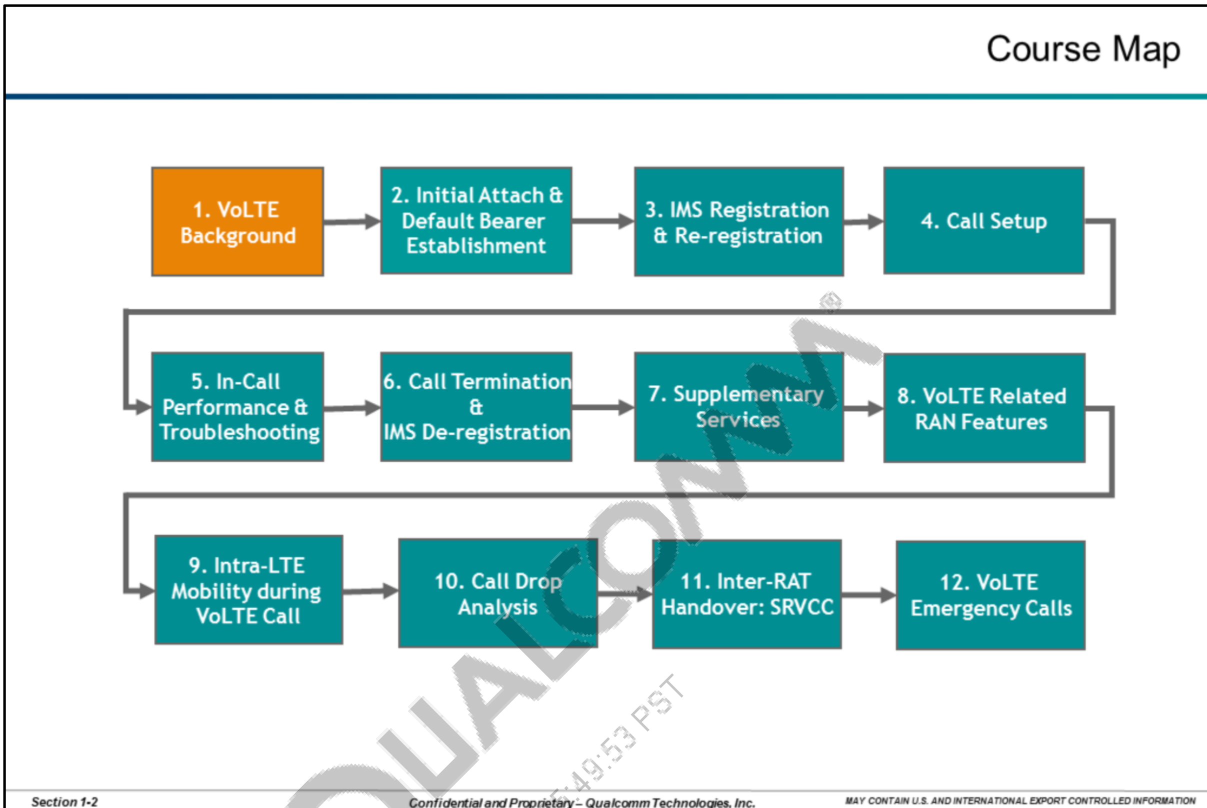
Course Map
1. VoLTE Background
2. Initial Attach & Default Bearer Establishment
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Objectives

- List the options for voice support in LTE.
- Describe the two key VoLTE protocols.
- Explain the signaling procedure for a VoLTE call.
- Differentiate the roles of default and dedicated bearers in a VoLTE call.
- List VoLTE Key Performance Indicators (KPIs).

Notes

Voice Support in LTE

E-UTRAN is an all-IP network

- Circuit-switched (CS) connections are not supported

When a **UE is camped on E-UTRAN**, three options are available to **support Voice Services**

- **VoIP over LTE**
  - VoIP services supported by LTE through an IMS (IP Multimedia Service) framework
- **Circuit Switched Fallback (CSFB)**
  - No VoIP support required
  - Voice services are supported by falling back onto an existing 2G or 3G CS network
  - Paging delivered over LTE for MT calls
- **SVLTE (Simultaneous Voice and LTE Data)**
  - Device-based solution requiring dual radio UEs
  - Simultaneous communication with the legacy network for voice services and E-UTRAN network for data services

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Options to Support Voice in LTE

When a UE is attached to the E-UTRAN, CS voice can be supported in the following ways:

- **VoIP over LTE**: VoIP call support over an LTE network requires IMS support. When a UE with an active VoIP call leaves LTE coverage to an area with only 1xRTT coverage, the call can be seamlessly handed over from the LTE-IMS to the 1xRTT CS domain. Call continuity from IMS to the CS domain is maintained with the help of Single Radio Voice Call Continuity (SRVCC) anchoring.
- **Circuit Switch Fall Back (CSFB)**: If IMS is not implemented and LTE does not support VoIP, voice calls can be originated and terminated by falling back to an existing underlying 2G or 3G network. This technique does not require LTE network connectivity to IMS. For Mobile Terminated (MT) calls, the UE is paged over LTE.
- **Simultaneous Voice and LTE (SVLTE)**: This solution requires a dual radio device. SVLTE can simultaneously provide voice services over a legacy CS network and data services over E-UTRAN. This solution does not require any kind of interworking connections between the legacy network and LTE.

VoLTE and IMS

- The **IP Multimedia Subsystem (IMS)** is an architectural framework for delivering Internet Protocol (IP) multimedia services.
- IMS uses protocols that **enable sending voice, data, and video** between communication devices of IP addressable data networks.
- **A minimum feature set of IMS is required** to support VoIP over LTE
  - Includes support for call waiting, conference calling, etc.
  - Uses Session Initiation Protocol (SIP) for call setup
  - Adaptive Multi-Rate (AMR) is the default codec
  - Supports SMS over IP

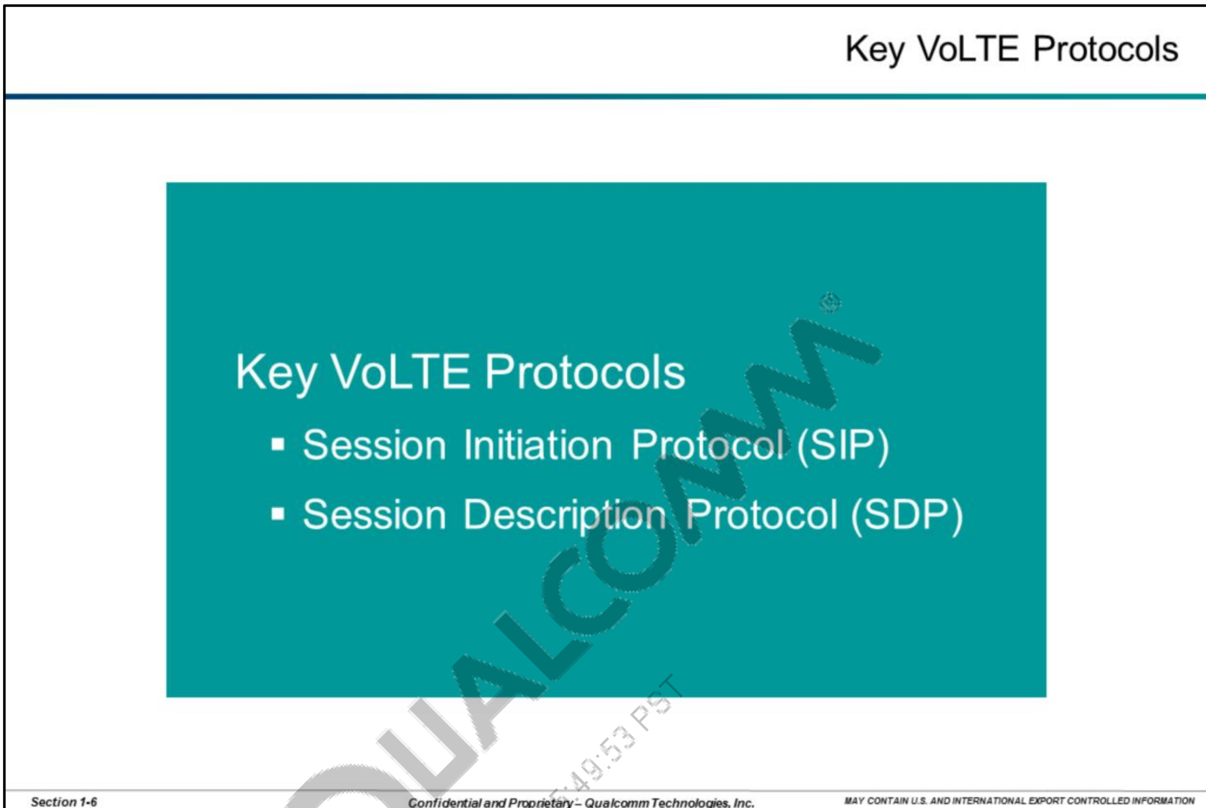
VoLTE and IMS

IP Multimedia Subsystem, developed by 3GPP, is described as:

"IP multimedia services are not the evolution of the circuit switched services but represent a new category of services, mobile terminals, services capabilities, and user expectations. Any new multimedia service, which may have a similar name or functionality to a comparable standardized service, does not necessarily have to have the same look and feel from the user's perspective of the standardized service. Voice communications (IP telephony) is one example of real-time service that would be provided as an IP multimedia application."

References:

- 3GPP TS 23.228: *IP Multimedia Subsystem (IMS)*
- 3GPP TS 23.292
- GSMA Document IR.92 - IMS Profile for Voice and SMS


Key VoLTE Protocols
Key VoLTE Protocols
Session Initiation Protocol (SIP)
Session Description Protocol (SDP)
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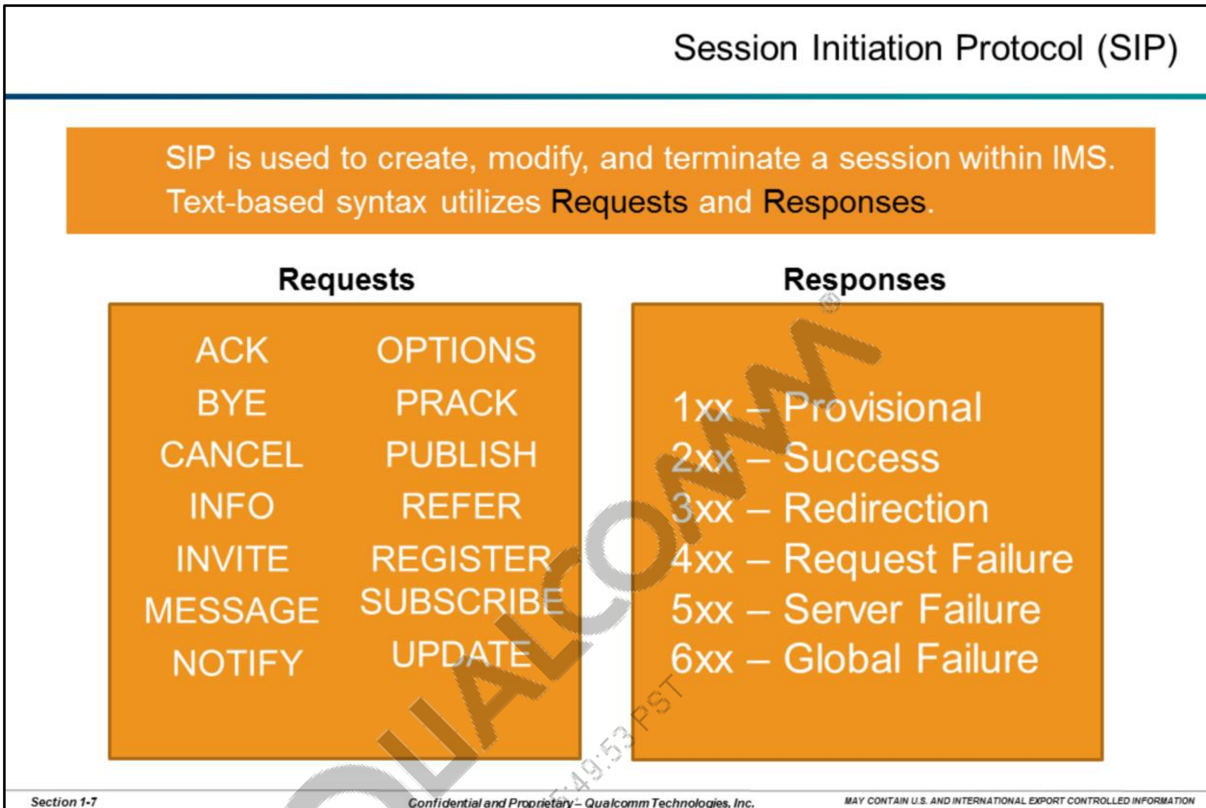


Session Initiation Protocol (SIP)

Session Initiation Protocol (SIP) is utilized in IMS to manage all aspects of a session including creation, modification, and termination. The UE and the network act as both a client and a server using a standard set of Requests, which are answered with a standard set of Responses.

The UE must support the SIP preconditions framework as specified in 3GPP TS 24.299 and RFC 3312 (updated in RFC 4032). The preconditions framework enables the enforcement of a set of constraints associated with a session. Through an exchange of messages, both the originator and the terminator are aware of any preconditions associated with a specific session and their current status. An example of a precondition could be the presence of resources to carry the media. An originator could define that it is mandatory that resources are available in both the send and receive direction before a session continues. If the preconditions are not met, the originator could decide to not continue a session.

Session Description Protocol (SDP)

- **Used in conjunction with SIP.**
- **Standardized text-based protocol to initiate and negotiate the characteristics of a multimedia session.**
  - Consists of three main information components:
    - **Session description**
    - **Timing description**
    - **Media description**
- **Each component consists of mandatory and optional fields.**
  - Mandatory fields are:
    - Session Name
    - Time the Session is Active
    - Session Media
    - Session Owner/Originator
    - Media Ports and Addresses

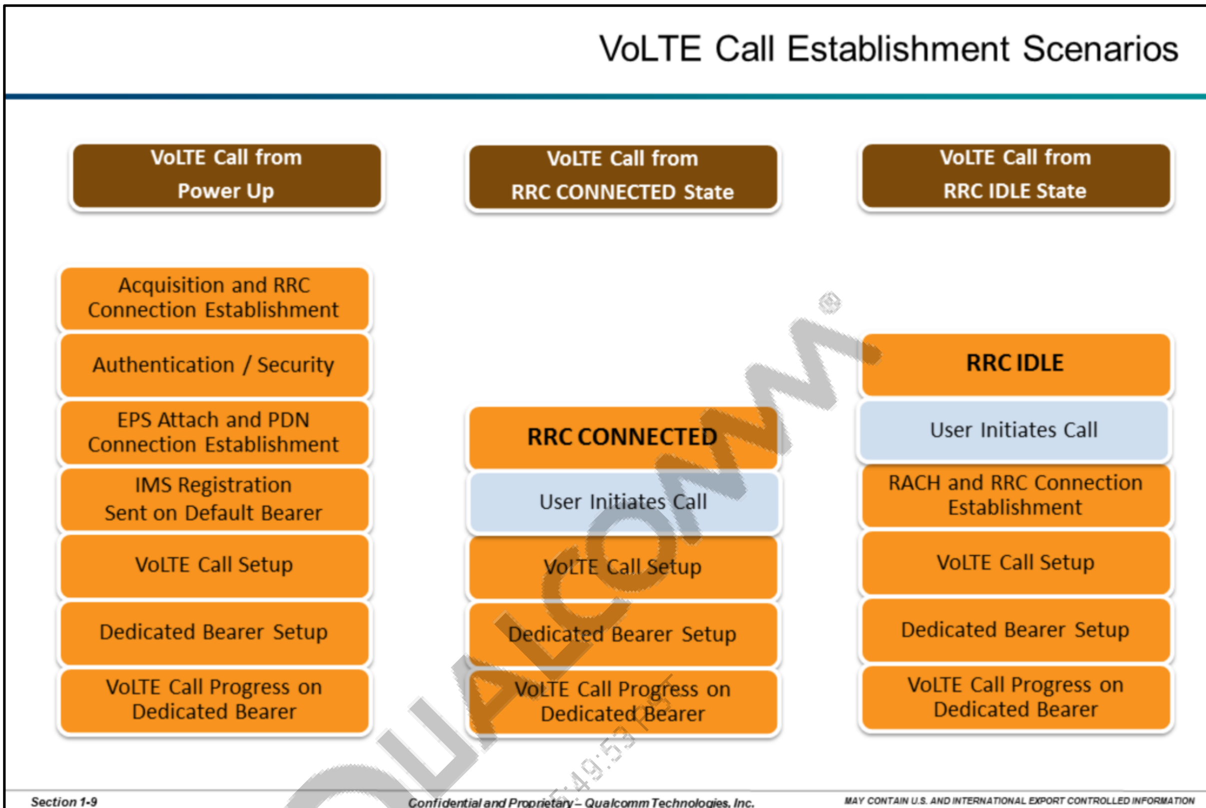
Session Description Protocol (SDP)

Session Description Protocol is utilized within SIP to enable the characteristics of a session and the associated media to be specified. SDP is referred to as an Offer/Answer model in which the client proposes a set of characteristics to which the server responds. There is no guarantee that the answer will contain the same characteristics as the offer.

A important aspect of SDP is the use of Attributes. These can be employed to extend the core protocol to provide additional session level or media level configuration.

The table below shows the **mandatory** and optional SDP session, timing, and media fields.

Session			**Timing**	
Protocol Version	v		**Timing**	t
Origin	o		Repeat Times	r
Session Name	s			
Session Information	i		**Media**	
URI	u		**Media Description**	m
Email Address	e		Session Information	i
Phone Address	p		Connection Data	c
Connection Data	c		Bandwidth	b
Bandwidth	b		Encryption Keys	k
Time Zones	z		Attributes	a
Encryption Keys	k			
Attributes	a			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Notes

Signaling Procedure of a VoLTE Call

RRC Connection Establishment

- Exchange of VoLTE-related UE capability (in initial attach)
- VoLTE signaling and media are sent on different EPS bearers
  - Default bearer is used for signaling (non-GBR, QCI = 5)
  - Dedicated bearer is used for media (GBR, QCI = 1)

IMS Registration

- Mutual authentication of UE and IMS core network
- P-CSCF discovery
- Registration of the UE in the IMS

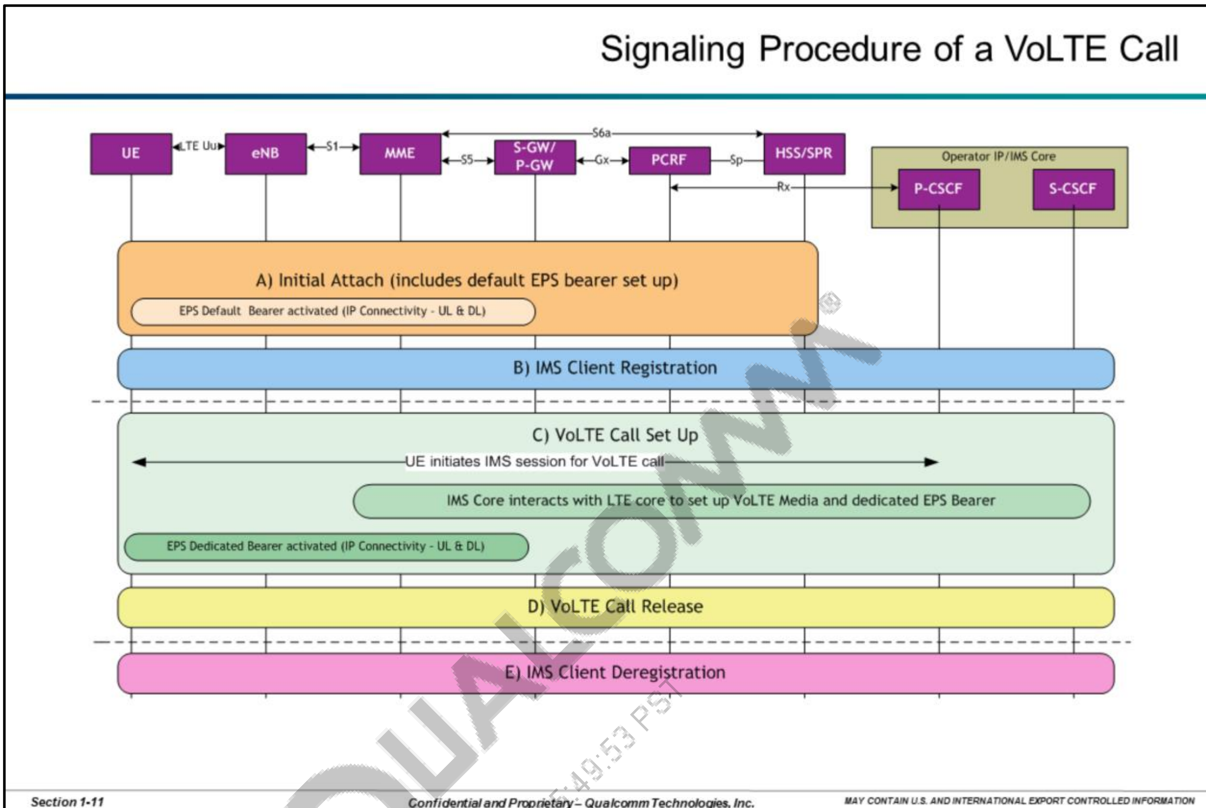
Call Setup

- Codec selection
- Dedicated EPS bearer establishment (if necessary)
- QoS negotiations
- Alerting UE on both ends

Call Release

- Call terminated by either party

Notes



Signaling Procedure of a VoLTE Call

Key phases in a VoLTE call are highlighted in the diagram above. Various aspects addressed in this section for each of the phases are detailed below.

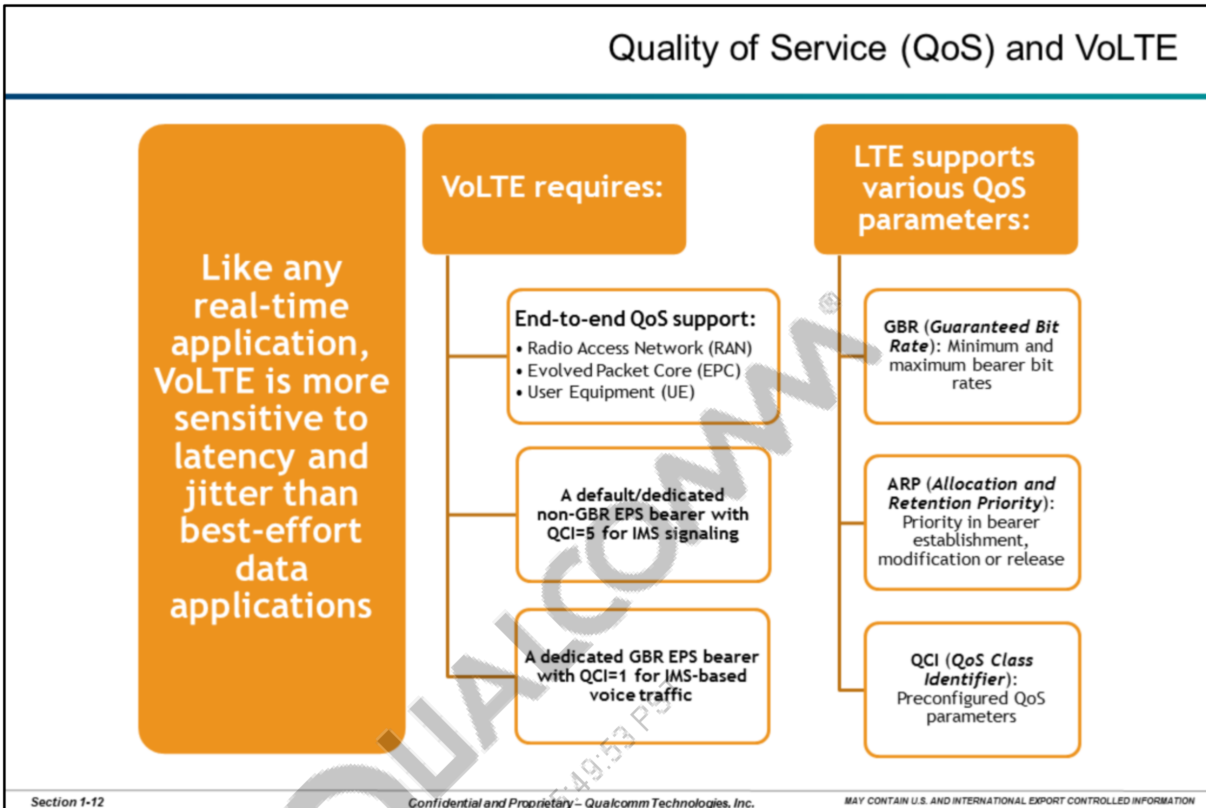
A. Initial LTE attach, includes RRC connection set up, authentication and security procedures, PDN connection set up (includes default and an optional dedicated bearer set up). With respect to VoLTE, PDN connection set up can be broadly classified into either single initial IMS PDN set up or an initial PDN set up followed by subsequent IMS PDN set up. In addition, VoLTE related UE capability is exchanged in the initial ATTACH process.

B. IMS client registration. The IMS registration procedure allows the UE to create, maintain, and remove a binding between its public user identity and its contact address. Mutual authentication of UE and IMS CN is accomplished through the registration process. Key steps include P-CSCF discovery and registration of the UE in the IMS.

C. After initial LTE attach and subsequent IMS registration, VoLTE call set up involves IMS core interaction with LTE core setting up VoLTE media (codec selection), dedicated EPS bearer establishment (if necessary), QoS negotiations, and alerting UE on both ends. Key functionality covered in this section includes various VoLTE call scenarios, MO/MT call setup, and VoLTE call QoS.

D. VoLTE Call Release. The call release mechanism when a UE experiences radio link failure during a VoLTE call is discussed as well as the signaling when either party hangs up the call.

E. IMS Client Deregistration. Triggers for deregistration are discussed.



QoS and VoLTE

Voice is one of the LTE services that requires a GBR bearer (QCI=1). The voice traffic requires a low bit rate bearer and where the bearer data rate is related to the bit rate of the selected voice codec (example: AMR 12.2 Kbps). The network resources associated with the VoLTE voice GBR bearer must be permanently allocated when this bearer is set up. The UE must also comply with the GBR requirements.

The VoLTE IMS signaling is to be carried to a non-GBR bearer with the highest priority (QCI=5).

GBR bearers have minimum and maximum bit rate values for which dedicated transmission resources are permanently allocated at bearer establishment/modification.

- A default EPS-bearer is always non-GBR. A dedicated EPS-bearer can be either GBR or non-GBR.

Guaranteed Bit Rate (GBR) vs. Non-GBR

- GBR bearers have minimum and maximum bit rate values for which dedicated transmission resources are allocated. Non-GBR bearers do not guarantee any particular bit rate.
- The APN AMBR limits the aggregate bit rate across all non-GBR bearers and across all PDN connections of the same APN (excess traffic may get discarded).
- The UE AMBR limits the aggregate bit rate across all non-GBR bearers of a UE (excess traffic may get discarded by a rate shaping function).

Allocation and Retention Priority (ARP)

- Each bearer has an associated ARP.
- ARP controls priority in bearer establishment/modification, or bearer release if resources are limited.
- The ARP priority level ranges from 1 to 15; 1 is the highest level of priority.

QoS Class Identifier (QCI)

- Each bearer has an associated QCI.
- Each QCI is characterized by priority, packet delay budget, and an acceptable packet loss rate.
- QCI label determines how a bearer will be handled at the eNode B.

More details on the QCI characteristics for different traffic types are provided in Section 4. The related references are 3GPP TS 23.401, 23.203 (PCC), 24.301 (NAS), 36.413 (S1-AP).

Default vs. Dedicated EPS Bearers for VoLTE

- Due to strict latency and BLER requirements, GBR bearers (with QCI=1) are needed to transport PS voice.
- Default EPS bearers are non-GBR bearers.
  - At least one default bearer is established at initial attach.
- To provide guaranteed QoS (data rates, latency, error bound) for VoLTE, dedicated EPS bearers are activated by the network at call setup.
- Multiple dedicated bearers can be established to accommodate different traffic requirements.
- Each dedicated bearer must have an associated default bearer.
- In the following sections, we assume the common case of:
  - SIP signaling is carried over the default bearer.
  - RTP (voice) traffic is carried over the dedicated bearer.

Dedicated EPS Bearers for VoLTE

To ensure voice quality, PS voice traffic needs to be carried over GBR (guaranteed bit rate) bearers with QCI=1. Default bearers are non-GBR bearers (Refer 3GPP TS 23.401 sec 4.7.2.1). As such, these bearers enable Best Effort transport of user data and QoS cannot be guaranteed for data carried over these bearers.

In EPS, a dedicated EPS bearer can be used to transport application data requiring a specific QoS. The establishment of these bearers in the UE and the EPS guarantees requested or negotiated QoS.

There are multiple ways the Dedicated EPS bearer(s) can be established. In UE initiated Dedicated EPS bearer set up (also known as Bearer Resource Allocation procedure), the UE requests a specific QoS (QCI) and optionally sends a GBR requirement for a new traffic flow aggregate. If the network accepts the request, it invokes a dedicated EPS bearer context activation procedure.

The network initiated Dedicated EPS bearer setup is triggered by:

- UE registering with IMS core for IMS services and establishing an IMS VoIP call
- IMS node triggering PCRF to establish corresponding dedicated bearers

The default EPS bearer with the PDN must be established before the dedicated EPS bearer can be established.

VoLTE Key Performance Indicators (KPIs)

- User Plane KPIs
  - KPIs that affect the end user experience
- Control Plane KPIs
  - KPIs that affect call setup and signaling
- Mobility KPIs
  - KPIs that affect the call performance during handover
- Voice Quality

Notes

User Plane KPIs

KPI	Unit	Details
RTP Packet Loss Rate	%	Packets dropped due to either radio link-related issues, core network issues or PDCP discard
Average RTP Inter-arrival Time	ms	Difference in packet time spacing at the receiver compared to the sender for a pair of packets
RTP End-to-End (E2E) Delay	ms	One-way delay from mic to speaker, also known as mouth-to-ear delay

Notes

Control Plane KPIs

KPI	Unit	Details
IMS Registration Duration	ms	Delay from the transmission of the REGISTER message by the UE till 200 OK is received from the network
IMS Registration Success Rate	%	Success rate of the IMS registration
Call Setup Time	ms	Delay from the Call Establishment trigger at the MO UE till actual 180 RINGING is received
Dedicated Bearer Setup	ms	Delay encountered from the reception of the RRC Connection reconfiguration, configuring the dedicated bearer till the UE sends Bearer Context Accept
Call Setup Success Rate	%	Ratio of the number of successful call setup to the total number of attempted calls

Notes

Mobility KPIs

KPI	Unit	Details
Handover frequency	sec	Time interval between handovers
Handover success rate	%	Ratio of the number of successful handovers to the total number of attempted handovers
Average RTP packet loss during inter-frequency handover	value	Average number of dropped RTP packets per inter-frequency handover
Average RTP packet loss during intra-frequency handover	value	Average number of dropped RTP packets per intra-frequency handover
Average RTP packet loss during SRVCC handover	value	Average number of dropped RTP packets per SRVCC handover
Average RTP interruption delay at handover	ms	Average delay in RTP traffic at handover

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Voice Call Quality

KPI	Unit	Details
PoLQA Score	value	Voice quality, measured by comparing the received voice file to a reference file

Notes

Specifications References

Specifications	Title
3GPP TS 23.228	IP Multimedia Subsystem (IMS)
3GPP TS 24.299	IP multimedia call control protocol based on Session Initiation Protocol (SIP) and Session Description Protocol (SDP); Stage 3
RFC 3261	SIP: Session Initiation Protocol
RFC 3312	Integration of Resource Management and SIP
RFC 4566	SDP: Session Description Protocol
GSMA IR.92	IMS Profile for Voice and SMS

Specifications References

3GPP specifications are available at www.3gpp.org

IETF RFCs are available at www.ietf.org

GSMA specifications are available at www.gsma.com

Comments/Notes


2
Initial Attach and Default Bearer Establishment
www.qualcommwirelessacademy.com
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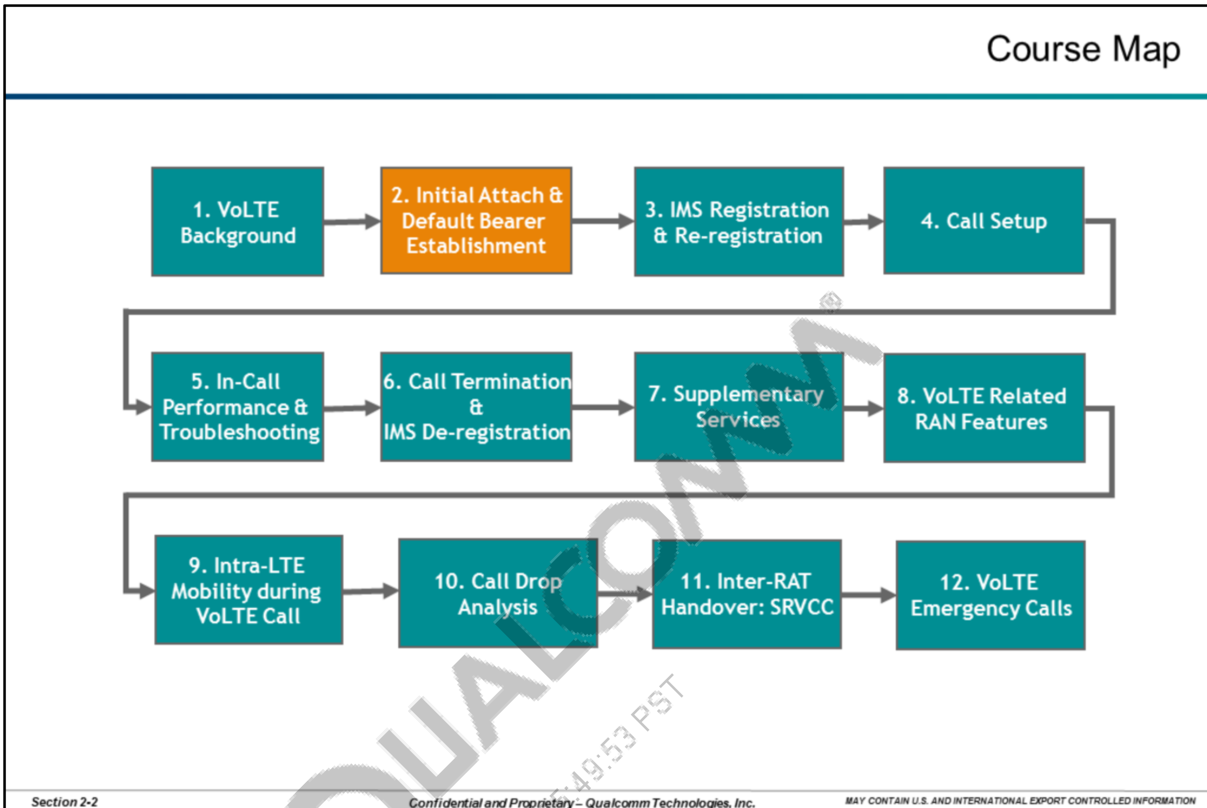
Course Map
1. VoLTE Background
2. Initial Attach & Default Bearer Establishment
3. IMS Registration & Re-registration
4. Call Setup
5. In-Call Performance & Troubleshooting
6. Call Termination & IMS De-registration
7. Supplementary Services
8. VoLTE Related RAN Features
9. Intra-LTE Mobility during VoLTE Call
10. Call Drop Analysis
11. Inter-RAT Handover: SRVCC
12. VoLTE Emergency Calls
Section 2-2
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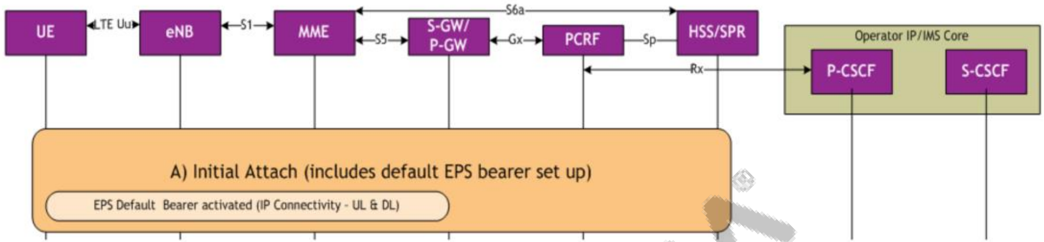
Notes

Objectives

- Identify attach type and options of UE settings for VoLTE.
- Describe initial attach and default bearer setup call flow.
- Analyze initial attach and default bearer setup log.

Notes

Initial Attach



More information on the attach procedure is provided in the "LTE Troubleshooting and Performance Workshop", offered by Qualcomm ("Attach Procedure", 80-W2899-2).

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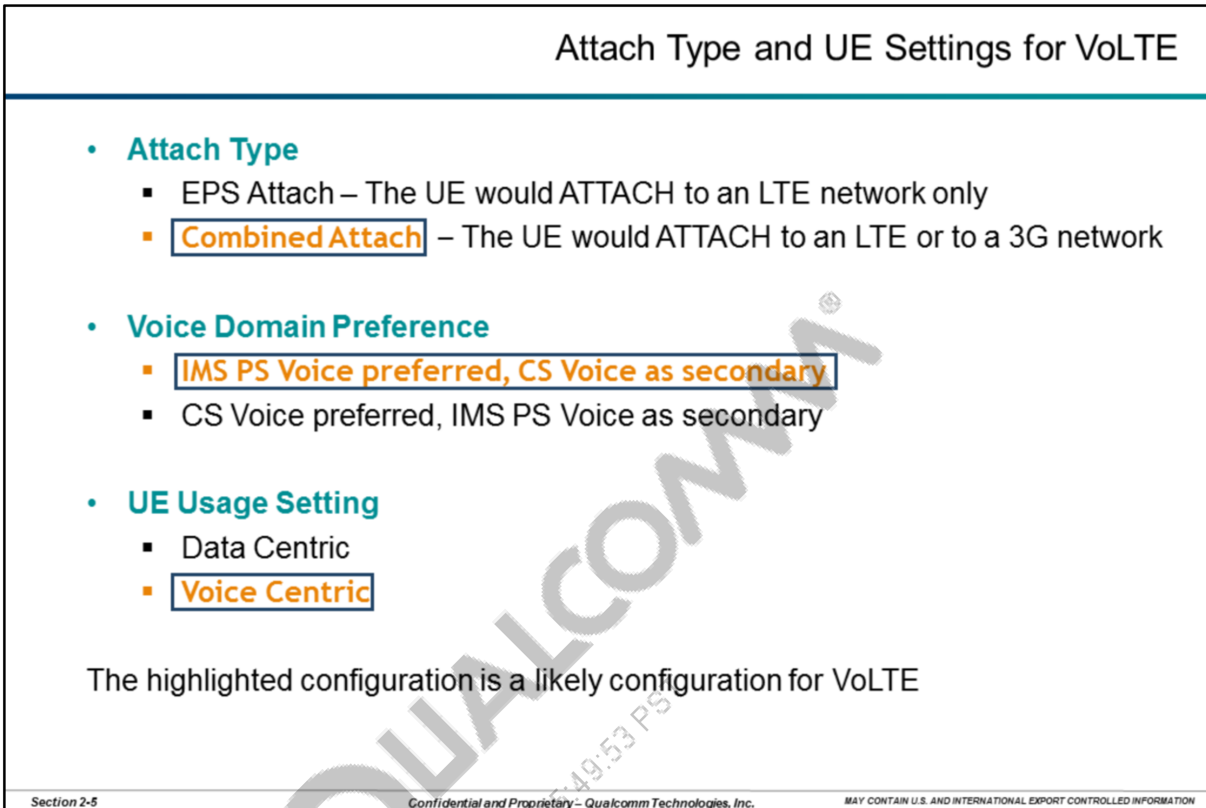
Notes



Attach Type and UE Settings for VoLTE

Attach Type

Based on the determination made during the domain selection process, the UE:

- May elect to register itself in more than one RAT network. This ATTACH type is referred to as *Combined ATTACH*.
- Elects to register on the LTE network only. This ATTACH type is referred to as *EPS ATTACH*.

Under certain circumstances, when the UE initiates Combined ATTACH, the network may indicate a preference for EPS ATTACH only. This is accomplished in the ATTACH Accept message through the "EPS Attach Result" IE. Refer to 3GPP TS 24.301 for more details.

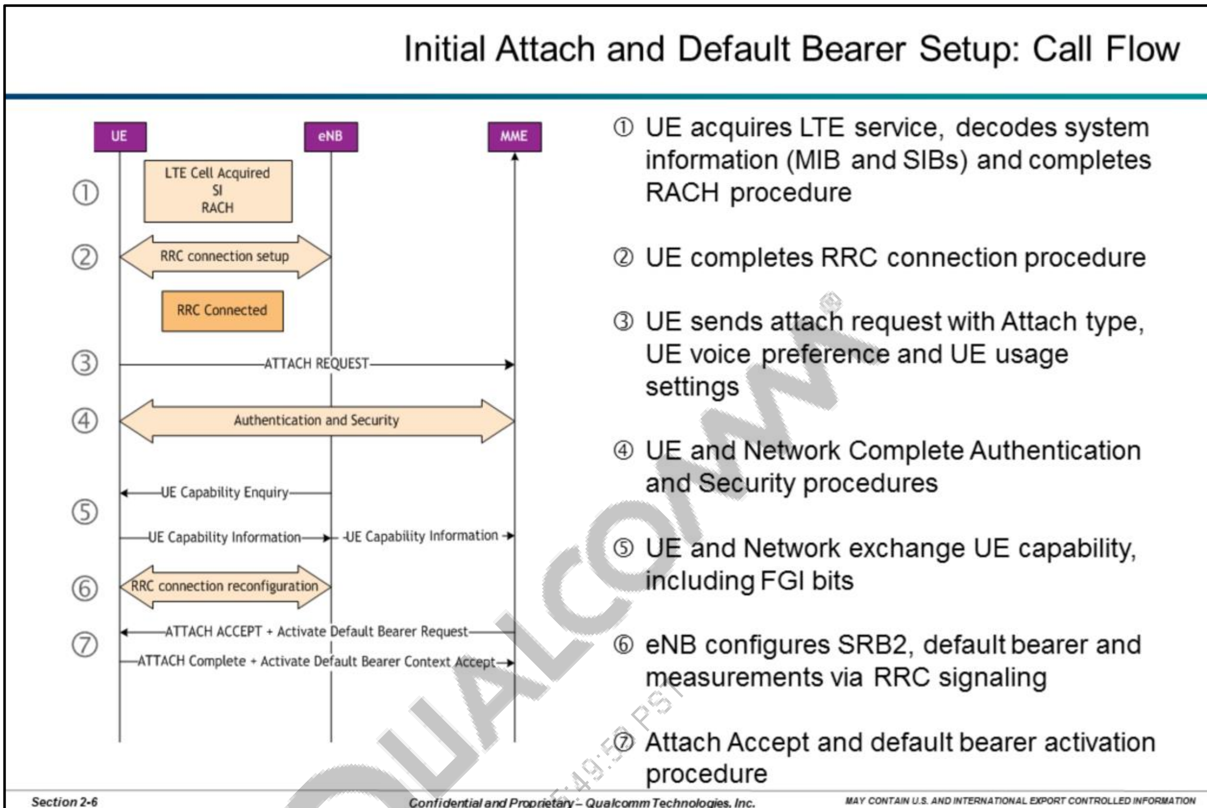
For details of Domain Selection and UE Usage Setting, refer to 3GPP TS 23.221, Clause 7.2.

Voice Domain Preference

- IMS PS Voice preferred, CS Voice as secondary: UE attempts VoLTE (PS) first and will only attempt CS (CSFB or SVRCC) if directed by the network.
- CS Voice preferred, IMS PS Voice as secondary: UE attempts CS (CSFB or SVRCC) first.

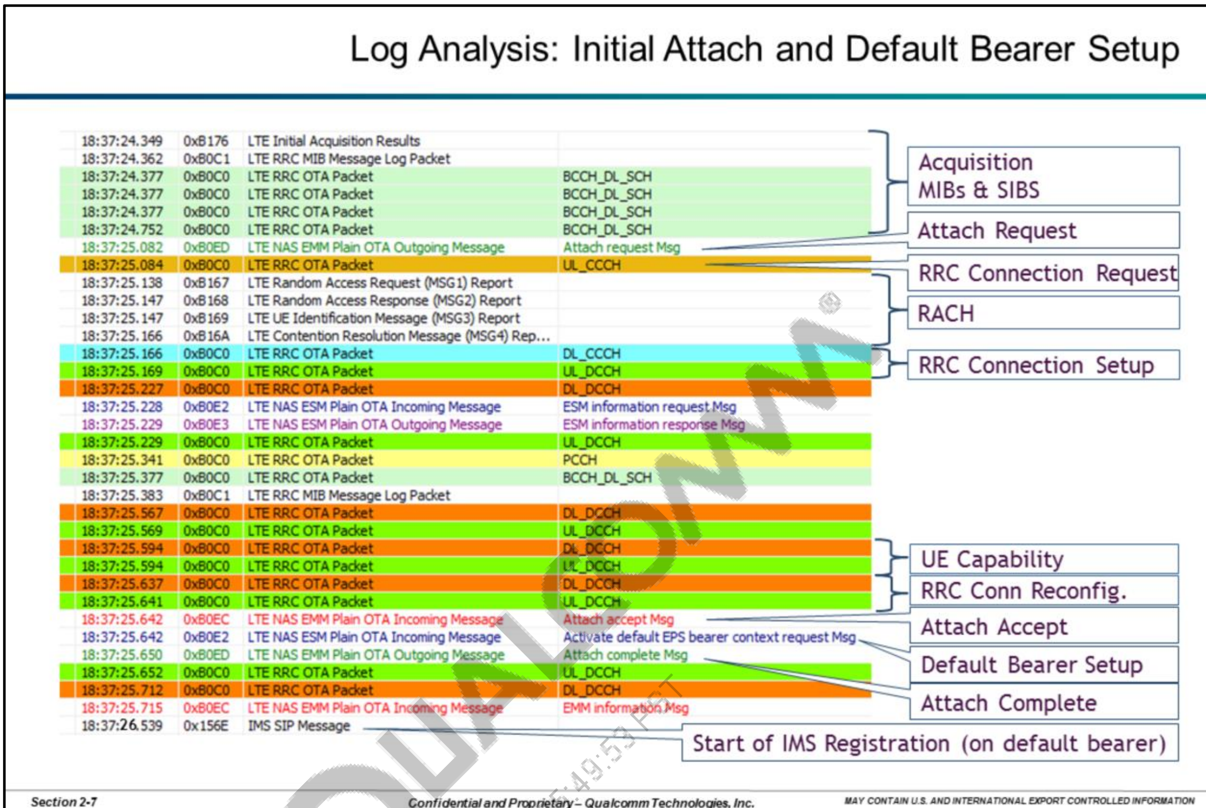
UE Usage Setting

- Data Centric: UE does not support CS voice. An LTE USB modem is an example of such a data-centric device.
- Voice Centric: UE supports CS voice and will camp on a RAT where voice services can be supported.



Initial Attach and Default Bearer Setup: Call Flow

- The default bearer established during the attach procedure is referred to as “attach bearer.”
- The attach bearer configuration is operator dependent and could be either and Internet or IMS PDN bearer


Log Analysis: Initial Attach and Default Bearer Setup
18:37:24.349 0xB176 LTE Initial Acquisition Results
18:37:24.362 0xB0C1 LTE RRC MIB Message Log Packet
18:37:24.377 0xB0C0 LTE RRC OTA Packet BCCH_DL_SCH
18:37:24.377 0xB0C0 LTE RRC OTA Packet BCCH_DL_SCH
18:37:24.377 0xB0C0 LTE RRC OTA Packet BCCH_DL_SCH
18:37:24.752 0xB0C0 LTE RRC OTA Packet BCCH_DL_SCH
18:37:25.082 0xB0ED LTE NAS EMM Plain OTA Outgoing Message Attach request Msg
18:37:25.084 0xB0C0 LTE RRC OTA Packet UL_CCCH
18:37:25.138 0xB167 LTE Random Access Request (MSG1) Report
18:37:25.147 0xB168 LTE Random Access Response (MSG2) Report
18:37:25.147 0xB169 LTE UE Identification Message (MSG3) Report
18:37:25.166 0xB16A LTE Contention Resolution Message (MSG4) Rep...
18:37:25.166 0xB0C0 LTE RRC OTA Packet DL_CCCH
18:37:25.169 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:37:25.227 0xB0C0 LTE RRC OTA Packet DL_DCCH
18:37:25.228 0xB0E2 LTE NAS ESM Plain OTA Incoming Message ESM information request Msg
18:37:25.229 0xB0E3 LTE NAS ESM Plain OTA Outgoing Message ESM information response Msg
18:37:25.229 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:37:25.341 0xB0C0 LTE RRC OTA Packet PCCH
18:37:25.377 0xB0C0 LTE RRC OTA Packet BCCH_DL_SCH
18:37:25.383 0xB0C1 LTE RRC MIB Message Log Packet
18:37:25.567 0xB0C0 LTE RRC OTA Packet DL_DCCH
18:37:25.569 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:37:25.594 0xB0C0 LTE RRC OTA Packet DL_DCCH
18:37:25.594 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:37:25.637 0xB0C0 LTE RRC OTA Packet DL_DCCH
18:37:25.641 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:37:25.642 0xB0EC LTE NAS EMM Plain OTA Incoming Message Attach accept Msg
18:37:25.642 0xB0E2 LTE NAS ESM Plain OTA Incoming Message Activate default EPS bearer context request Msg
18:37:25.650 0xB0ED LTE NAS EMM Plain OTA Outgoing Message Attach complete Msg
18:37:25.652 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:37:25.712 0xB0C0 LTE RRC OTA Packet DL_DCCH
18:37:25.715 0xB0EC LTE NAS EMM Plain OTA Incoming Message EMM information Msg
18:37:26.539 0x156E IMS SIP Message
Acquisition MIBs & SIBS
Attach Request
RRC Connection Request
RACH
RRC Connection Setup
UE Capability
RRC Conn Reconfig.
Attach Accept
Default Bearer Setup
Attach Complete
Start of IMS Registration (on default bearer)
Section 2-7
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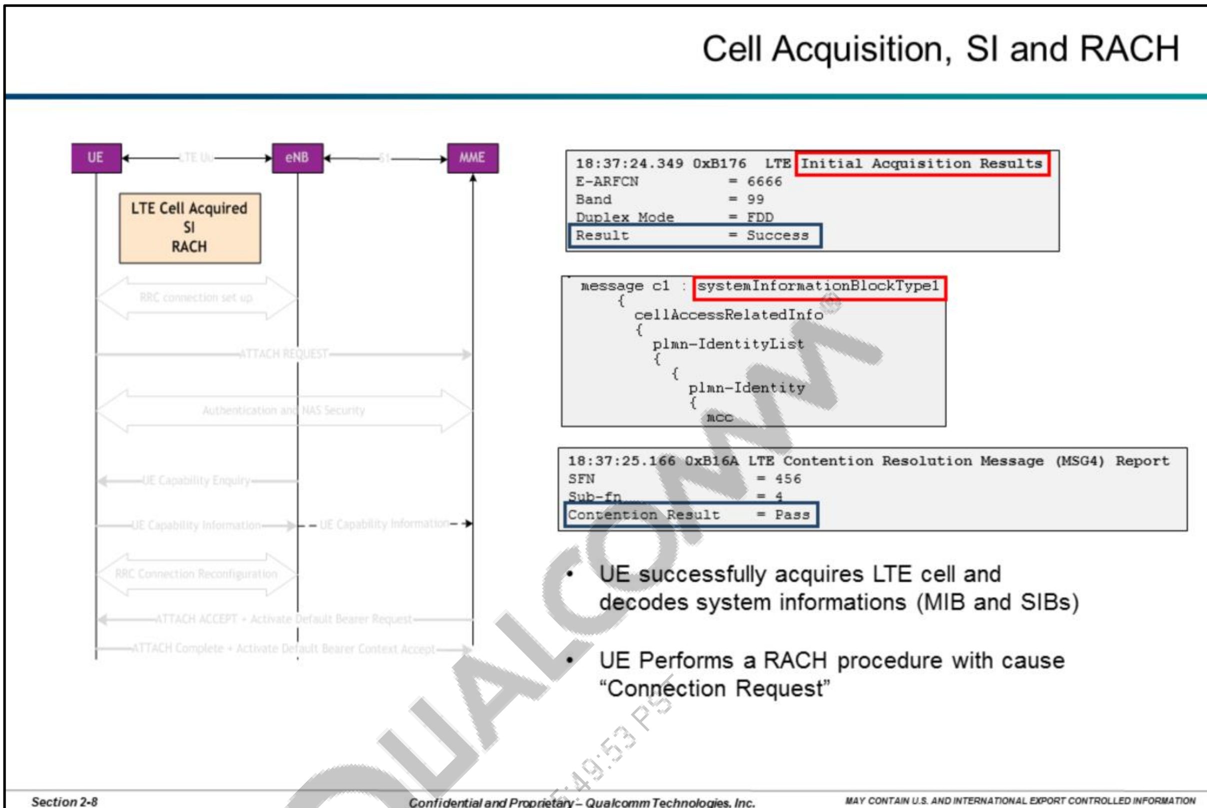
Notes


Cell Acquisition, SI and RACH
UE
eNB
MME
LTE Cell Acquired
SI
RACH
RRC connection set up
ATTACH REQUEST
Authentication and NAS Security
UE Capability Enquiry
UE Capability Information
UE Capability Information
RRC Connection Reconfiguration
ATTACH ACCEPT + Activate Default Bearer Request
ATTACH Complete + Activate Default Bearer Context Accept
18:37:24.349 0xB176 LTE Initial Acquisition Results
E-ARFCN = 6666
Band = 99
Duplex Mode = FDD
Result = Success
message c1 : systemInformationBlockType1
{
cellAccessRelatedInfo
{
plmn-IdentityList
{
{
plmn-Identity
{
mcc
18:37:25.166 0xB16A LTE Contention Resolution Message (MSG4) Report
SFN = 456
Sub-fn = 4
Contention Result = Pass
• UE successfully acquires LTE cell and decodes system informations (MIB and SIBs)
• UE Performs a RACH procedure with cause "Connection Request"
Section 2-8
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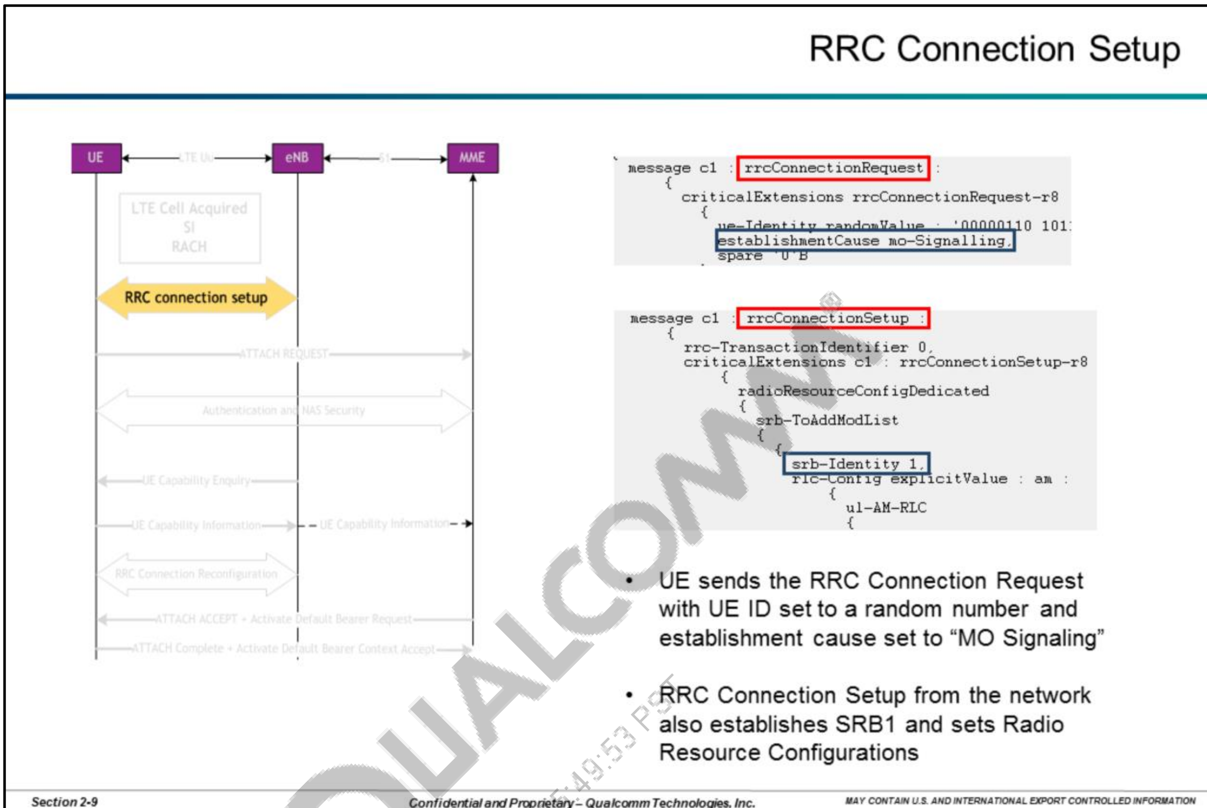
Notes


RRC Connection Setup
UE
eNB
MME
LTE Cell Acquired
SI
RACH
RRC connection setup
ATTACH REQUEST
Authentication and NAS Security
UE Capability Enquiry
UE Capability Information
UE Capability Information
RRC Connection Reconfiguration
ATTACH ACCEPT + Activate Default Bearer Request
ATTACH Complete + Activate Default Bearer Context Accept
message c1 : rrcConnectionRequest :
{
criticalExtensions rrcConnectionRequest-r8
{
ue-Identity randomValue : '00000110 101
establishmentCause mo-Signalling,
spare '0'B
message c1 : rrcConnectionSetup :
{
rrc-TransactionIdentifier 0,
criticalExtensions c1 : rrcConnectionSetup-r8
{
radioResourceConfigDedicated
{
srb-ToAddModList
{
{
srb-Identity 1,
rlc-Config explicitValue : am :
{
ul-AM-RLC
{
• UE sends the RRC Connection Request with UE ID set to a random number and establishment cause set to "MO Signaling"
• RRC Connection Setup from the network also establishes SRB1 and sets Radio Resource Configurations
Section 2-9
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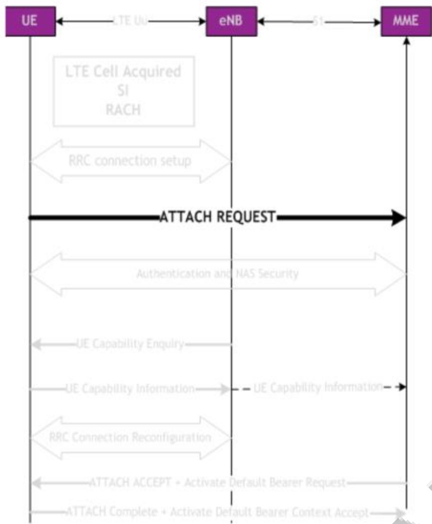
Notes

Attach Request



0xB0ED LTE NAS EMM Plain OTA Outgoing Message -- Attach request Msg

```
pkt_version = 1 (0x1)
rel_number = 9 (0x9)
rel_version_major = 5 (0x5)
rel_version_minor = 0 (0x0)
security_header_or_skip_ind = 0 (0x0)
prot_disc = 7 (0x7) (EPS mobility management messages)
msg_type = 65 (0x41) (Attach request)
lte_emm_msg
  emm_attach_request
    tsc = 0 (0x0) (cached sec context)
    nas_key_set_id = 0 (0x0)
    att_type = 2 (0x2) (combined EPS/IMSI attach)
...
...
 voice_domain_pref_incl = 1 (0x1)
    voice_domain_pref
      length = 1 (0x1)
      UE usage setting = 1 (0x1) (Data centric
   voice_domain_pref_for_EUTRAN = 3 (0x3) (IMS PS Voice preferred, CS Voice as secondary)
```

ATTACH Request includes

- Attach type (Combined attach)
- UE Usage setting = (Data centric)
- Voice Domain Preference = (IMS PS Voice preferred, CS Voice as secondary)

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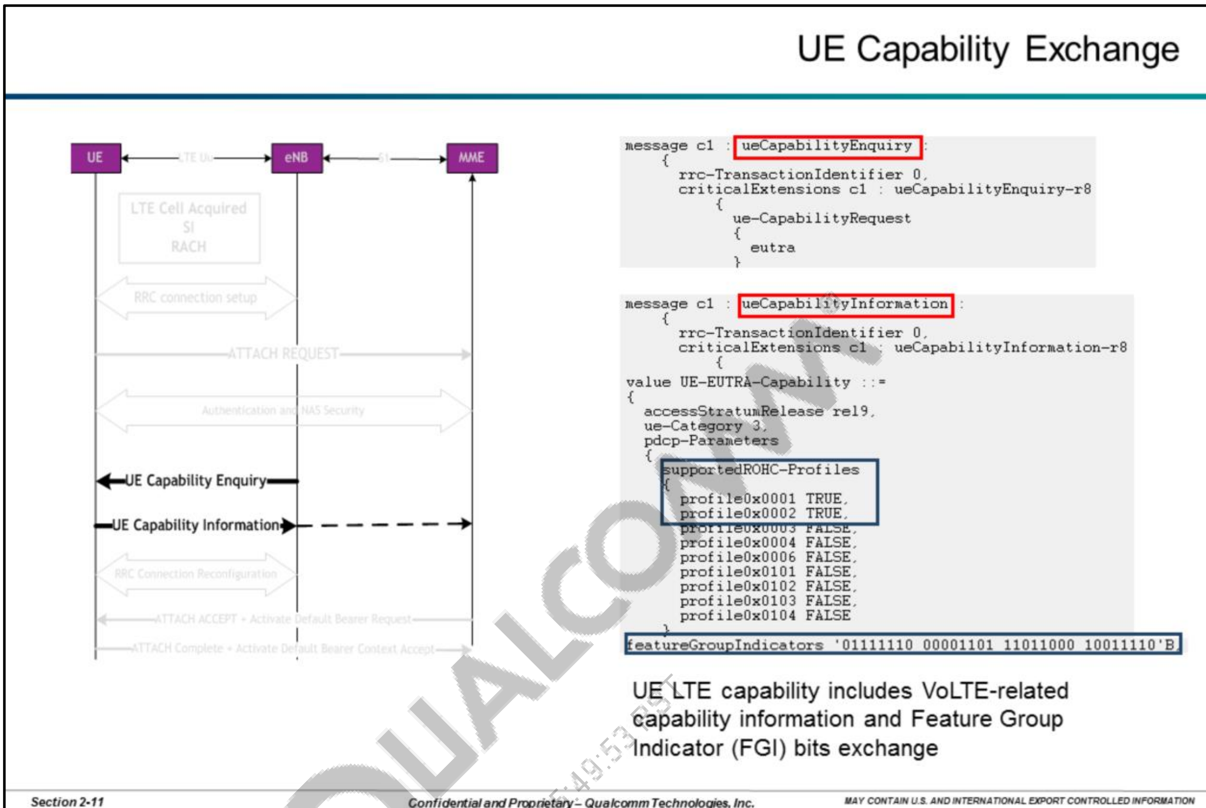
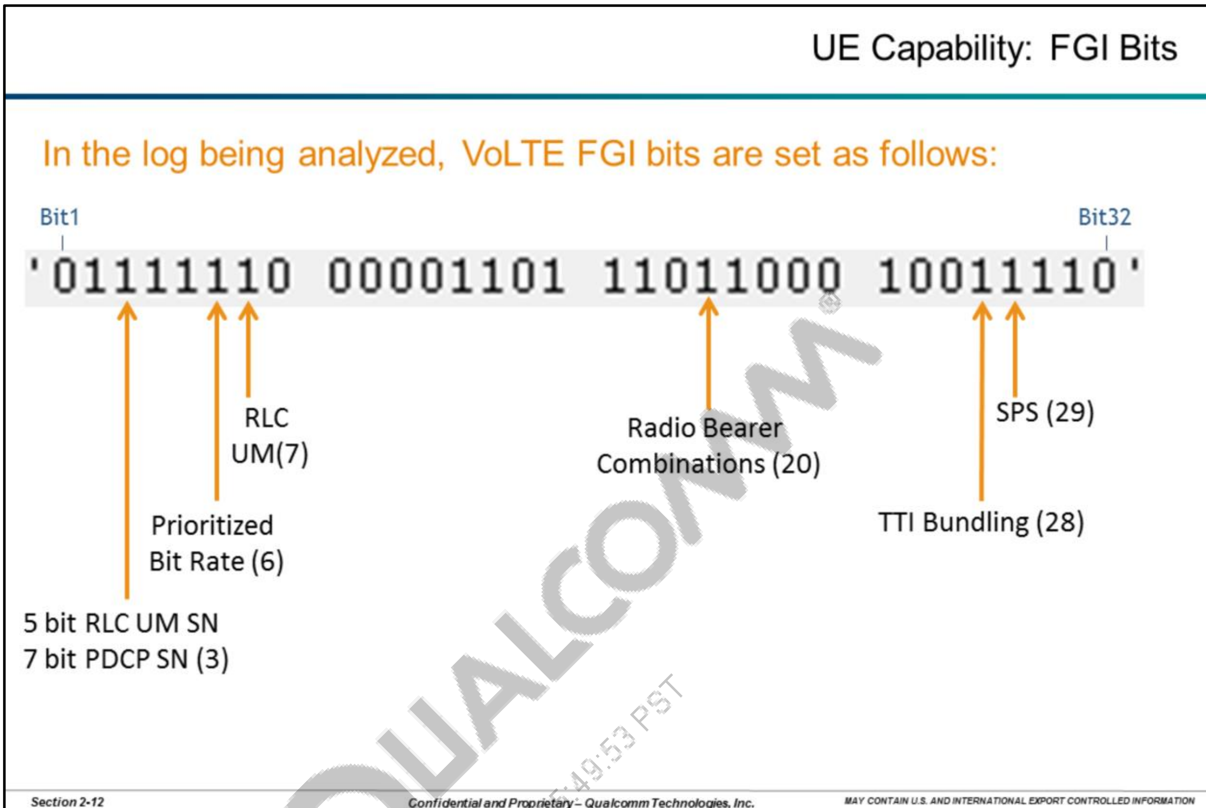
Notes



UE Capability Exchange

VoLTE UE and network must support the following RoHC profiles for both IPv4 and IPv6:

- Profile 0x0001: RTP/UDP/IP
- Profile 0x0002: UDP/IP



UE Capability: FGI Bits

For detailed information about FGI bits, refer to 3GPP TS 36.331, Release-9, Annex B.

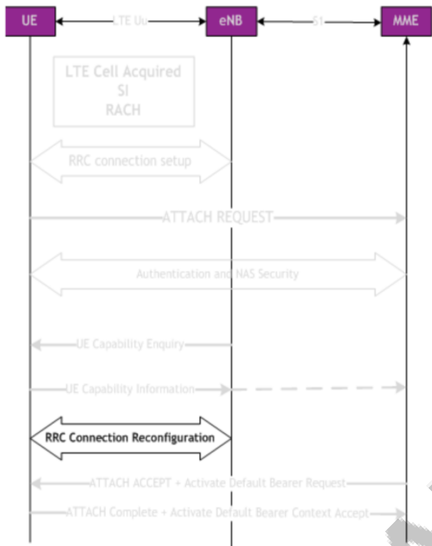
Using **Feature Group Indicators (FGI) bits,** the UE signals to the network that a particular feature is supported. This is done by setting the corresponding FGI bit to ‘1’.

VoLTE- and SRVCC-related FGI bits are given below.

Feature	FGI Bit(s)
5 bit RLC UM SN; 7 bit PDCP SN	3
Short and Long DRX Cycles	4, 5
Prioritized bit rate	6
RLC UM	7
LTE to UMTS active HO	8
SRVCC	9, 11, 27

Feature	FGI Bit(s)
Event B1	15
Event B2	22-24, 26
Radio Bearer Combinations	20
PUSCH Hopping	21
TTI Bundling	28
SPS	29

RRC Connection Reconfiguration




```
message c1 : rrcConnectionReconfiguration :
    {
      rrc-TransactionIdentifier 0,
      criticalExtensions c1 : rrcConnectionReconfiguration-r8
        {
          measConfig
          {
            measObjectToAddModList
            {
              {
                measObjectId 1,
```

```
srb-ToAddModList
{
  {
    srb-Identity 2,
    rlc-Config explicitValue : am :
      {
        ul-AM-RLC
```

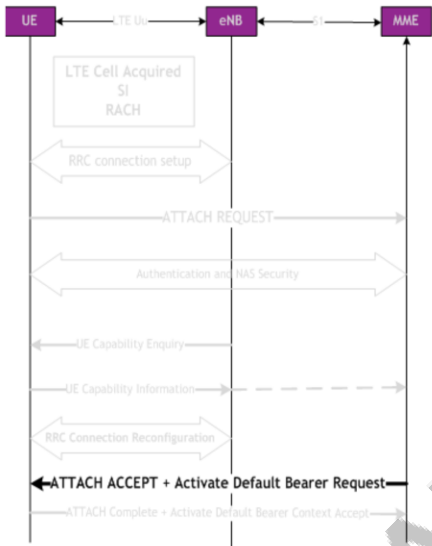
```
drb-ToAddModList
{
  {
    eps-BearerIdentity 5,
    drb-Identity 3,
    pdcp-Config
    {
      discardTimer ms300,
      rlc-AM
```

Network configures the following through RRC Connection Reconfiguration:

- VoLTE-related RAN features
- Measurement(s) configuration(s)
- SRB2 (for NAS signaling)
- Default bearer

Notes

Attach Accept



Attach Accept includes the following:

- Activate default EPS bearer context request
- PDN address
- APN name
- P-CSCF address*
- IMS Voice over PS support indication

```
prot_disc = 7 (0x7) (EPS mobility management messages)
msg_type = 66 (0x42) (Attach accept)
lte_emm_msg
  emm_attach_accept
    attach_result = 2 (0x2) (combined EPS/IMSI attach)
```

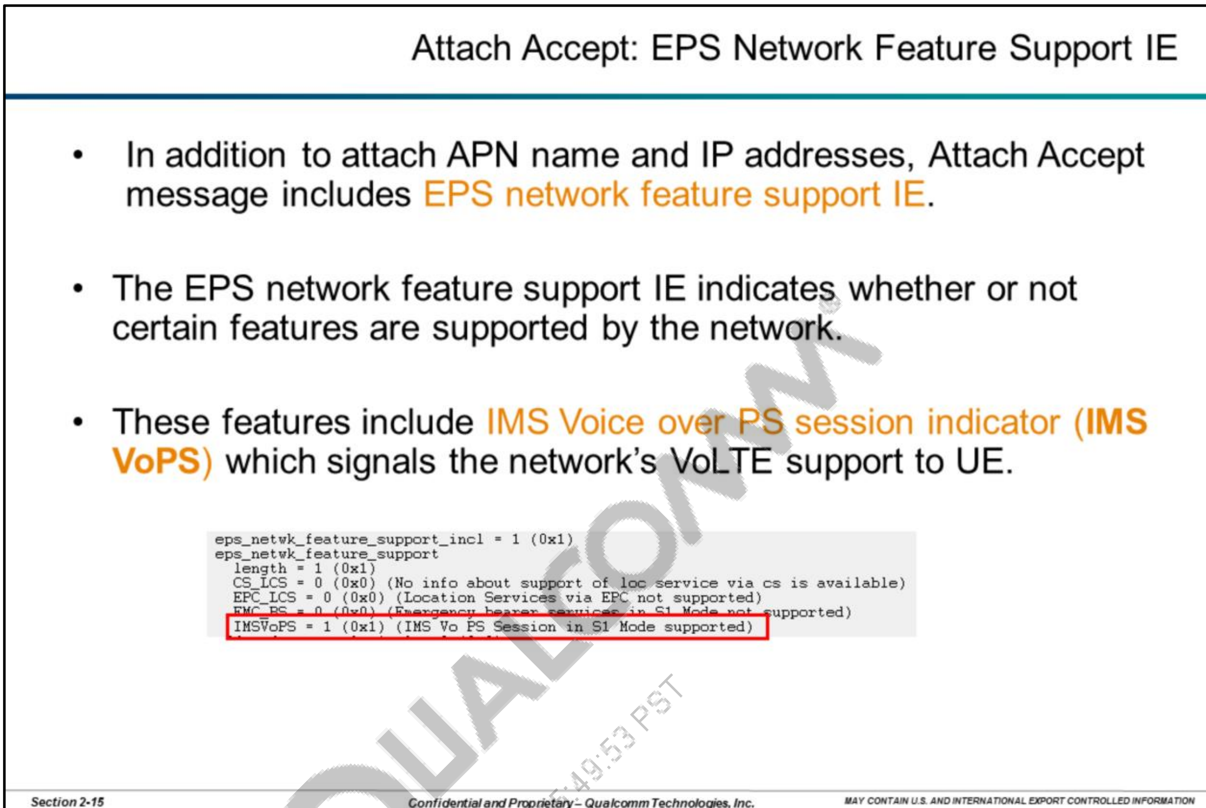
```
esm_msg_container
  eps_bearer_id_or_skip_id = 5 (0x5)
  prot_disc = 2 (0x2) (EPS session management messages)
  trans_id = 29 (0x1d)
  msg_type = 193 (0xc1) (Activate default EPS bearer context request)
  lte_esm_msg
    act_def_eps_bearer_context_req
      eps_qos
        qci = 5 (0x5) (QC5)
```

From RRC

```
drb-ToAddModList
{
  {
    eps-BearerIdentity 5,
    drb-Identity 3,
```

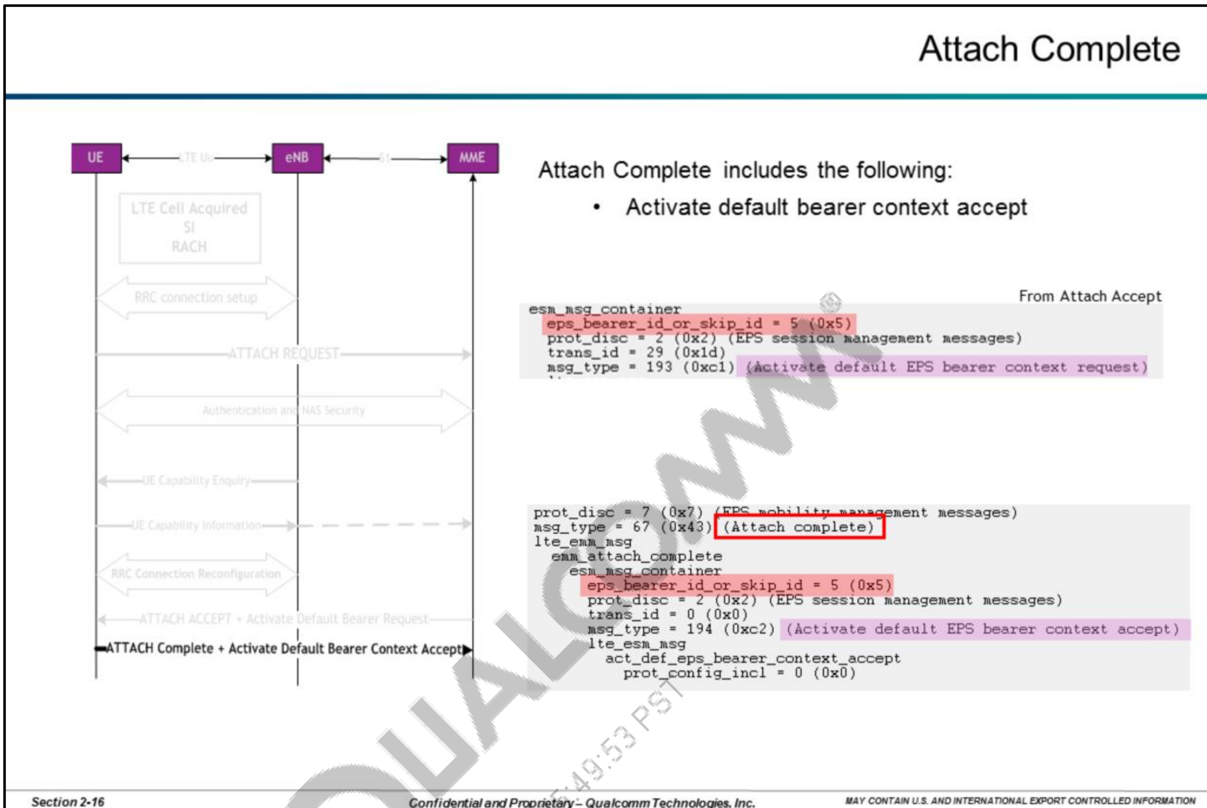
*Covered in Section 3 of this workshop

Notes



Attach Accept: EPS Network Feature Support IE

For detailed information about EPS network feature support IE, refer to 3GPP TS 24.301, Paragraph 9.9.3.12A .


Attach Complete
UE
eNB
MME
LTE Uu
S1
LTE Cell Acquired
SI
RACH
RRC connection setup
ATTACH REQUEST
Authentication and NAS Security
UE Capability Enquiry
UE Capability Information
RRC Connection Reconfiguration
ATTACH ACCEPT + Activate Default Bearer Request
ATTACH Complete + Activate Default Bearer Context Accept
Attach Complete includes the following:
• Activate default bearer context accept
From Attach Accept
esm_msg_container
eps_bearer_id_or_skip_id = 5 (0x5)
prot_disc = 2 (0x2) (EPS session management messages)
trans_id = 29 (0x1d)
msg_type = 193 (0xc1) (Activate default EPS bearer context request)
prot_disc = 7 (0x7) (EPS mobility management messages)
msg_type = 67 (0x43) (Attach complete)
lte_emm_msg
emm_attach_complete
esm_msg_container
eps_bearer_id_or_skip_id = 5 (0x5)
prot_disc = 2 (0x2) (EPS session management messages)
trans_id = 0 (0x0)
msg_type = 194 (0xc2) (Activate default EPS bearer context accept)
lte_esm_msg
act_def_eps_bearer_context_accept
prot_config_incl = 0 (0x0)
Section 2-16
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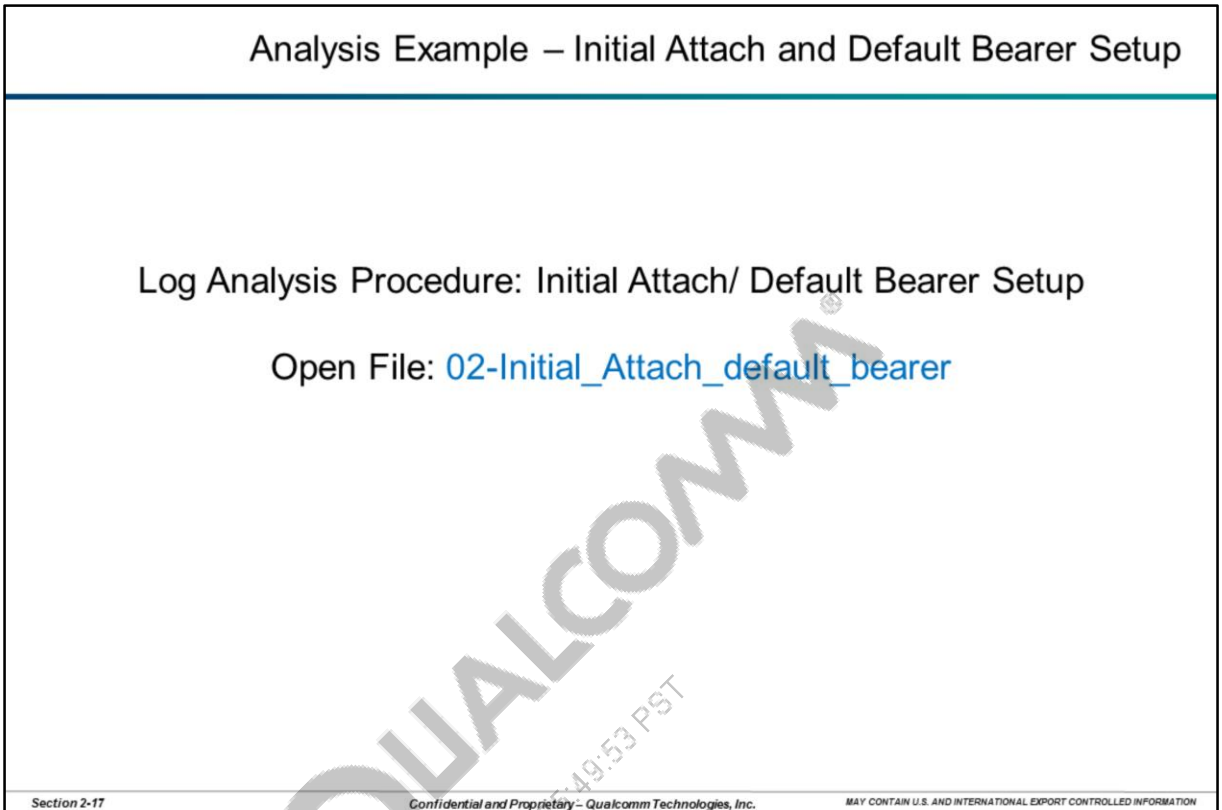
Notes


Analysis Example – Initial Attach and Default Bearer Setup
Log Analysis Procedure: Initial Attach/ Default Bearer Setup
Open File: 02-Initial_Attach_default_bearer
Section 2-17
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Notes

Initial Attach and Default Bearer Setup: Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	Cell Acquisition	0xB176	18:37:24.349	Successful acquisition
2	MIB, SIBs decoding	0xB0C1 0xB0C0	18:37:24.362 18:37:24.377	MIB, SIB1 and SIB2 are decoded
3	Attach Request	0xB0ED	18:37:25.082	Attach type: Combined Attach Usage Setting: Data-Centric Voice domain pref: IMS PS Voice preferred PDN connectivity request
4	RRC Connection Request	0xB0C0	18:37:25.084	establishmentCause mo-Signaling
5	RACH Procedure	0xB167 0xB168 0xB169 0xB16A	18:37:25.138 Through 18:37:25.166	MSG1 through MSG4 Successful contention resolution at msg4
6	RRC Connection Setup/ Setup Complete	0xB0C0	18:37:25.166 18:37:25.169	Setup od SRB1 (srb-Identity 1)
7	RRC Security Procedure	0xB0C0	18:37:25.567 18:37:25.569	securityModeComplete

Notes

Initial Attach and Default Bearer Setup: Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
8	UE Capability Inquiry	OxB0C0	18:37:25.594	ue-CapabilityRequest set to 'EUTRA"
9	UE Capability Information	OxB0C0	18:37:25.594	RoHC Profiles 1 and 2 are supported; FGI bits are properly set for VoLTE support
10	RRC Connection Reconfiguration	0xB0C0	18:37:25.637	srb-ToAddModList: srb-Identity 2 drb-ToAddModList: eps-BearerIdentity 5
11	Attach Accept	0xB0EC	18:37:25.642	Activate default EPS bearer context request; IP addresses; IMS VoPS set to '1' QCI = 5 for the default bearer
12	Activate Dedicated Bearer Req	0xB0E2	18:37:25.642	Activate default EPS bearer context request
13	Attach Complete	0xB0ED	18:37:25.650	Activate default EPS bearer context accept
14	IMS SIP Registration	0x156E	18:37:26.539	IMS_SIP_REGISTER (from UE to Network)

Section 2-19 Confidential and Proprietary – Qualcomm Technologies, Inc. MAY CONTAIN U.S. AND INTERNATIONAL EXPORT CONTROLLED INFORMATION

Notes

Initial Attach and Default Bearer – Questions

Fill the blanks using the log file:

1. What is the Physical Cell ID of the cell the UE camped on? ________________
2. What is the Attach type the UE is requesting? _______________
3. What is the UE's Voice preference? ____________________
4. Does the UE announce support for TTI Bundling? ____________ How?__________________
5. Does the UE announce RoHC support? ____________ How?__________________
6. Was SRB2 setup? ______ When? _______________
7. Does the network signal VoLTE support? __________, How?_________________________
8. Is a default Bearer activated? ______ When?__________
9. Is a dedicated Bearer established? _____ When?_____________

Notes

Initial Attach and Default Bearer– Answers

Fill the blanks using the log file:

1. What is the Physical Cell ID of the cell the UE camped on? 267 (18:37:24.349)
2. What is the Attach type the UE is requesting? Combined Attach (18:37:25.082)
3. What is the UE's Voice preference? IMS PS Voice preferred, CS Voice as secondary
4. Does the UE announce support for TTI Bundling? Yes How? FGI bit 28 set to '1' (UE Capability Information message)
5. Does the UE announce RoHC support? YES, Profiles 0001 and 0002 How? In the UE Capability Information message
6. Was SRB2 setup? YES When? RRC Connection reconfiguration (18:37:25.637)
7. Does the network support VoLTE? Yes How? IMS VoPS set to '1' in the Attach Accept message
8. Is a default Bearer activated? Yes When? In the Attach complete message
9. Is a dedicated Bearer established? No When? N/A

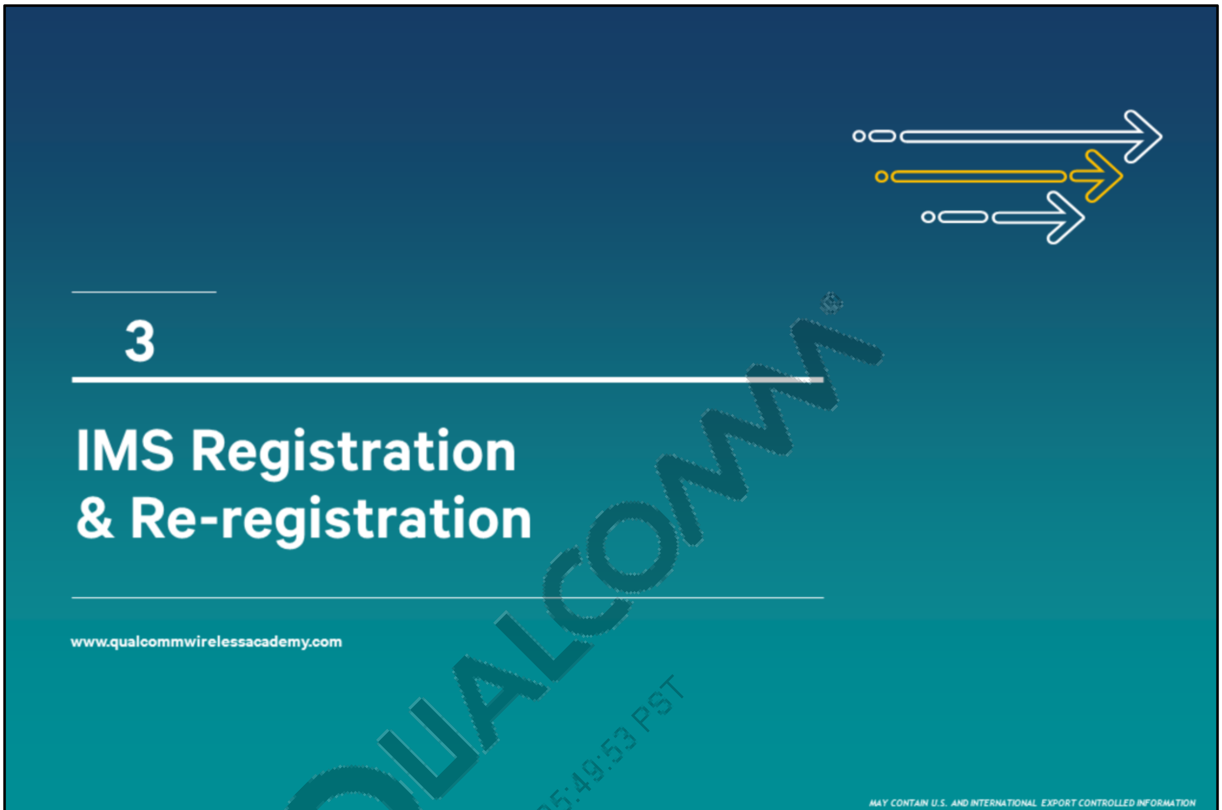
Notes

Specifications References

Specifications	Title
3GPP TS 23.221	Architectural requirements
3GPP TS 36.331	E-UTRA Radio Resource Control (RRC) protocol specification
3GPP TS 24.301	Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS)
3GPP TS 36.321	E-UTRA Medium Access Control (MAC) protocol specification

Specifications References

3GPP LTE specifications available at www.3gpp.org.


3
IMS Registration
& Re-registration
www.qualcommwirelessacademy.com
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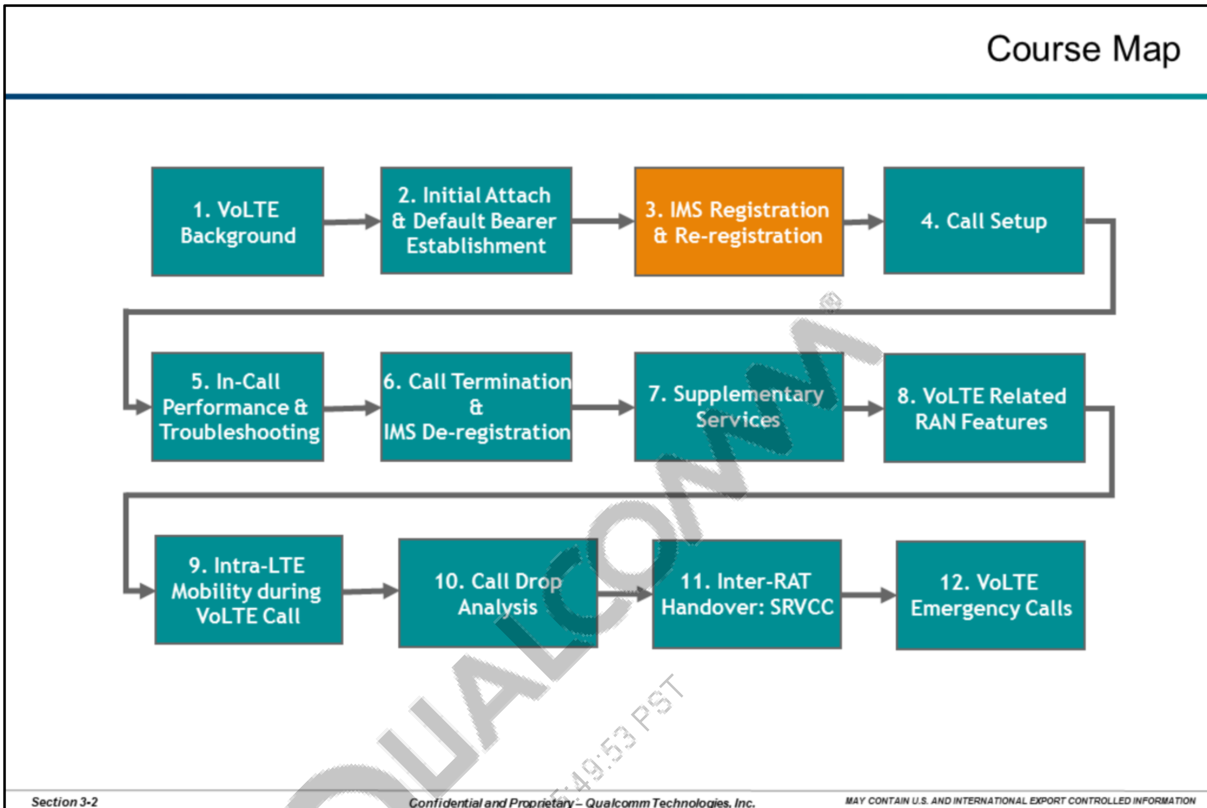
Course Map
1. VoLTE Background
2. Initial Attach & Default Bearer Establishment
3. IMS Registration & Re-registration
4. Call Setup
5. In-Call Performance & Troubleshooting
6. Call Termination & IMS De-registration
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12. VoLTE Emergency Calls
Section 3-2
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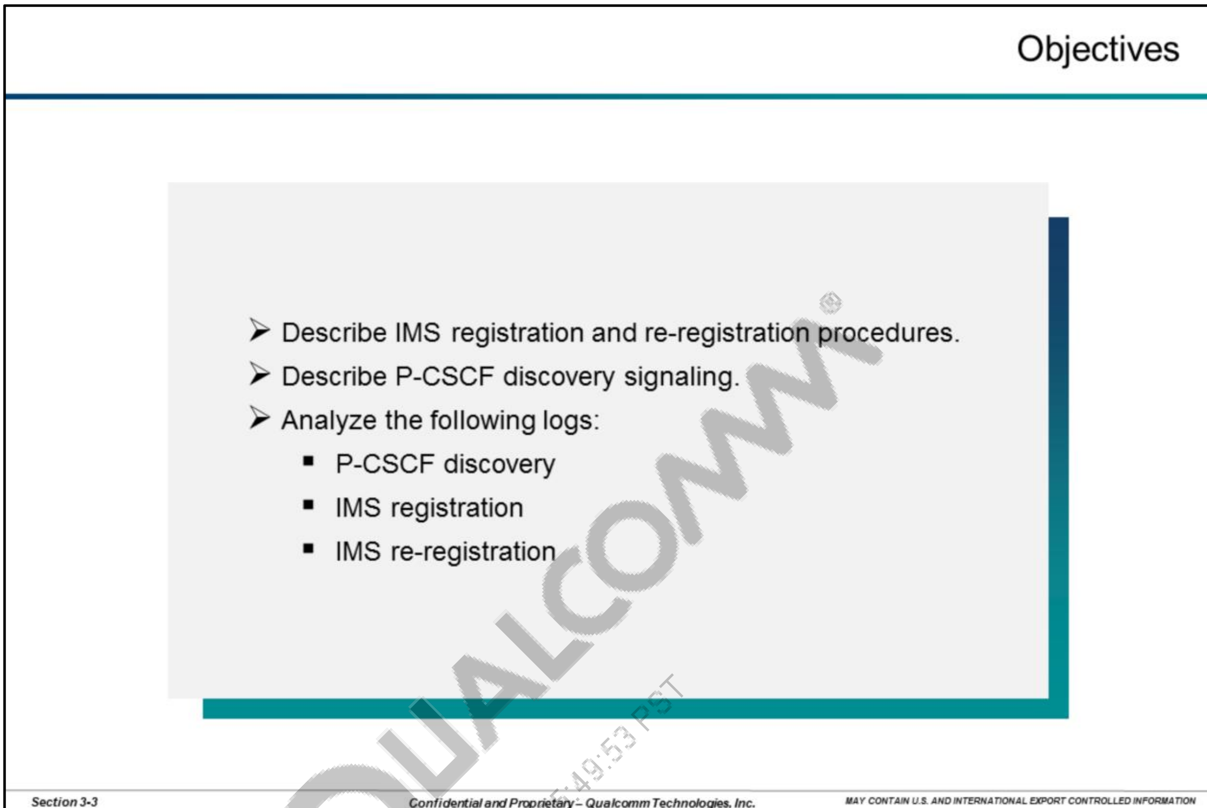
Notes


Objectives
Describe IMS registration and re-registration procedures.
Describe P-CSCF discovery signaling.
Analyze the following logs:
P-CSCF discovery
IMS registration
IMS re-registration
Section 3-3
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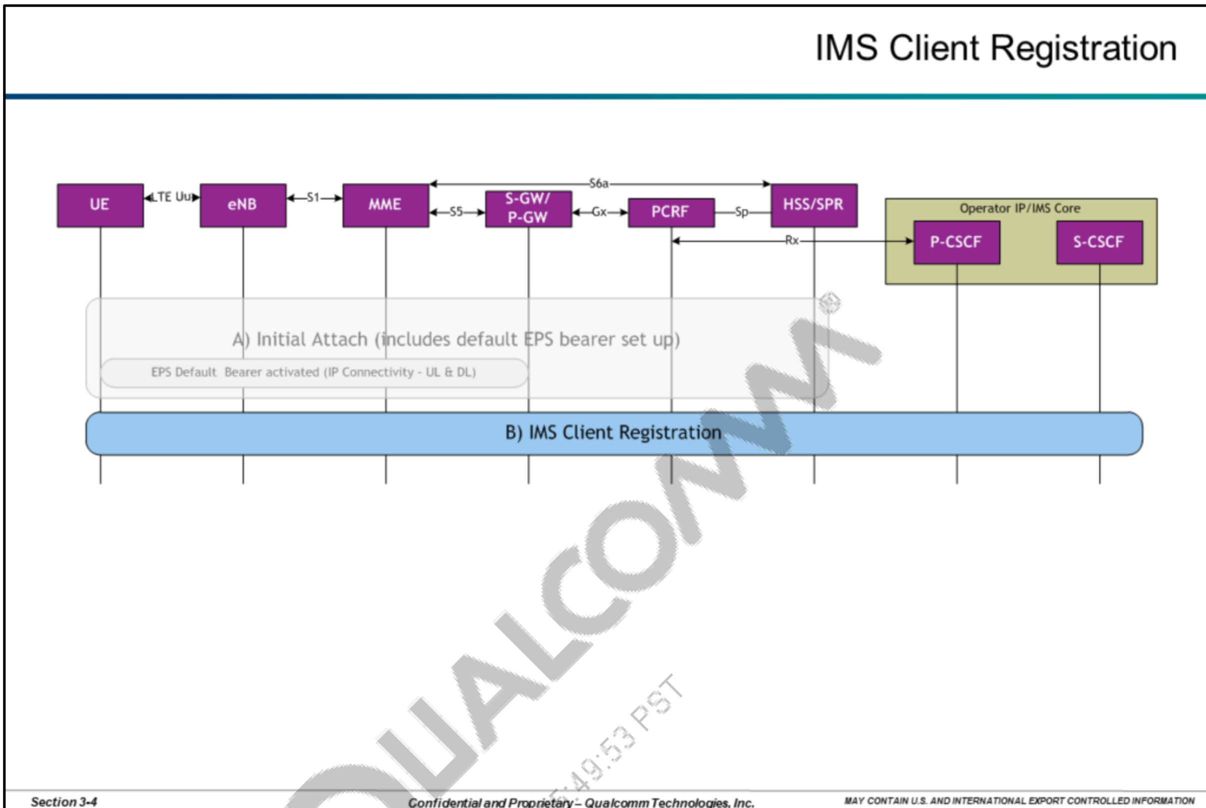
Notes


IMS Client Registration
UE
LTE Uu
eNB
S1
MME
S6a
S5
S-GW/
P-GW
Gx
PCRF
Sp
HSS/SPR
Rx
Operator IP/IMS Core
P-CSCF
S-CSCF
A) Initial Attach (includes default EPS bearer set up)
EPS Default Bearer activated (IP Connectivity - UL & DL)
B) IMS Client Registration
Section 3-4
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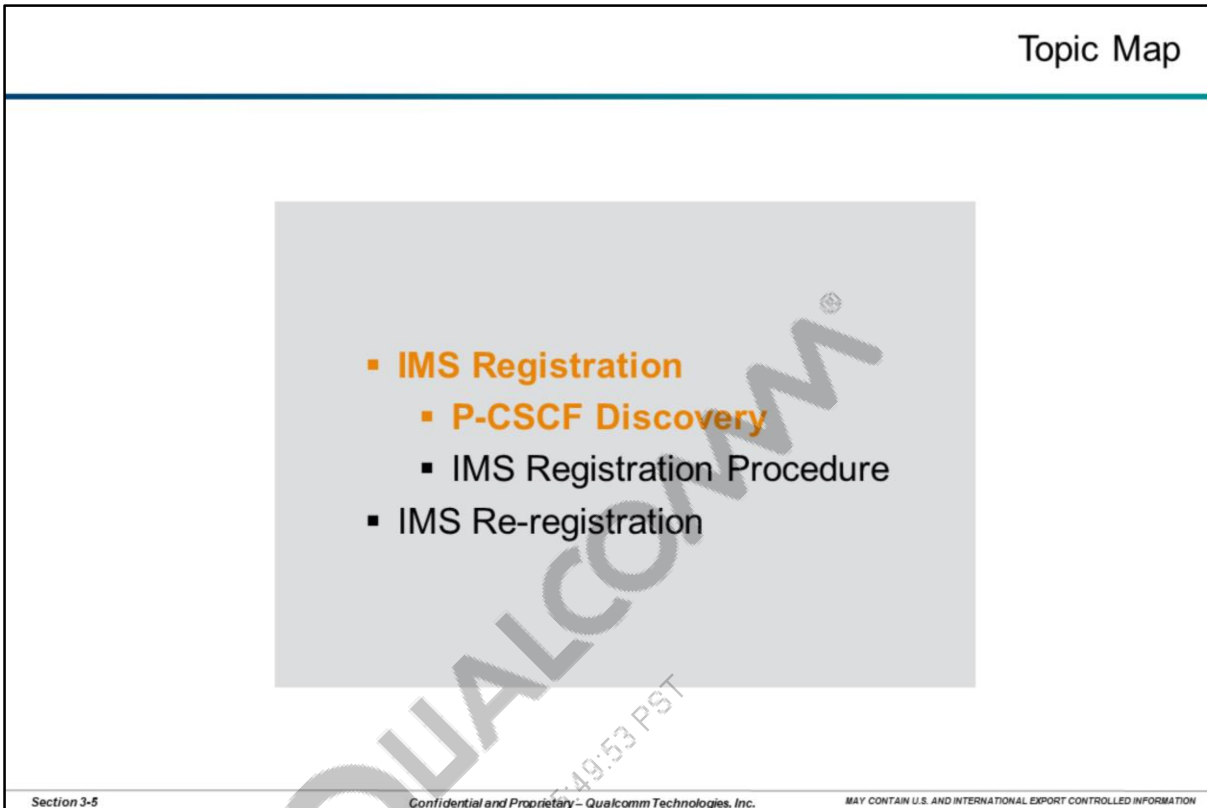
Notes


Topic Map
▪ IMS Registration
▪ P-CSCF Discovery
▪ IMS Registration Procedure
▪ IMS Re-registration
Section 3-5
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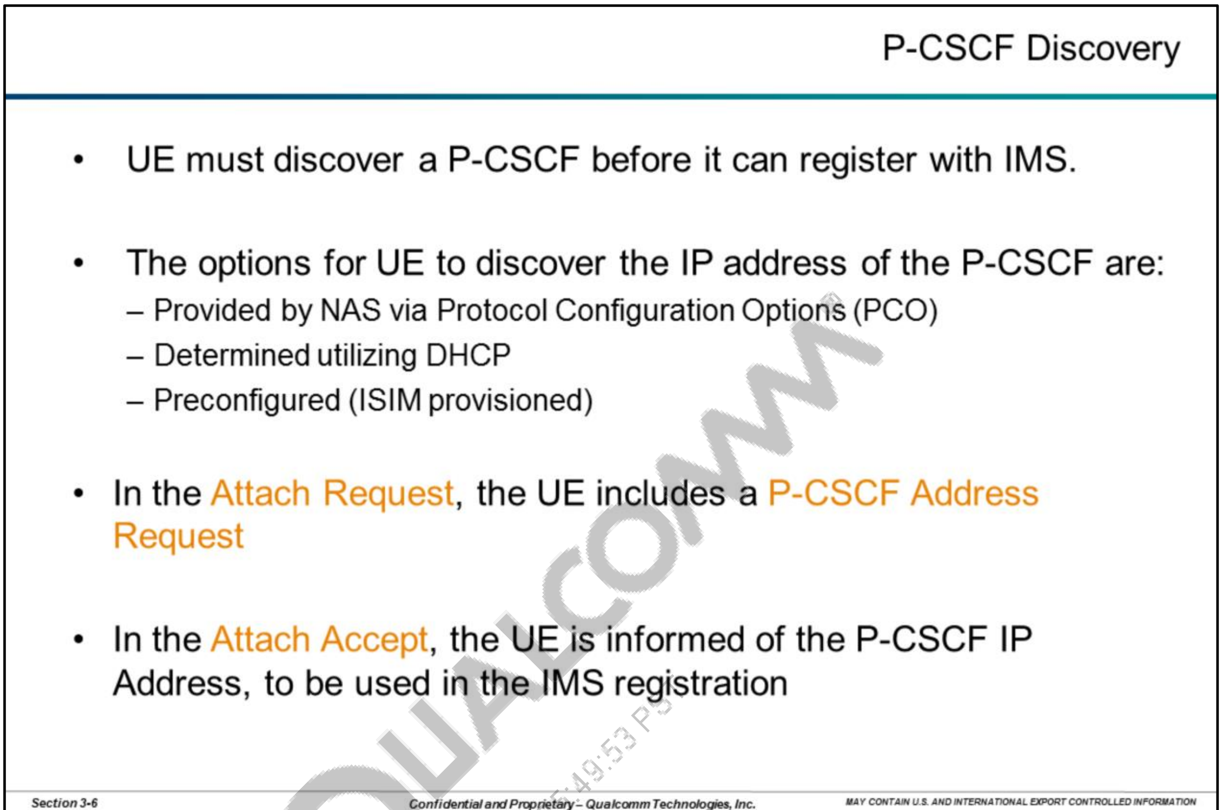
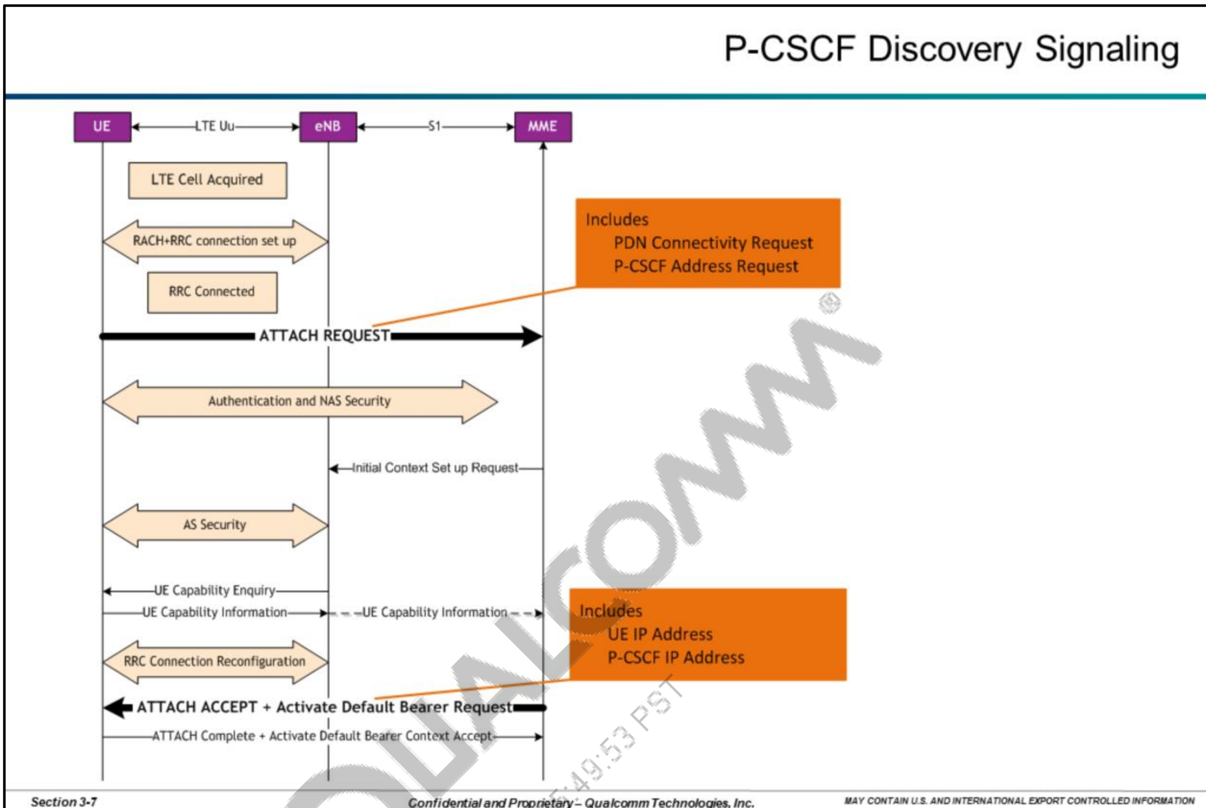
Notes



P-CSCF Discovery

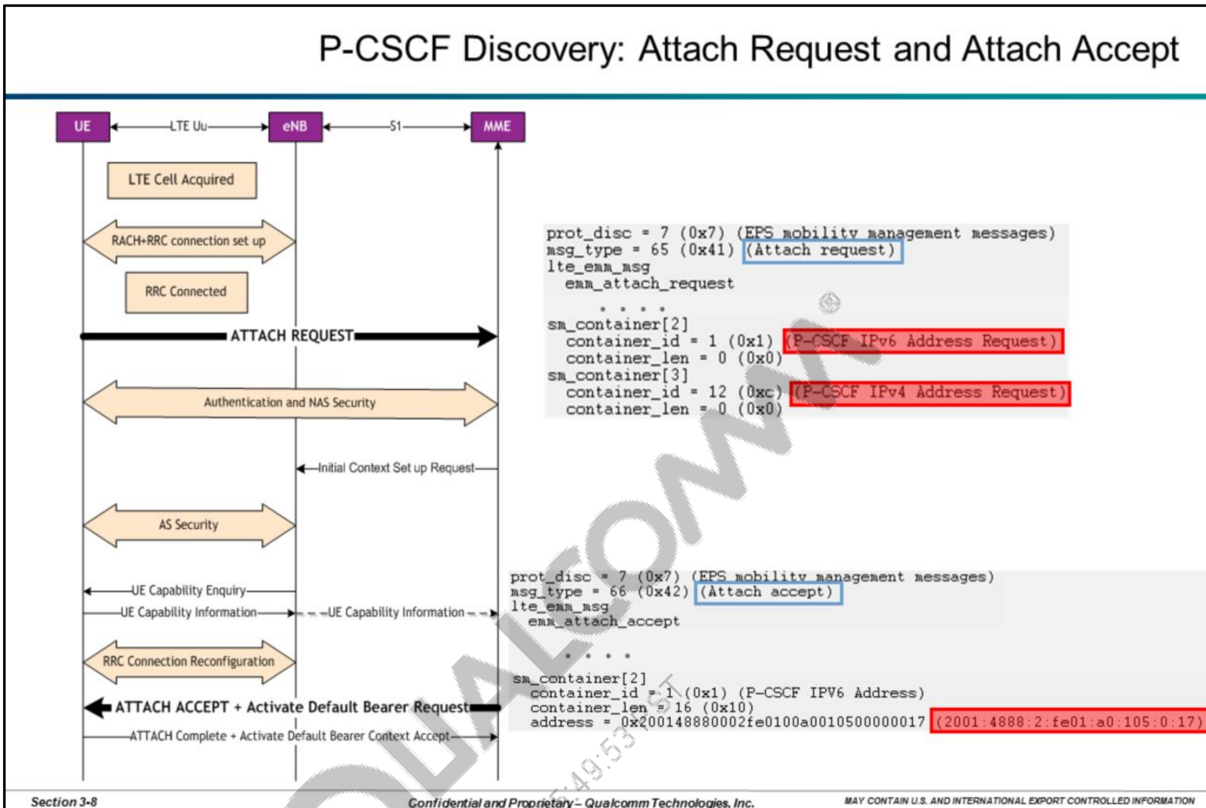
P-CSCF (Proxy Call Session Control Function) is the gateway to the IMS domain. It serves as the outbound proxy server for the UE. The UE must discover a P-CSCF before it can perform IMS registration. It needs to determine the IP address of the P-CSCF, the server port of the P-CSCF, and a transport protocol to exchange signaling with the P-CSCF. The process to determine this triplet is referred to as P-CSCF discovery. Signaling related to P-CSCF discovery can be performed over any bearer and there are no related QoS requirements.

P-CSCF discovery can be accomplished in the ways outlined above. This course discusses the P-CSCF discovery process using PCO during bearer activation.



P-CSCF Discovery Signaling

- As a part of the Attach Request procedure, UE requests IP address of P-CSCF.
- UE can request an IPv4 or IPv6 address and the network assigns the IP address in the Attach Accept message.



P-CSCF Discovery: Attach Request and Attach Accept

- The UE requested IPv4 or IPv6 address of the P-CSCF in the Attach Request.
- Network responded with an IPv6 Address of the P-CSCF in the Attach Accept.

Analysis Example – P-CSCF Discovery

Log Analysis Procedure: P-CSCF Discovery

Open File: 02-Initial_Attach_default_bearer

Analysis Files

P-CSCF Discovery: Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	Attach Request	0xB0ED	18:37:25.082	The UE requested P-CSCF IP Address
2	Attach Accept	0xB0EC	18:37:25.642	P-CSCF IP Address is signaled to the UE

Analysis Summary

The arrival of messages during logging could impact the order in which time stamps are shown.

P-CSCF Discovery – Questions

Fill the blanks using the log file:

1. Did the UE request P-CSCF IP address? ________; Where? ________________
2. What type of P-CSCF IP address did the UE request? __________________
3. What type of P-CSCF IP address was the UE granted? __________________

Notes

P-CSCF Discovery – Answers

Fill the blanks using the log file:

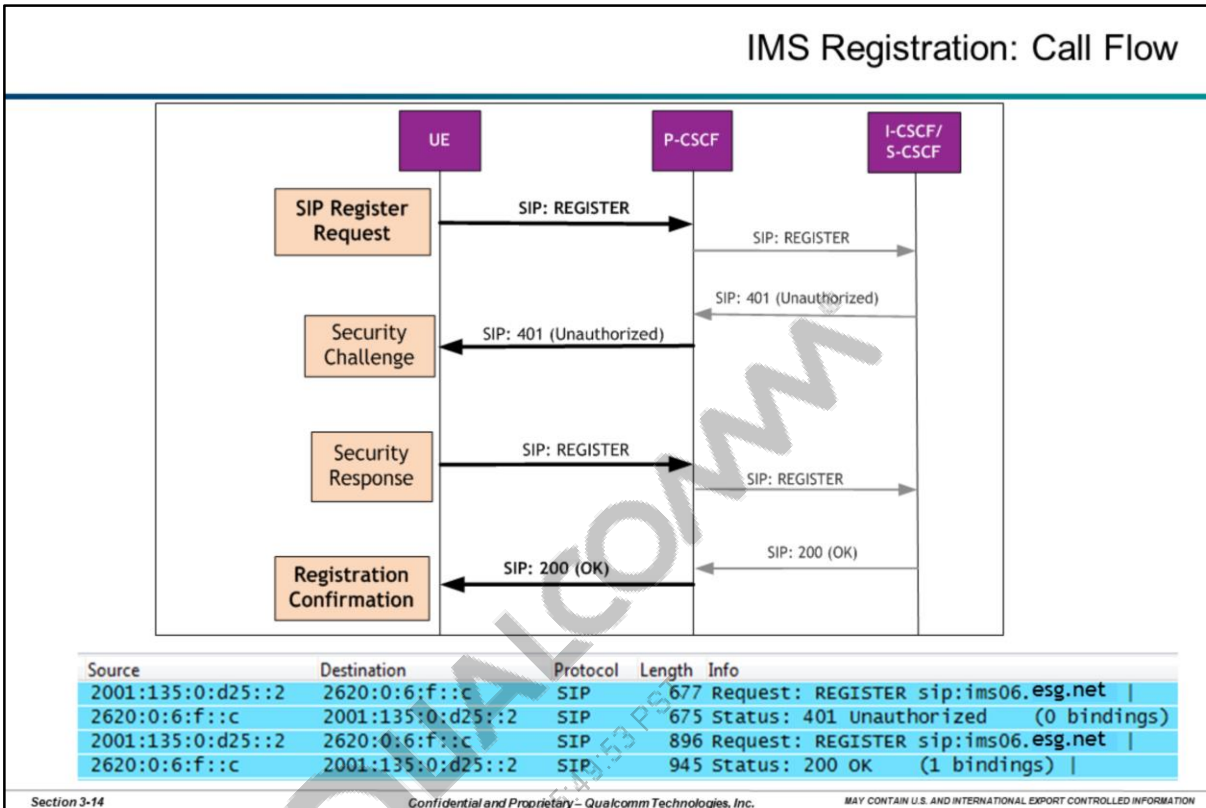
1. Did the UE request P-CSCF IP address? Yes; Where? Attach Request
2. What type of P-CSCF IP address did the UE request? IPv4 or IPv6
3. What type of P-CSCF IP address was the UE granted? IPv6; Where? Attach Accept

Notes

Topic Map

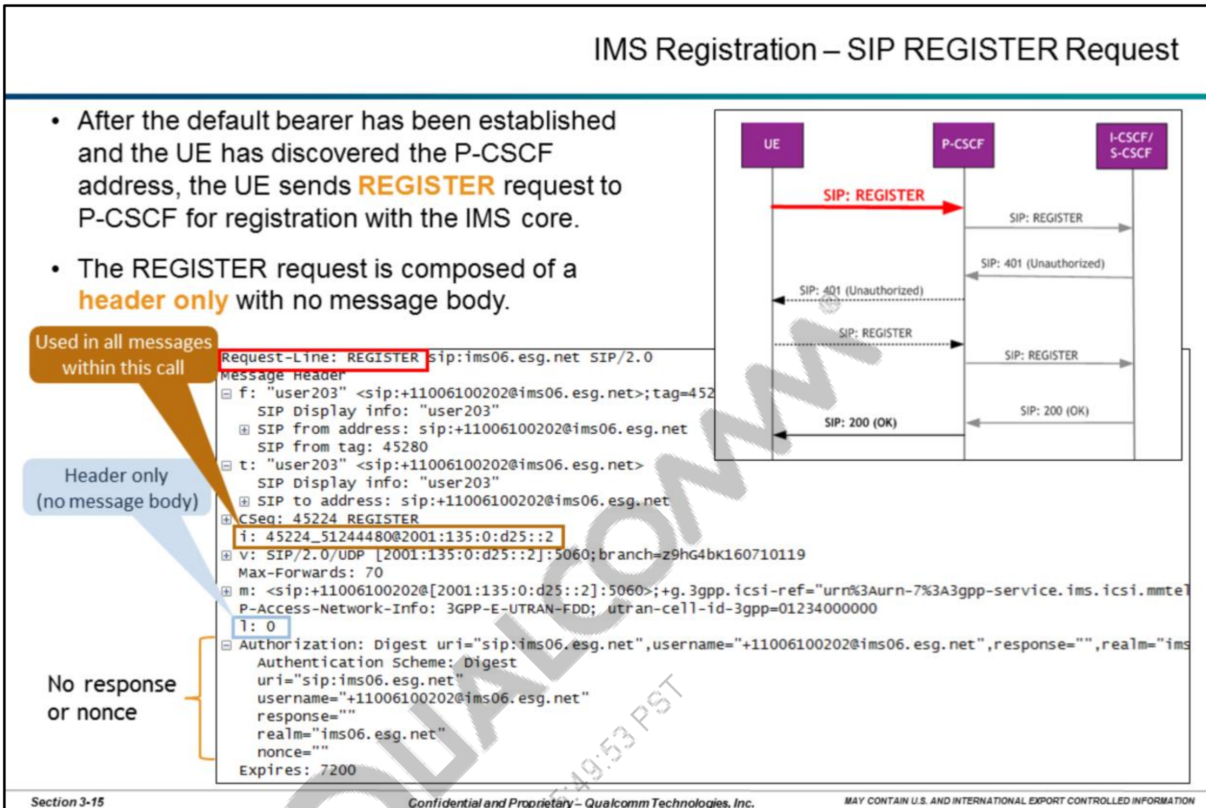
- IMS Registration
  - P-CSCF Discovery
  - **IMS Registration Procedure**
- IMS Re-registration

Notes



IMS Registration Process

1) IMS registration starts with UE establishing a bearer for SIP signaling. The UE begins initial registration with IMS by sending a SIP REGISTER request to P-CSCF. This message is not protected by any security association but includes security parameters required for IMS registration.
2) P-CSCF temporarily stores security parameters received in SIP signaling message. P-CSCF then forwards REGISTER message to the selected S-CSCF via I-CSCF. S-CSCF obtains an authentication vector from HSS. The authentication method typically used is AKAv1. It challenges the UE with a 401 Unauthorized response. This response is sent back to P-CSCF via I-CSCF.
3) P-CSCF, upon receiving 401 unauthorized response, extracts from the message, integrity, and cipher keys. It then adds its own security parameters on 401 Unauthorized response and sends it to the UE.
4) The UE, on receiving 401 Unauthorized message, decodes, constructs, and sends a REGISTER request with same header value as initial REGISTER request.
5) P-CSCF checks the security field of the received REGISTER request and removes the security-verify and security-client headers. It then forwards the message to S-CSCF via I-CSCF indicating that the message is integrity protected.
6) S-CSCF checks the challenge response from the UE and matches the response locally. In the event of successful registration, S-CSCF will generate a 200 OK response including a list of registered public user identities.
7) This response is forwarded to the UE via I-CSCF and P-CSCF. The UE upon receiving 200 OK response indicating successful authentication, stores a list of registered public user identities in its P-associated URI (which is a SIP private URI provided by the operator).


IMS Registration – SIP REGISTER Request
• After the default bearer has been established and the UE has discovered the P-CSCF address, the UE sends REGISTER request to P-CSCF for registration with the IMS core.
• The REGISTER request is composed of a header only with no message body.
UE
P-CSCF
I-CSCF/ S-CSCF
SIP: REGISTER
SIP: REGISTER
SIP: 401 (Unauthorized)
SIP: 401 (Unauthorized)
SIP: REGISTER
SIP: REGISTER
SIP: 200 (OK)
SIP: 200 (OK)
Used in all messages within this call
Header only (no message body)
No response or nonce
Request-Line: REGISTER sip:ims06.esg.net SIP/2.0
Message Header
f: "user203" <sip:+11006100202@ims06.esg.net>;tag=452
SIP Display info: "user203"
SIP from address: sip:+11006100202@ims06.esg.net
SIP from tag: 45280
t: "user203" <sip:+11006100202@ims06.esg.net>
SIP Display info: "user203"
SIP to address: sip:+11006100202@ims06.esg.net
CSeq: 45224 REGISTER
i: 45224_51244480@2001:135:0:d25::2
v: SIP/2.0/UDP [2001:135:0:d25::2]:5060;branch=z9hG4bK160710119
Max-Forwards: 70
m: <sip:+11006100202@[2001:135:0:d25::2]:5060>;+g.3gpp.icsi-ref="urn%3Aurn-7%3A3gpp-service.ims.icsi.mmtel
P-Access-Network-Info: 3GPP-E-UTRAN-FDD; utran-cell-id-3gpp=01234000000
l: 0
Authorization: Digest uri="sip:ims06.esg.net",username="+11006100202@ims06.esg.net",response="",realm="ims
Authentication Scheme: Digest
uri="sip:ims06.esg.net"
username="+11006100202@ims06.esg.net"
response=""
realm="ims06.esg.net"
nonce=""
Expires: 7200
Section 3-15
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Notes

IMS REGISTER Request – Header Details

Header Field (compact form)	Description
Request-Line	<Method> <URI> <SIP Version>. In the log: Method → `REGISTER` URI → `sip:ims06.esg.net`. This is the destination of the request, *registrar* in this case SIP Version → `2.0`
From (f)	Identity of the initiator of the REGISTER request
tag	Used for identification purposes. Used if multiple requests are originated by the same UE.
To (t)	ID of the user to be registered; which is identical to the request initiator ('From' header) in the REGISTER request.
CSeq (Command Sequence)	CSeq consists of a sequence number and a method. The number is initialized at the start of a call and incremented for each new request, with the exception of CANCEL and ACK requests*. In this log, CSeq is set to `45224 REGISTER`

*CANCEL and ACK requests will use the CSeq number of the request to which they refer

IMS Registration – Header Details

For additional details, refer to RFC 3261; SIP: Session Initiation Protocol; paragraph 8.1.1.

URI: Uniform Resource Identifier or an address.

From: Tag value, together with Call-ID, serves as a general mechanism to identify a dialog.

To: This field is used by the S-CSCF to send the response back.

CSeq: The next Request from the UE will have the CSeq number incremented, that is, it will be set to 4522**5** REGISTER.

IMS REGISTER Request – Header Details (2)

Header Field (compact form)	Description
Call-ID (i)	Unique identifier used to identify messages belonging to that call. All messages within this session will have the same Call-ID, regardless of the sender.
Via (v)	Records the route taken by the request, so the originator can be reached for Responses to this request.
Max-Forwards	Limit the number of hops a request can transit on the way to its destination and is decremented by one at each hop. This acts as a loop detector.
Contact (m)	IP address, port and unique device identifier where the UE can be reached for further Requests. It also includes a feature tag of services that the UE subscribes to.
P-Access-Network-Info	Indicates the RAN technology used to send the request, 3GPP EUTRA FDD in this example. Global cell ID is also given.
Content length (l)	Size of the message body in bytes. This field is set to '0' for REGISTER message, as it only contains a header.

IMS Registration – Header Details

For additional details, refer to RFC 3261; SIP: Session Initiation Protocol; paragraph 8.1.1.

Contact: Informs other elements of the address where further Requests to the UE should be sent.

Via header field tells other elements where to send the response; whereas the **Contact** header field tells other elements where to send future requests. So if the other party sends a Response to this Request (like 401 Unauthorized), it will send it to the Via address, but if the other party sends a Request (like BYE), it will send it to the Contact address.

Max-Forwards: If the Max-Forwards value reaches 0 before the request reaches its destination, it will be rejected with a 483 (Too Many Hops) error response.

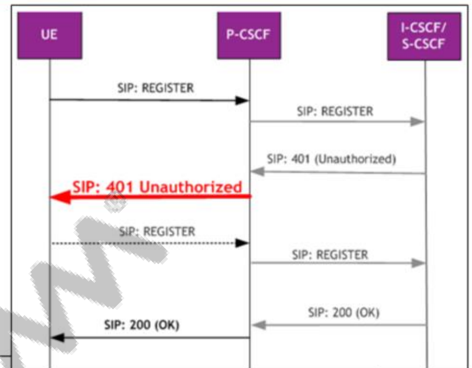
IMS REGISTER Request – Header Details (3)

Header Field (compact form)	Description
Authentication	Contains authentication credentials of the UE, including authentication scheme, Digest username and address and realm (authentication server).
Expires	Indicates the duration where this request (REGISTER) remains valid, in seconds. It is set to 7200 seconds (2 hours) in this log, so the UE will need to re-register before the expiration of this header. If Expires header field is not present, the registration expires in 3600 seconds (default).

Notes

IMS Registration – 401 Unauthorized

- In order to authenticate the UE, the S-CSCF rejects the initial REGISTER request with a **401 Unauthorized** response
- The **401 Unauthorized** response includes the authentication scheme and other authentication parameters



Same as REGISTER request

Populated

```
atus-Line: SI?/2.0 401 Unauthorized
ssage Header
i: 45224_51244480@2001:135:0:d25::2
v: SIP/2.0/UDP [2001:135:0:d25::2]:5060;received=2001:135:0:d25::2;branch=z9hG4bK160710119
t: "user203" <sip:+11006100202@ims06.esg.net>;tag=4e8186dd-1319188405250781
f: "user203" <sip:+11006100202@ims06.esg.net>;tag=45280
CSeq: 45224 REGISTER
Date: Fri, 21 Oct 2011 09:13:25 GMT
Server: ESG-SanDiegoCA-HPSS/3.0.3
[truncated] WWW-Authenticate: Digest realm="ims06.esg.net",\r\n   nonce="b7c9036dbf3054aea940e
  Authentication Scheme: Digest
  realm="ims06.esg.net"
  nonce="b7c9036dbf3054aea940e9703dc84ea137b5f84c2808"
  opaque="ESG:QbkRBthOEgEQAkgVEwwHRAIBHgkdHwQCQ1lFRkZWCgkxcnN1ay8qO3l8ZS0hO2E-NCZpYWVvZw__"
  algorithm=MD5
  qop="auth"
l: 0
```

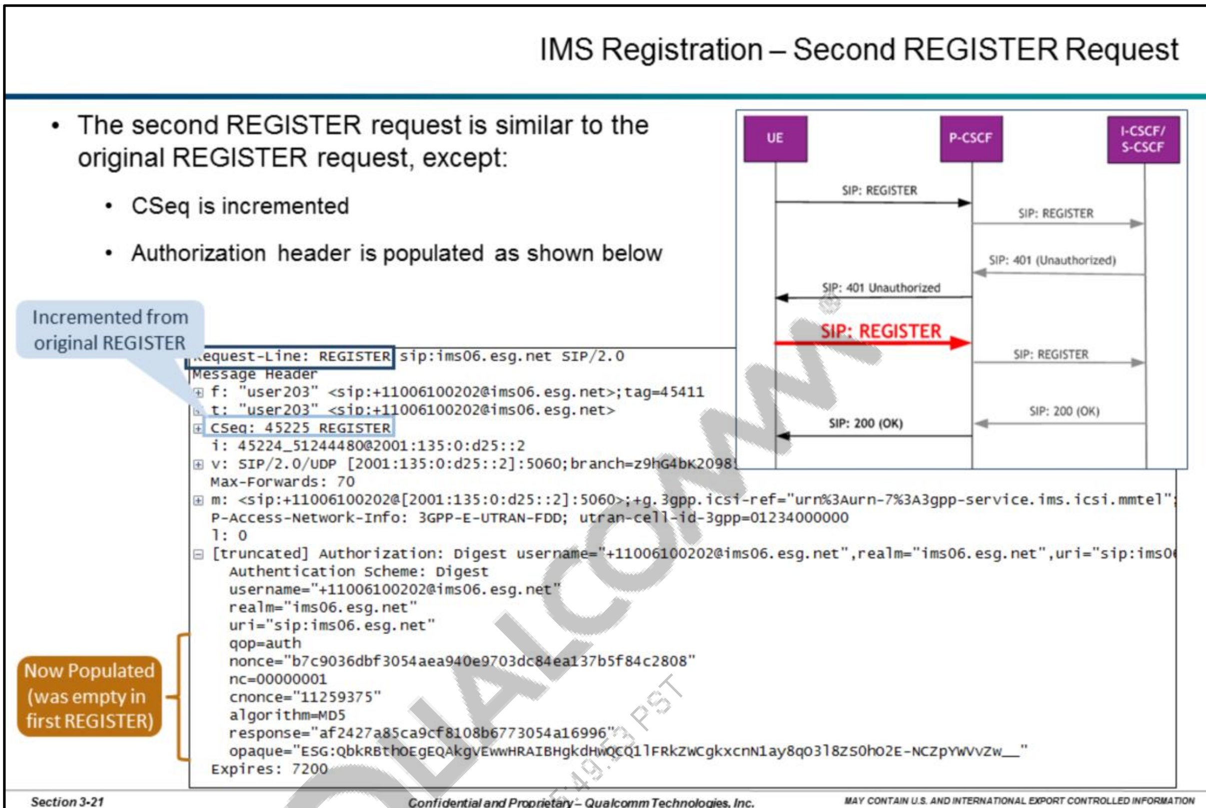

Notes

401 Unauthorized – Authentication Parameters

Parameter	Description
Authentication Scheme	In the log: `Authentication Scheme: Digest`
realm	Server performing authentication, should be set to the same setting as the REGISTER request. In the log: `realm="ims06.esg.net"`
nonce	Challenge generated by the network, including the *AUTH* and *RAND*. The UE will use *AUTH* to authenticate the network and will use *RAND* to generate the response.
opaque	The UE should return this parameter unchanged to the server in the second Register request.
algorithm	Algorithm used to create the Digest. In the log: `algorithm=MD5`
qop	Quality of protection. Can be set to either *auth* (authentication) or *auth-int* (authentication and integrity). In the log: `qop="auth"`

401 Unauthorized – Authentication Parameters

For authentication details, refer to RFC 2617 HTTP Authentication: Basic and Digest Access Authentication.



IMS Registration – Second REGISTER Request

In the Authorization header, the following parameter values are identical to those set in the 401 Unauthorized response:

- qop
- nonce
- algorithm
- opaque

Log Analysis - IMS Registration

Log Analysis Procedure: IMS Registration

Open File: 03-IMS_Registration

Notes

IMS Registration: Log Walk-Through

Step	Look for...	Timestamp	Verify...
1	SIP: REGISTER	16:05:12.075	• Method set to REGISTER in Request-Line. • 'From' and 'To' fields are populated with the UE ID. • Expires set 7200 (must be greater than '0' for initial registration).
2	SIP: 401 Unauthorized	16:05:12.158	• Call-ID is identical to Call-ID in the REGISTER request. • CSeq is identical to CSeq in the REGISTER request. • WWW-Authenticate is present and populated as outlined above.
3	SIP: REGISTER	16:05:12.377	• Method set to REGISTER in Request-Line. • CSeq is incremented. From tag is different. • Authorization header is properly populated.
4	200 OK	16:05:12.578	• Call-ID is identical to Call-ID in the second REGISTER request. • CSeq is identical to CSeq in the second REGISTER request.

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Notes

IMS Registration – Questions

Fill the blanks using the log file:

1. What is 'To' header field set to? ________________
2. What is 'From' header field set to? ________________
3. What is the CSeq of the initial Register request? ____________________
4. What is the CSeq of the second Register request? ____________________
5. What is the Authorization response of the initial Register request? ___________________
6. What is the Authorization response of the second Register request? ___________________
7. How many hops can this message go through? _________, Where?___________________

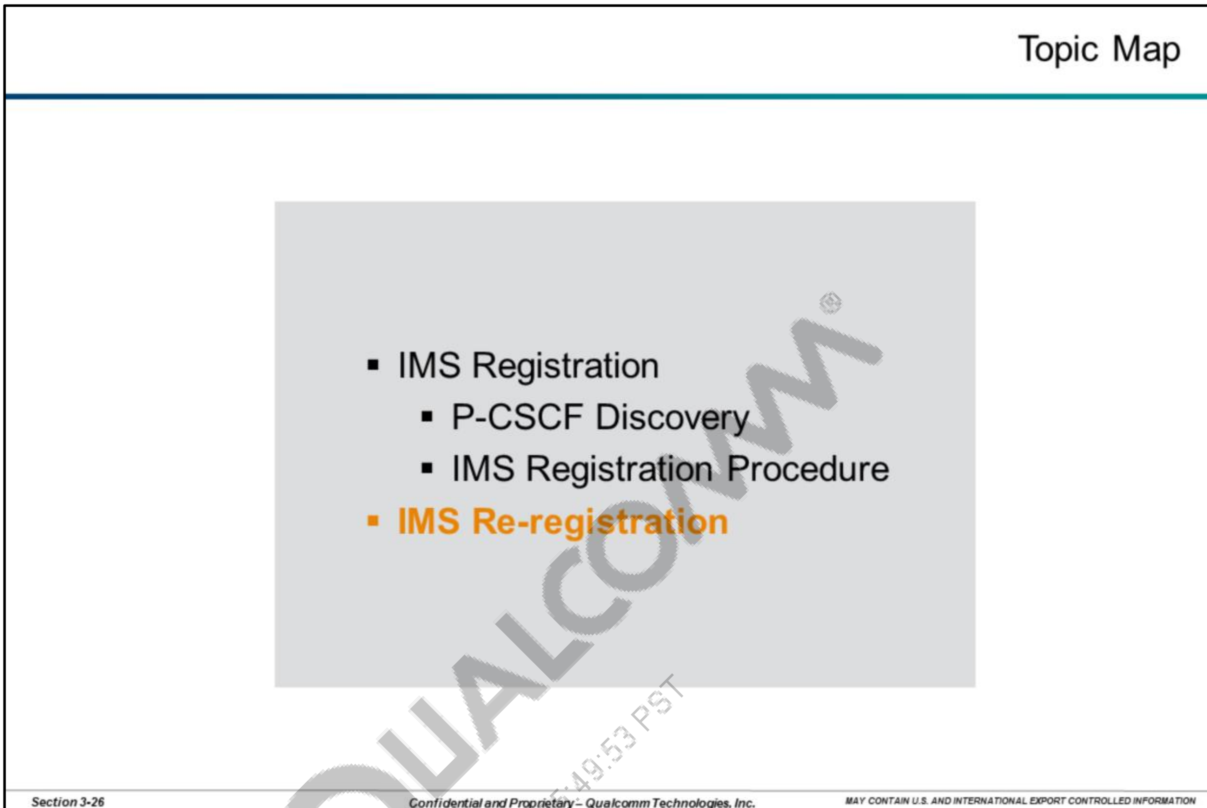
Notes

IMS Registration – Answers

Fill the blanks using the log file:

1. What is 'To' header field set to? +1234006100202@ims06.esg.net
2. What is 'From' header field set to? +1234006100202@ims06.esg.net
3. What is the CSeq of the initial Register request? 45224 REGISTER
4. What is the CSeq of the second Register request? 45225 REGISTER
5. What is the Authorization response of the initial Register request? *response*=""
6. What is the Authorization response of the second Register request? *response*="af242"
7. How many hops can this message go through? 70, Where? Max-Forwards: 70

Notes


Topic Map
IMS Registration
P-CSCF Discovery
IMS Registration Procedure
IMS Re-registration
Section 3-26
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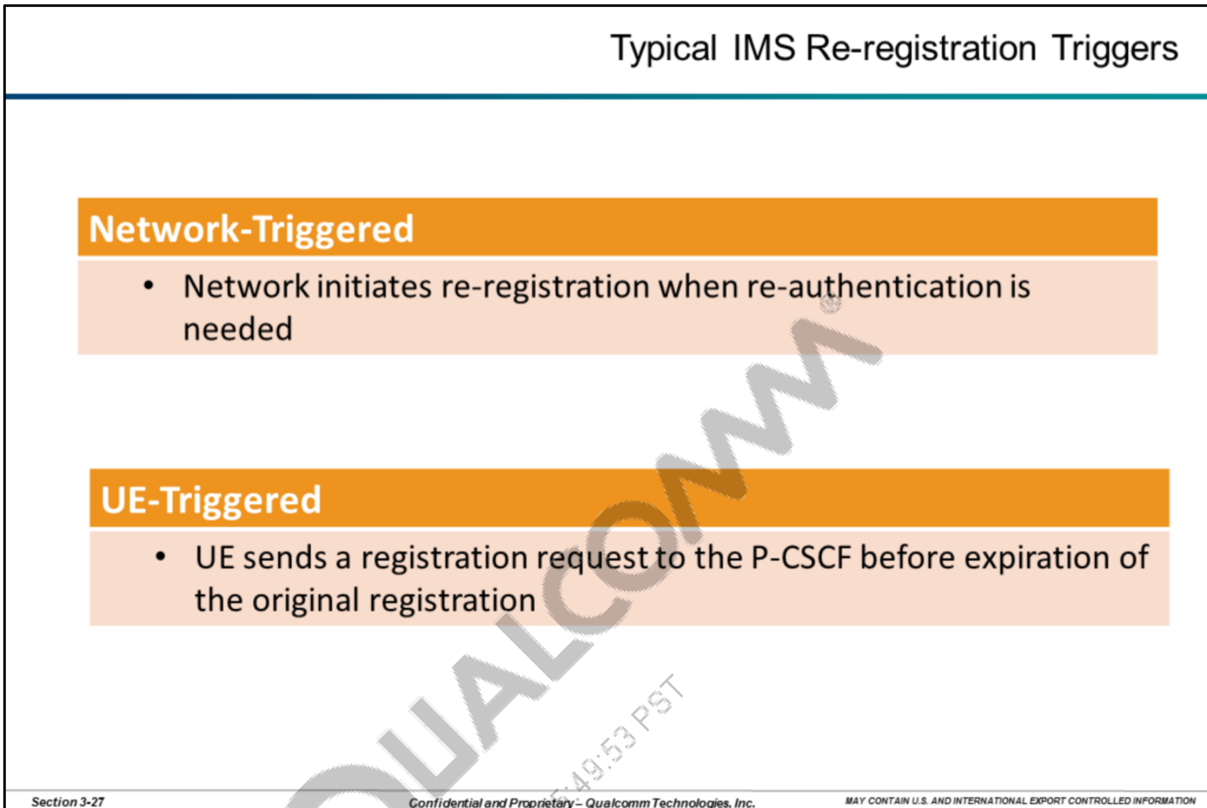
Notes



Typical IMS Re-registration Triggers

It is anticipated that many SIP devices will be wireless devices that will be always-on, and therefore, continually registered to the network. Unfortunately, history has shown that these devices can be compromised. To deal with this, an administrator will want to terminate or shorten a registration, and ask the device to re-register so it can be re-authenticated.

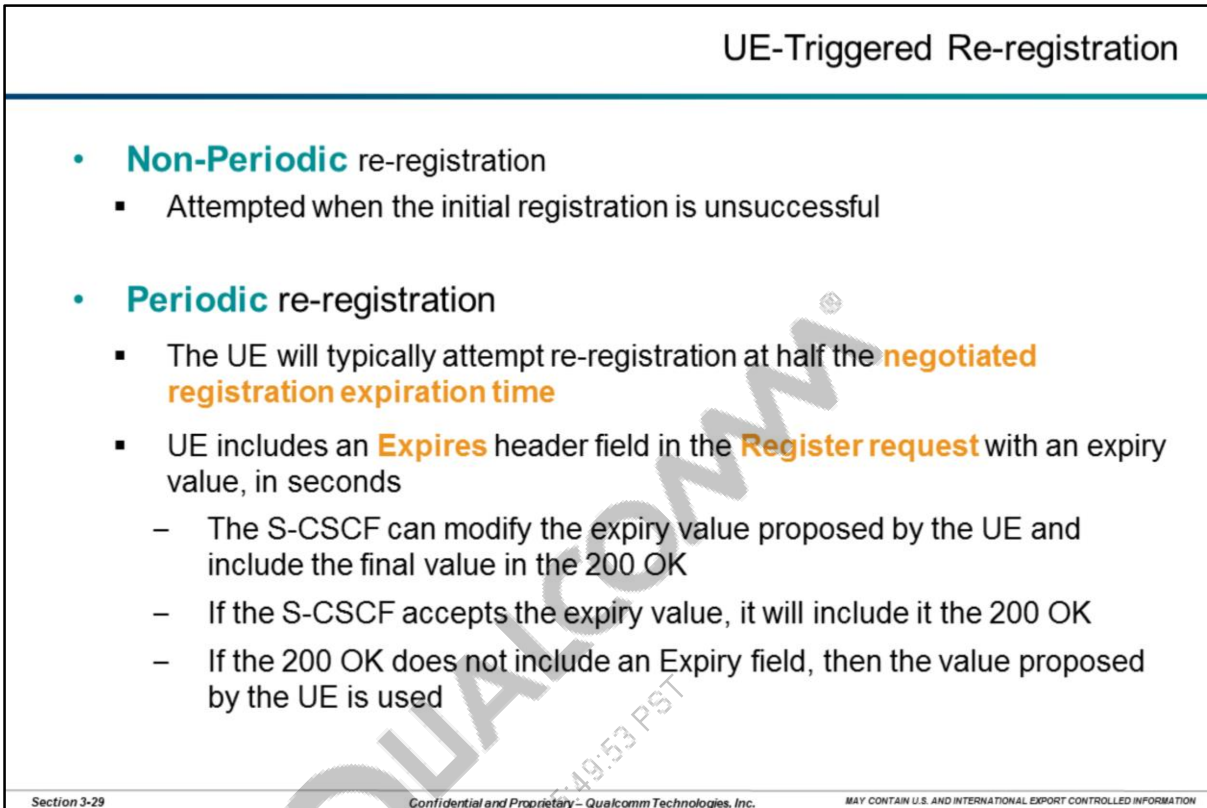
Additional re-registration triggers are covered in the VoLTE Technical Overview, 80-W3001-1.

Network-Triggered Re-registration

- The network can trigger UE re-registration to **re-authenticate** the UE
- This is done by shortening the registration time via a **NOTIFY** message sent by S-CSCF to UE
- NOTIFY header:

<contact id="123" state="active" **event="shortened" expires="300"**>

Notes

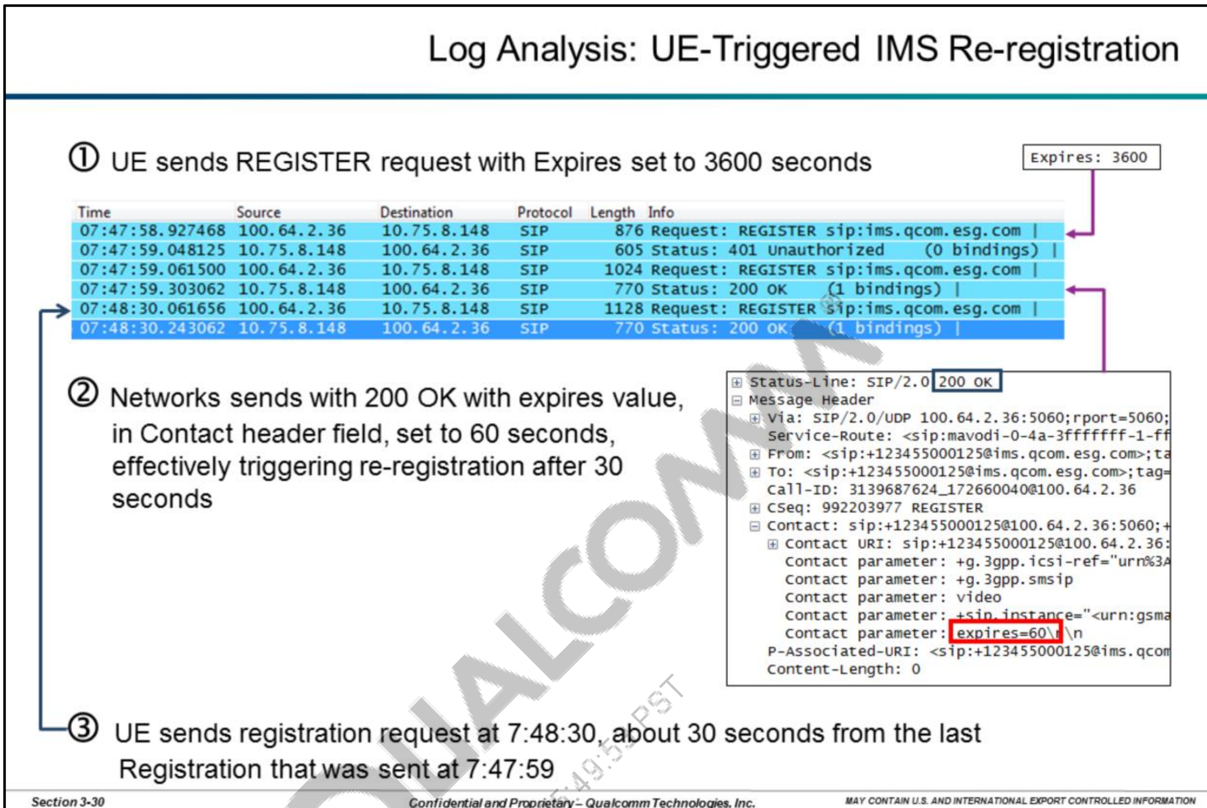


UE-Triggered Re-registration

Additional re-registration triggers are covered in the VoLTE Technical Overview, 80-W3001-1.

Periodic Re-registration

If the expiry value is less than the minimum expiry value of the S-CSCF, the S-CSF will reject the registration with 423 (Interval Too Brief) response, which includes a `Min-Expires` header field. In this case, the UE can re-try with a new Expires value, equal to or greater than the `Min-Expires` value. Refer to RFC 3261, Clause 20.23.


Log Analysis: UE-Triggered IMS Re-registration
① UE sends REGISTER request with Expires set to 3600 seconds
Expires: 3600
Time Source Destination Protocol Length Info
07:47:58.927468 100.64.2.36 10.75.8.148 SIP 876 Request: REGISTER sip:ims.qcom.esg.com |
07:47:59.048125 10.75.8.148 100.64.2.36 SIP 605 Status: 401 Unauthorized (0 bindings) |
07:47:59.061500 100.64.2.36 10.75.8.148 SIP 1024 Request: REGISTER sip:ims.qcom.esg.com |
07:47:59.303062 10.75.8.148 100.64.2.36 SIP 770 Status: 200 OK (1 bindings) |
07:48:30.061656 100.64.2.36 10.75.8.148 SIP 1128 Request: REGISTER sip:ims.qcom.esg.com |
07:48:30.243062 10.75.8.148 100.64.2.36 SIP 770 Status: 200 OK (1 bindings) |
② Networks sends with 200 OK with expires value, in Contact header field, set to 60 seconds, effectively triggering re-registration after 30 seconds
Status-Line: SIP/2.0 200 OK
Message Header
Via: SIP/2.0/UDP 100.64.2.36:5060;rport=5060;
Service-Route: <sip:mavodi-0-4a-3fffffff-1-ff
From: <sip:+123455000125@ims.qcom.esg.com>;ta
To: <sip:+123455000125@ims.qcom.esg.com>;tag=
Call-ID: 3139687624_172660040@100.64.2.36
CSeq: 992203977 REGISTER
Contact: sip:+123455000125@100.64.2.36:5060;+
Contact URI: sip:+123455000125@100.64.2.36:
Contact parameter: +g.3gpp.icsi-ref="urn%3A
Contact parameter: +g.3gpp.smsip
Contact parameter: video
Contact parameter: +sip.instance="<urn:gsma
Contact parameter: expires=60\r\n
P-Associated-URI: <sip:+123455000125@ims.qcom
Content-Length: 0
③ UE sends registration request at 7:48:30, about 30 seconds from the last Registration that was sent at 7:47:59
Section 3-30
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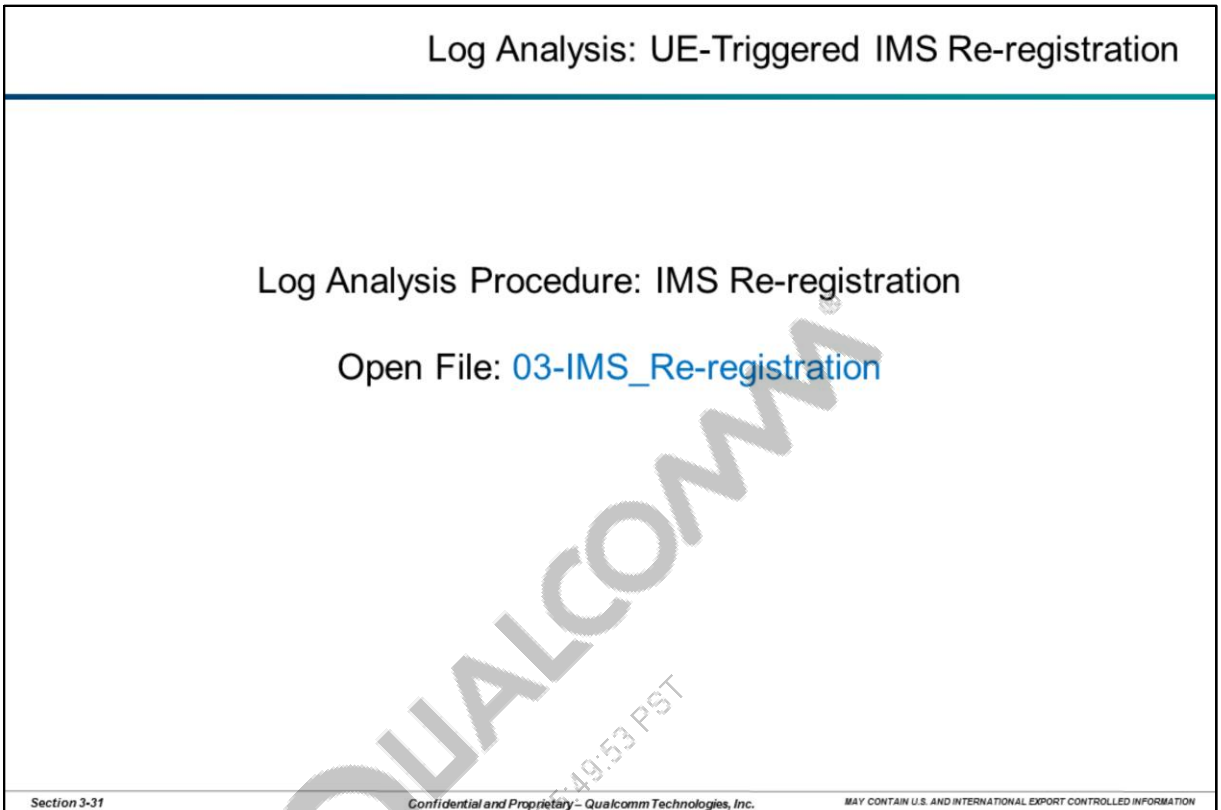

Analysis Files

UE-Triggered IMS Re-registration: Log Walk-Through

Step	Look for	Time Stamp	Verify
1	SIP: REGISTER	14:47:58.927	Initial registration with Expires = 3600 indicating the registration is valid for 3600 seconds (1 hour)
2	SIP: 401 Unauthorized	14:47:59.048	Response indicating authentication is needed
3	SIP: REGISTER	14:47:59.061	Registration with authorization header properly populated
4	200 OK	14:47:59.303	Network sets the Expired entry in the Contact header field to 60, indicating the registration is only valid for 60 seconds, and triggering re-registration after 30 seconds
5	SIP: REGISTER	14:48:30.061	Register request (i.e., re-registration) sent after about 30 seconds
6	200 OK	14:48:30.243	ACK for the re-registration

Notes

Specifications References

Specifications	Title
3GPP TS 36.331	E-UTRA Radio Resource Control (RRC); Protocol specification
3GPP TS 24.301	Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS)
3GPP TS 23.228	IP Multimedia Subsystem (IMS)
RFC 3261	SIP: Session Initiation Protocol
RFC 3265	Session Initiation Protocol (SIP)-specific Event Notification
RFC 3680	A Session Initiation Protocol (SIP) Event Package for Registrations
RFC 2617	HTTP Authentication: Basic and Digest Access Authentication

Specifications References

3GPP LTE specifications available at www.3gpp.org

IETF RFCs available at www.ietf.org

Comments/Notes


4
VoLTE Call Setup
Performance and Troubleshooting
www.qualcommwirelessacademy.com
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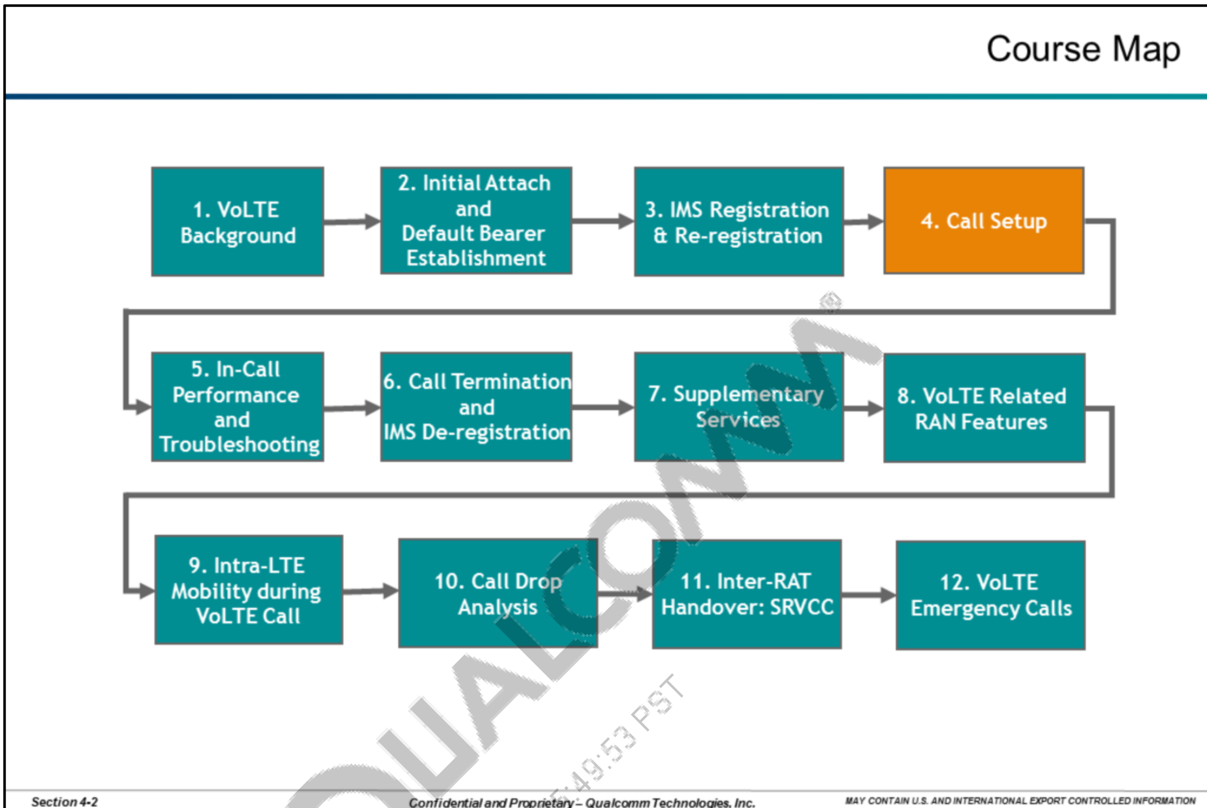
Course Map
1. VoLTE Background
2. Initial Attach and Default Bearer Establishment
3. IMS Registration & Re-registration
4. Call Setup
5. In-Call Performance and Troubleshooting
6. Call Termination and IMS De-registration
7. Supplementary Services
8. VoLTE Related RAN Features
9. Intra-LTE Mobility during VoLTE Call
10. Call Drop Analysis
11. Inter-RAT Handover: SRVCC
12. VoLTE Emergency Calls
Section 4-2
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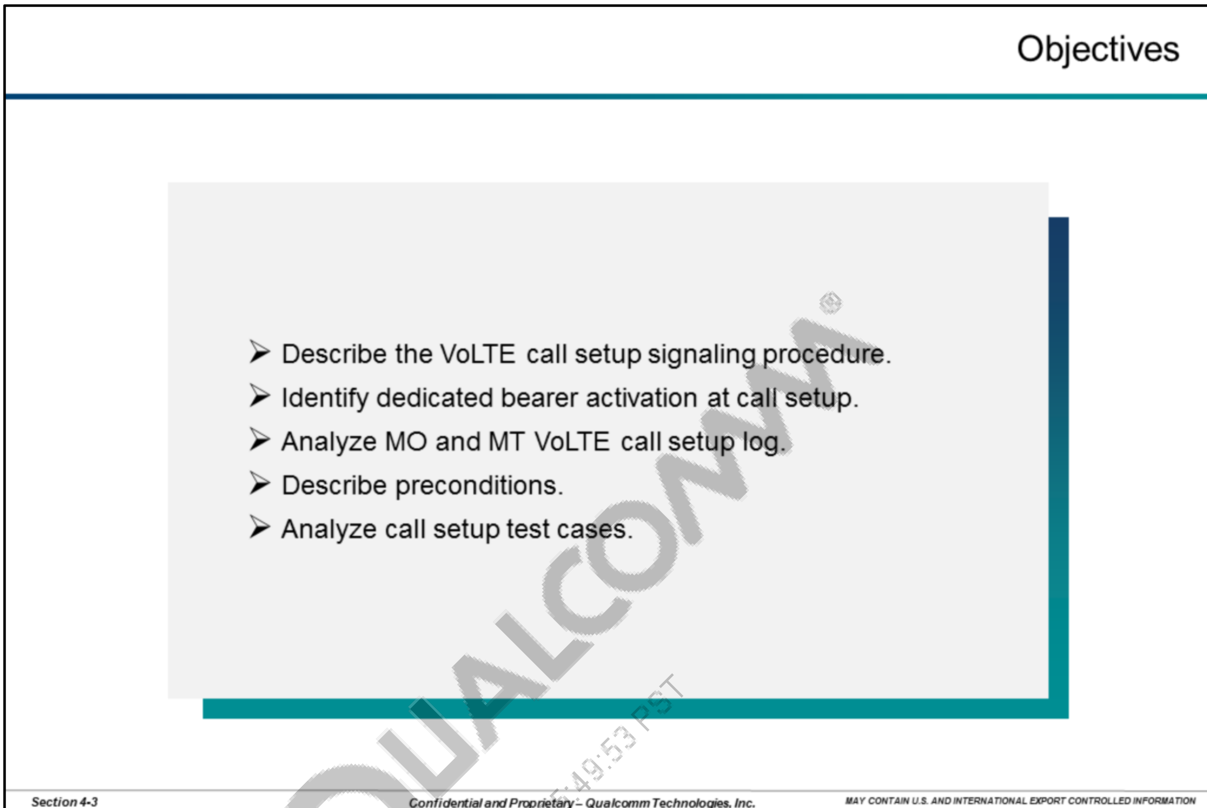
Notes


Objectives
➢ Describe the VoLTE call setup signaling procedure.
➢ Identify dedicated bearer activation at call setup.
➢ Analyze MO and MT VoLTE call setup log.
➢ Describe preconditions.
➢ Analyze call setup test cases.
Section 4-3
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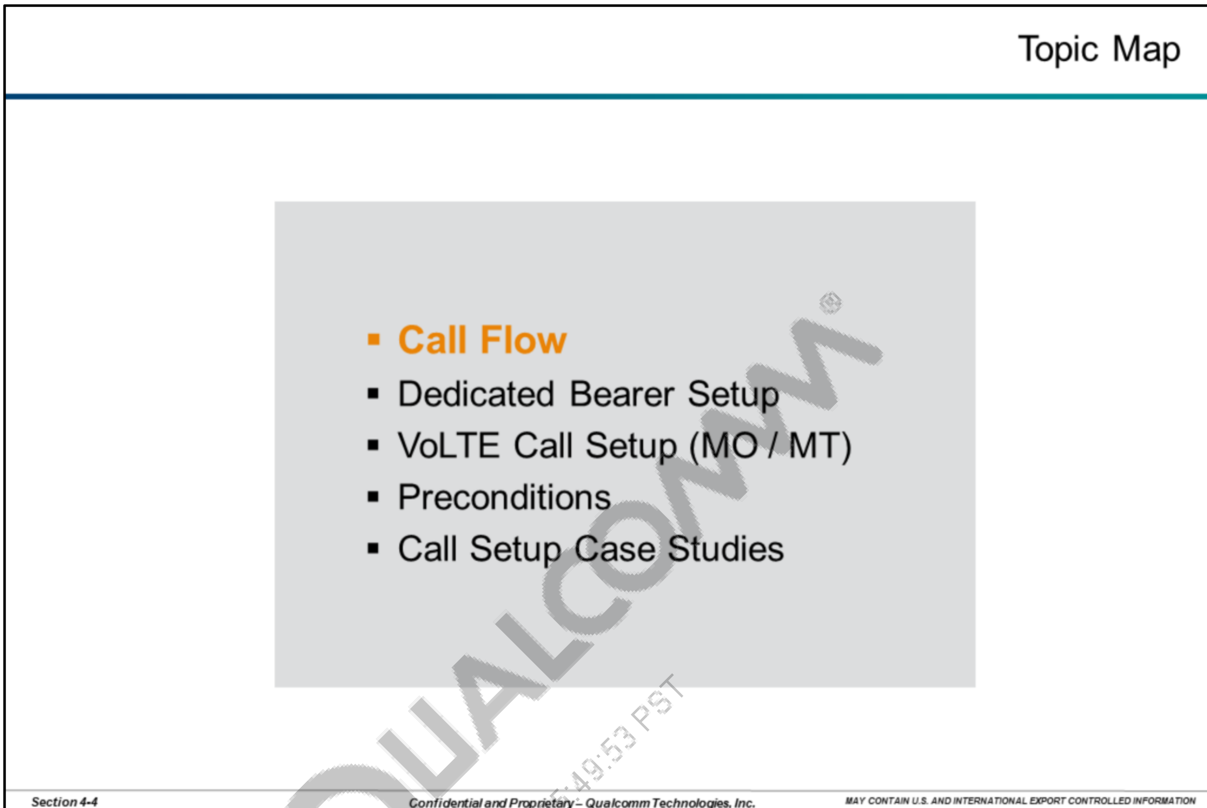
Notes


Topic Map
Call Flow
Dedicated Bearer Setup
VoLTE Call Setup (MO / MT)
Preconditions
Call Setup Case Studies
Section 4-4
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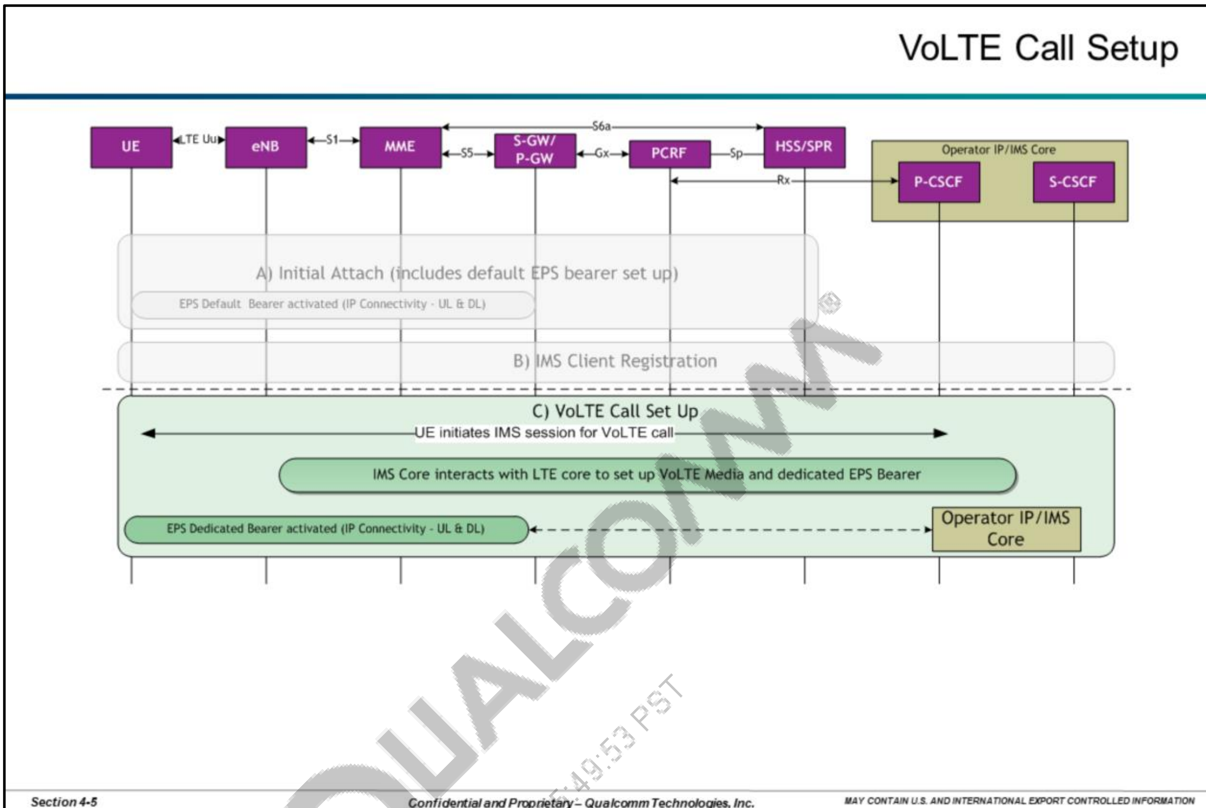
Notes


VoLTE Call Setup
UE
LTE Uu
eNB
S1
MME
S6a
S5
S-GW/
P-GW
Gx
PCRF
Sp
HSS/SPR
Operator IP/IMS Core
P-CSCF
S-CSCF
Rx
A) Initial Attach (includes default EPS bearer set up)
EPS Default Bearer activated (IP Connectivity - UL & DL)
B) IMS Client Registration
C) VoLTE Call Set Up
UE initiates IMS session for VoLTE call
IMS Core interacts with LTE core to set up VoLTE Media and dedicated EPS Bearer
EPS Dedicated Bearer activated (IP Connectivity - UL & DL)
Operator IP/IMS Core
Section 4-5
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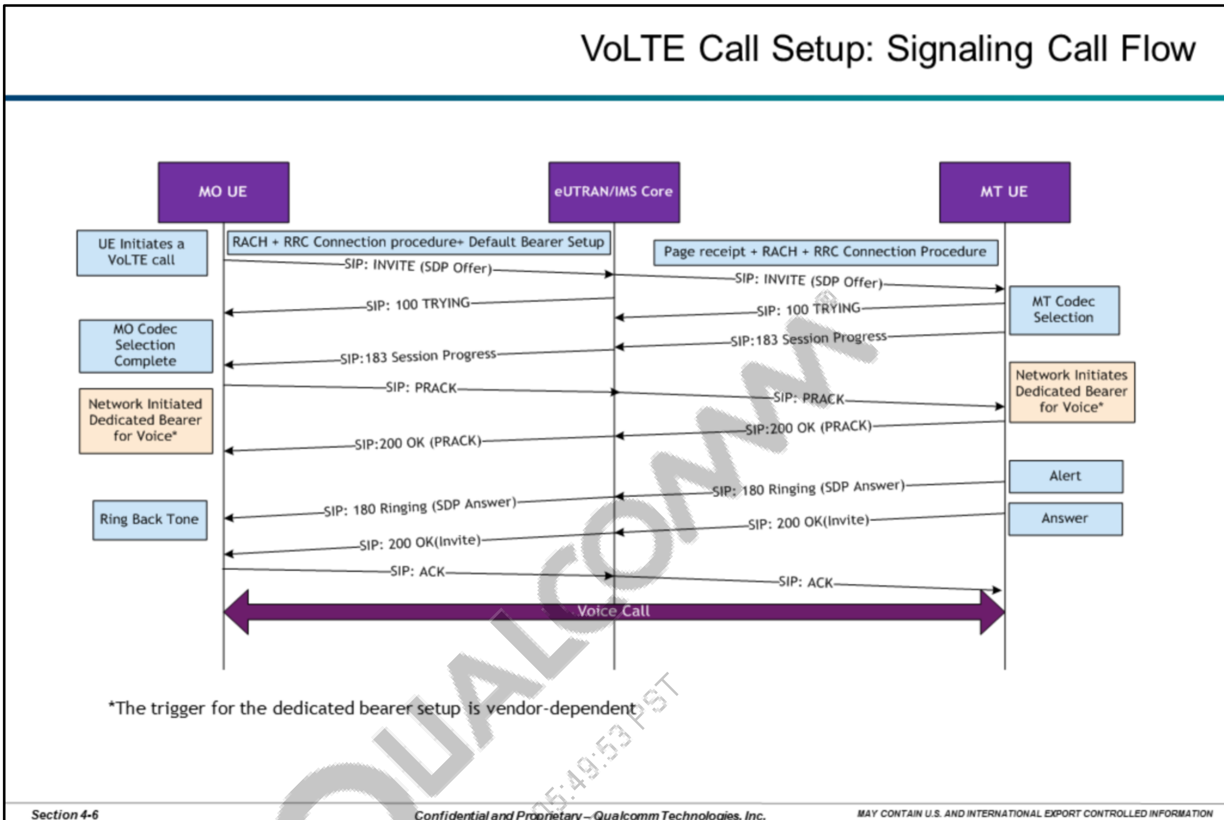
Notes



VoLTE Call Setup: Signaling Call Flow

Additional details of VoLTE call setup are covered in VoLTE Technical Overview (80-W3001-1).

This slide shows an example of the SIP signaling involved in setting up a typical mobile-to-mobile VoLTE call.

The originating UE sends a SIP INVITE with SDP offer (which includes order of preference for Audio Codecs) to the terminating UE via the IMS core network. The terminating UE responds with a SIP 100 TRYING to the MO UE acknowledging that SIP INVITE was received successfully. Now MT UE also sends 183 Session progress message that includes the SDP answer (to indicated the selected codec).

The IMS core would trigger the setup of a dedicated bearer to carry the voice call payload on both MO and MT UEs. The trigger for dedicated bearer setup is vendor-dependent.

The originating UE sends a Provisional Acknowledgement (PRACK) to the terminating UE via the IMS core network to confirm that codec selection is completed and terminating UE acknowledges this.

The Terminating UE then sends a 180 Ringing to the originating UE which, upon receipt, triggers a ringback tone to the originator. The terminating UE then sends a 200 OK for the original SIP INVITE and after this, the voice call path is fully established.

VoLTE Call Setup – Request and Response Messages

Request	Description
INVITE	Used to initiate a session. The INVITE request also includes the SDP (session description protocol) to negotiate media components.
PRACK	Provisional Acknowledgement. Used to acknowledge the reception of 183 Session Progress response
ACK	Confirmation (or acknowledgement)

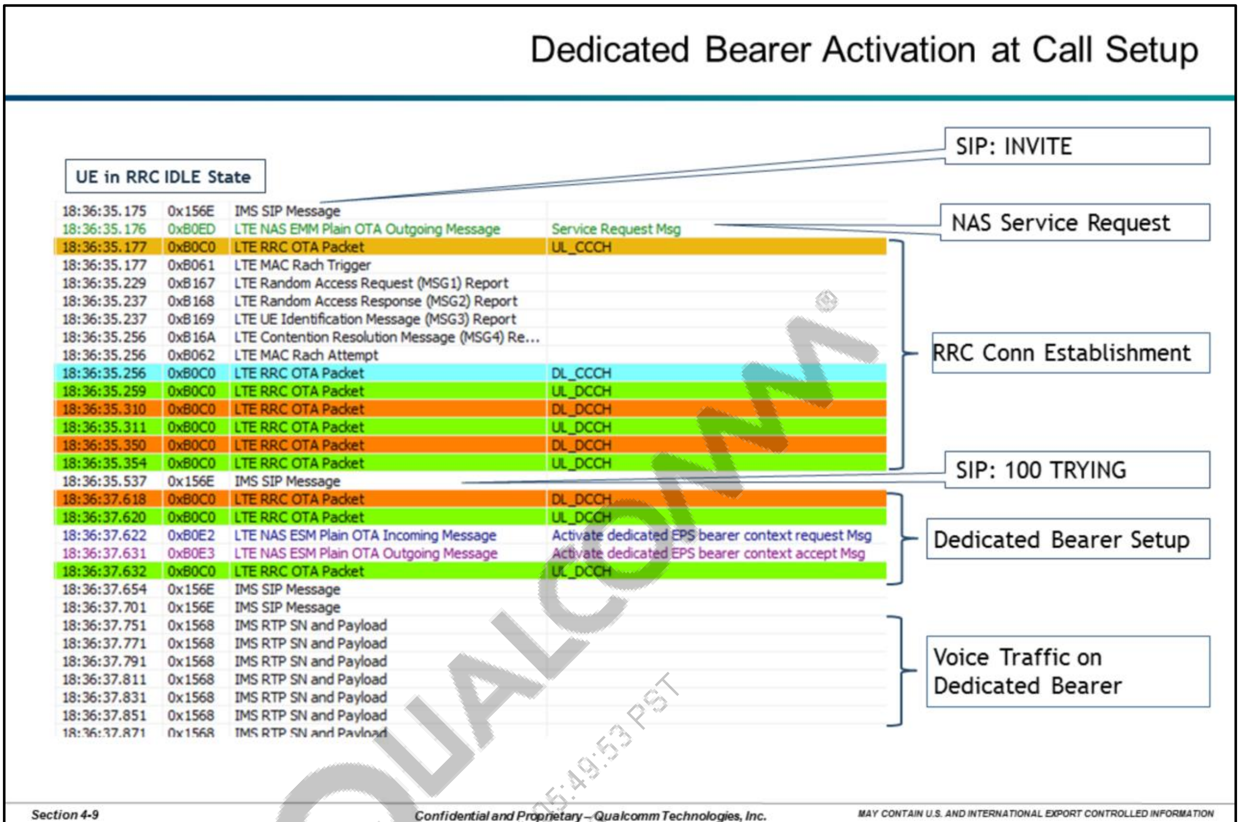
Response	Description
100 TRYING	Acknowledge the reception of the INVITE request
183 SESSION PROGRESS	Carry information about the codec selected by MT UE
200 OK	Acknowledge the reception of the INVITE and PRACK
180 Ringing	Generate ringback tone

Notes

Topic Map

- Call Flow
- **Dedicated Bearer Setup**
- VoLTE Call Setup (MO / MT)
- Preconditions
- Call Setup Case Studies

Notes



Dedicated bearer Activation at Call Setup

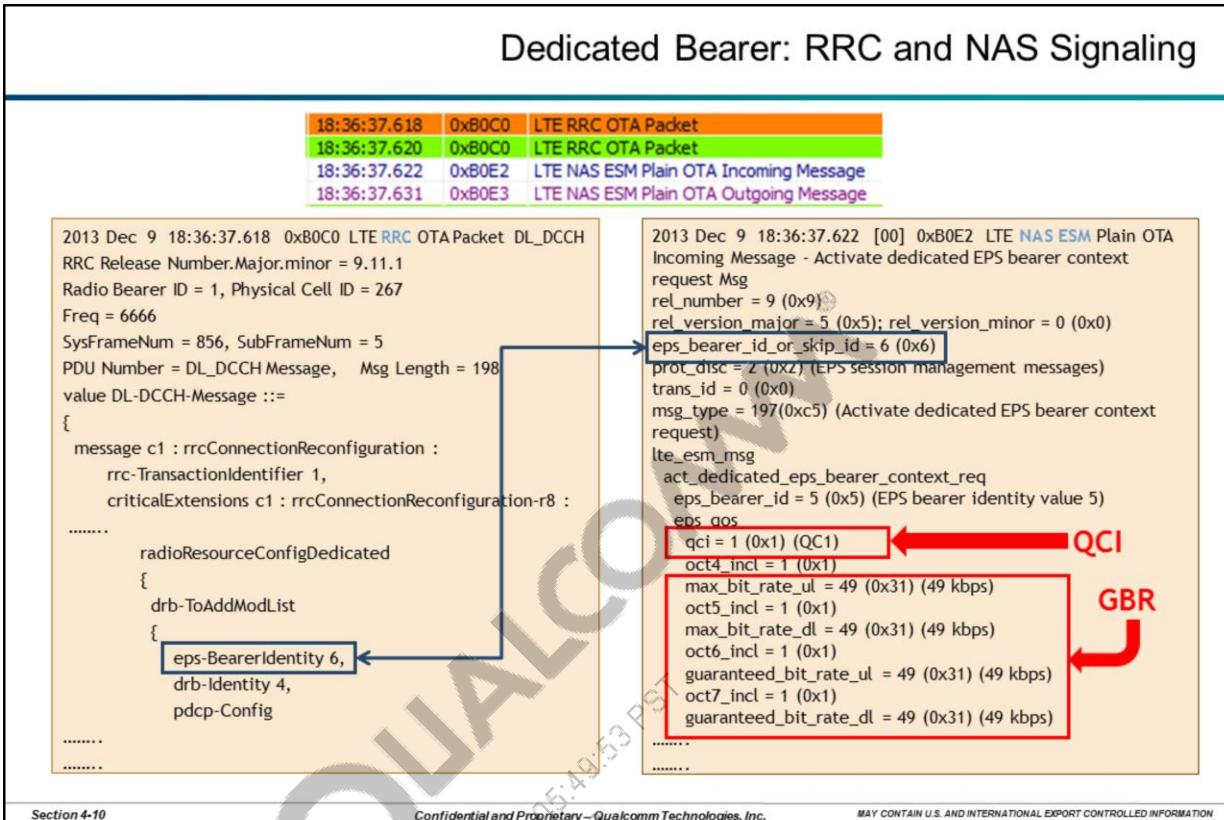
Details of the network initiated dedicated bearer set-up process can be found in 3GPP 23.401 Section 5.4.1

In the log shown above, the user triggers a VoLTE call.

The SIP INVITE triggers a NAS Service request which, in turn, triggers the RRC Connection request and the RACH procedure.

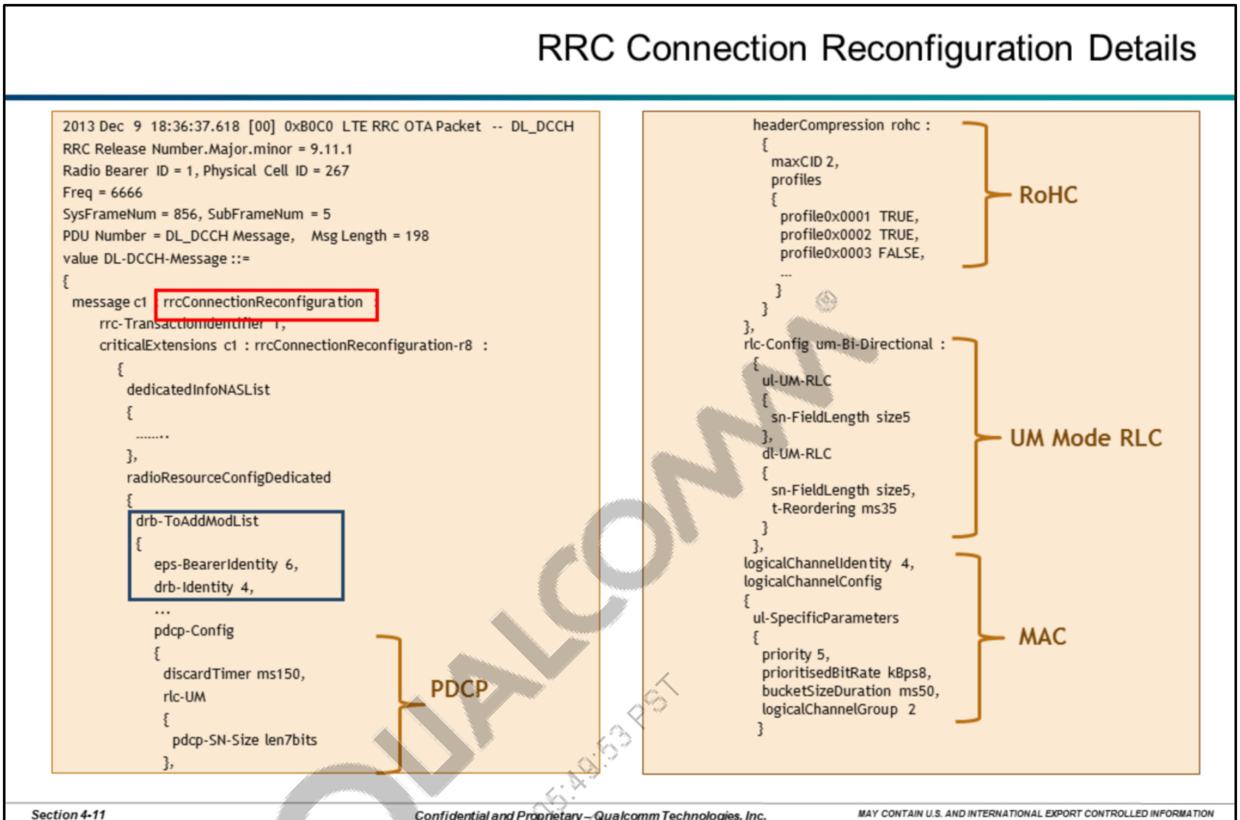
Once the RRC Connection is established, the SIP INVITE is sent out and the IMS core responds with SIP: 100 TRYING to confirm the receipt of the INVITE request.

In this example, the network established the dedicated bearer after sending the SIP: 100 TRYING



Dedicated Bearer: RRC and NAS Messaging

During the call setup process, the network configures and activates the dedicated bearer.



RRC Connection Reconfiguration Details

PDCP Configuration for VoLTE

The DRB configured for VoLTE operation includes PDCP configuration where the Sequence Number (SN) length is set to 7 bits.

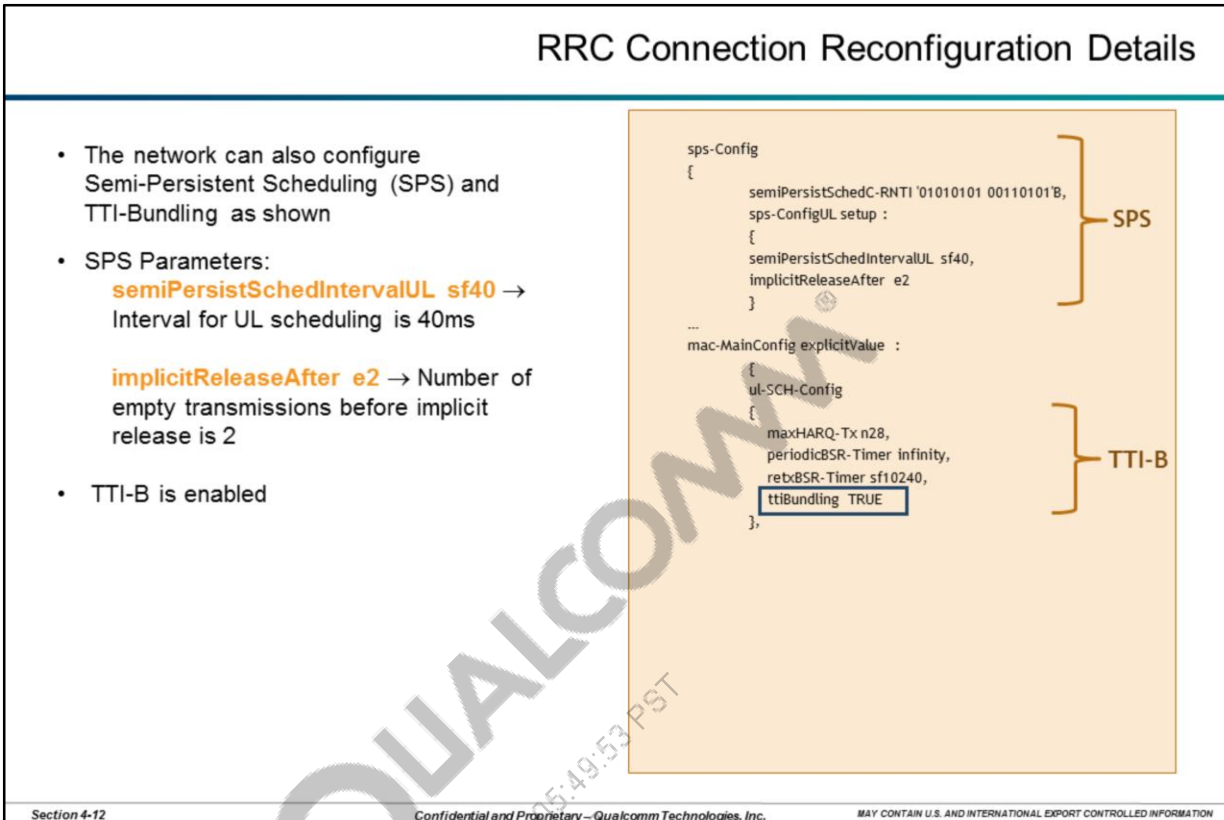
PDCP specifications (3GPP TS36.323) include optimizations to enable more efficient VoLTE operation. A special PDCP format with a short PDCP sequence number (7 bits) is introduced for DRBs mapped onto RLC-UM only. This reduces the header overheads by 50% (from 2 bytes to 1 byte).

RLC Configuration for VoLTE

Similarly, RLC is configured for Unacknowledged Mode (UM) as re-transmissions are not needed. Also, the choice of smaller RLC headers (5-bit sequence number) for UMD PDU reduces the overhead.

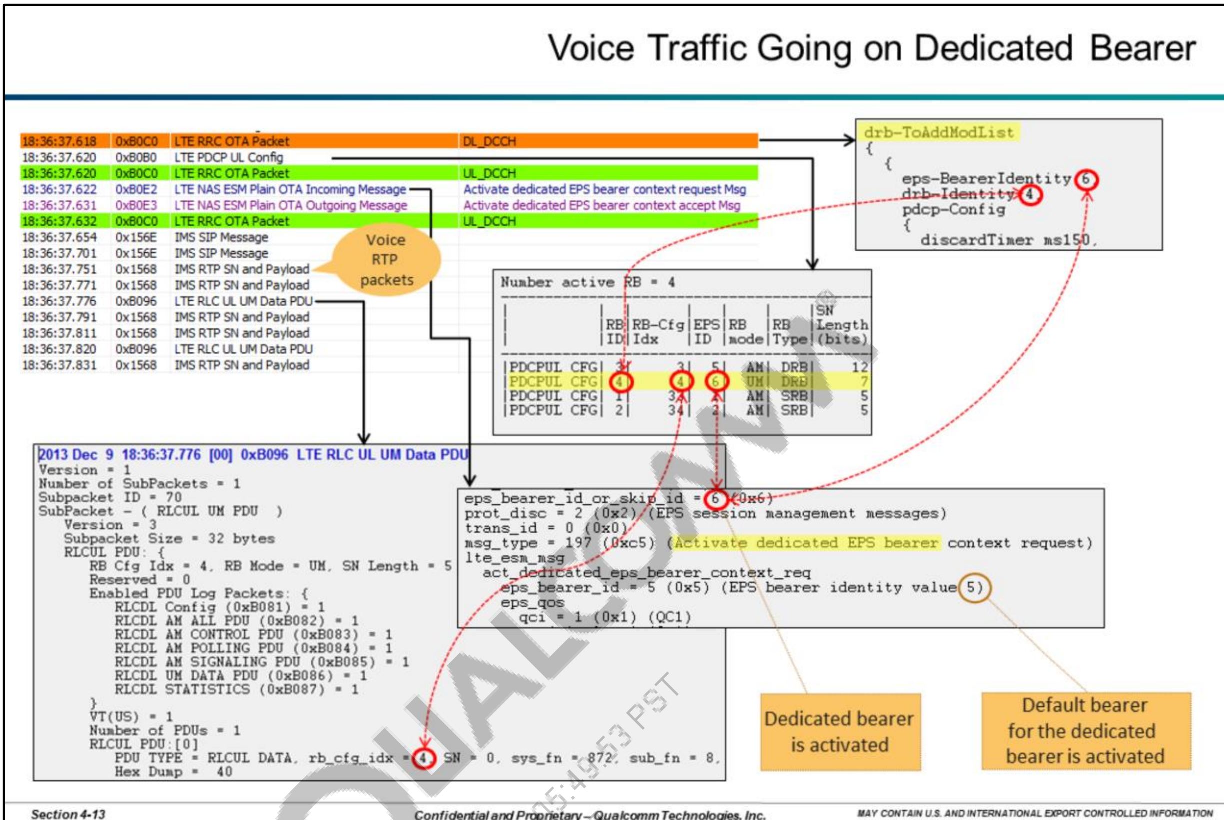
RoHC Configuration for VoLTE

At a minimum, two RoHC profiles should be supported:
1. Profile 0x0001 "RTP/UDP/IP" to compress RTP packets
2. Profile (0x0002) "UDP/IP" to compress RTCP packets.
The UE and the network must support these profiles for both IPv4 and IPv6.



RRC Connection Reconfiguration Details

For additional details of SPS and RoHC, refer to VoLTE Technical Overview, 80-W3001-1



Voice Traffic Going on Dedicated Bearer

Dedicated bearers are setup during VoLTE call setup to carry voice traffic.

In this slide:

- RRC/NAS add/activate a dedicated bearer with eps-BearerID 6 and drb-bearerID 4
- The PDCP shows rb-config-idx 4 maps to RB-ID (i.e., drb-bearerID) 4
- Form the RLC log packet, the voice traffic, after call is established, flows on rb-config-idx 4 which is the dedicated bearer that has been activated


Log Analysis: Dedicated Bearer Establishment
Log Analysis Procedure: Dedicated Bearer Establishment
Open File: 04-01-Dedicated_Bearer
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Notes

Dedicated Bearer Establishment: Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	RRC Connection Released	0xB0C0	18:36:26.456	UE is released (inactivity timer expiration)
2	IMS SIP Message	0x156E	18:36:35.175	User initiates a call (SIP INVITE initiated)
3	NAS EMM Outgoing Message	0xB0ED	18:36:35.176	Service Request
4	RRC Connection Request	0xB0C0	18:36:35.177	Establishment Cause: mo-Data
5	RACH Trigger	0xB061	18:36:35.177	RACH Reason = Connection Request
6	RACH Procedure	0xB167 0xB168 0xB169 0xB16A	18:36:35.229 through 18:36:35.256	MSG1 through MSG4
7	RACH Attempt	0xB062	18:36:35.256	Rach result = Success
8	IMS SIP Message	0x156E	18:36:35.537	SIP 100 TRTYING is received from the P-CSCF to indicate that the SIP:INVITE has been received and forwarded to MT UE
9	RRC Connection Reconfiguration	0xB0C0	18:36:37.618	DRB drb-Identity 4 is added. RLC UM mode.
10	NAS ESM Outgoing Message	0xB0E2	18:36:37.622	Activate dedicated EPS bearer context request. QCI set to 1 and GDR rates are set

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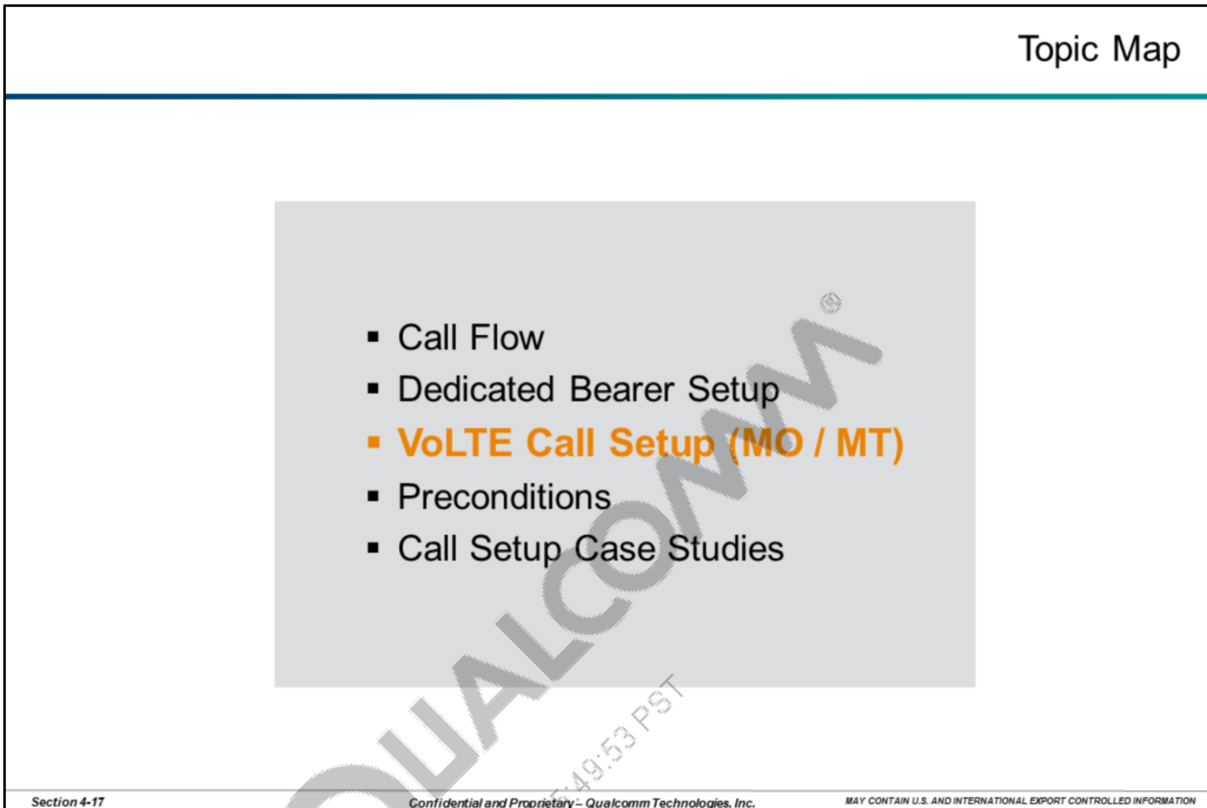
Notes

Dedicated Bearer Setup: Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
11	LTE PDCP UL Config	0xB0B0	18:36:37.620	Mapping of Radio Bearer ID, RB Config Index and EPS Bearer ID
12	IMS RTP SN and Payload	0x1568	18:36:37.751	First RTP packet. Sequence number = 0
13	LTE RLC UL UM Data PDU	0xB096	18:36:37.776	Mapped RB Cofig Index equals the same value as that of the dedicated bearer (Set to '4' in this example). RB Mode = UM

Notes


Topic Map
Call Flow
Dedicated Bearer Setup
VoLTE Call Setup (MO / MT)
Preconditions
Call Setup Case Studies
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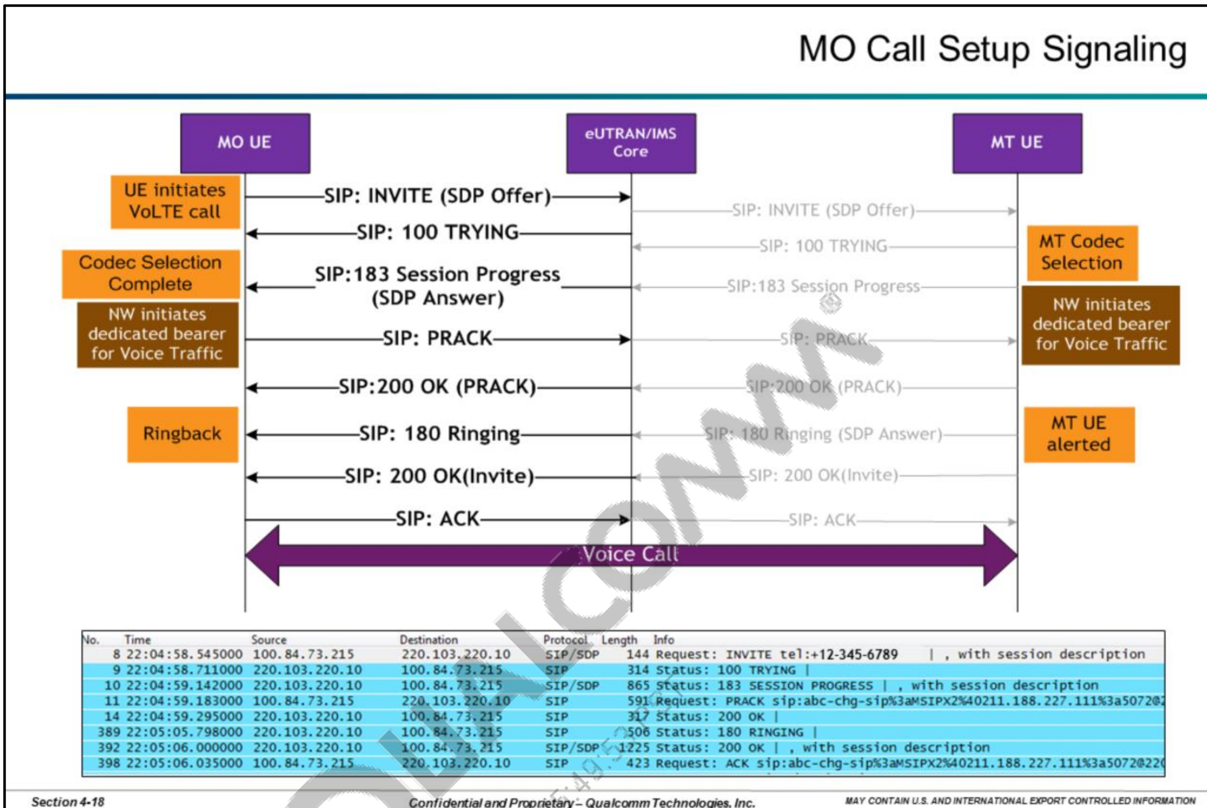
Notes


MO Call Setup Signaling
MO UE
eUTRAN/IMS Core
MT UE
UE initiates VoLTE call
Codec Selection Complete
NW initiates dedicated bearer for Voice Traffic
Ringback
MT Codec Selection
NW initiates dedicated bearer for Voice Traffic
MT UE alerted
SIP: INVITE (SDP Offer)
SIP: 100 TRYING
SIP:183 Session Progress (SDP Answer)
SIP: PRACK
SIP:200 OK (PRACK)
SIP: 180 Ringing
SIP: 200 OK(Invite)
SIP: ACK
SIP: INVITE (SDP Offer)
SIP: 100 TRYING
SIP:183 Session Progress
SIP: PRACK
SIP:200 OK (PRACK)
SIP: 180 Ringing (SDP Answer)
SIP: 200 OK(Invite)
SIP: ACK
Voice Call
No. Time Source Destination Protocol Length Info
8 22:04:58.545000 100.84.73.215 220.103.220.10 SIP/SDP 144 Request: INVITE tel:+12-345-6789 | , with session description
9 22:04:58.711000 220.103.220.10 100.84.73.215 SIP 314 Status: 100 TRYING |
10 22:04:59.142000 220.103.220.10 100.84.73.215 SIP/SDP 865 Status: 183 SESSION PROGRESS | , with session description
11 22:04:59.183000 100.84.73.215 220.103.220.10 SIP 591 Request: PRACK sip:abc-chg-sip%3aMSIPX2%40211.188.227.111%3a5072@
14 22:04:59.295000 220.103.220.10 100.84.73.215 SIP 317 Status: 200 OK |
389 22:05:05.798000 220.103.220.10 100.84.73.215 SIP 506 Status: 180 RINGING |
392 22:05:06.000000 220.103.220.10 100.84.73.215 SIP/SDP 1225 Status: 200 OK | , with session description
398 22:05:06.035000 100.84.73.215 220.103.220.10 SIP 423 Request: ACK sip:abc-chg-sip%3aMSIPX2%40211.188.227.111%3a5072@22
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Notes

SIP INVITE with SDP (Session Description Protocol)

- To initiate a VoLTE call, the MO UE sends a **SIP INVITE** with **SDP (Session Description Protocol)** information.
- The SDP information carries the description and QoS requirements for the media and its source transport address.
- SDP is referred to as an Offer/Answer model.
  - The client offers a set of characteristics to which the server responds.
  - There is no guarantee that the answer will contain the same characteristics as the offer.

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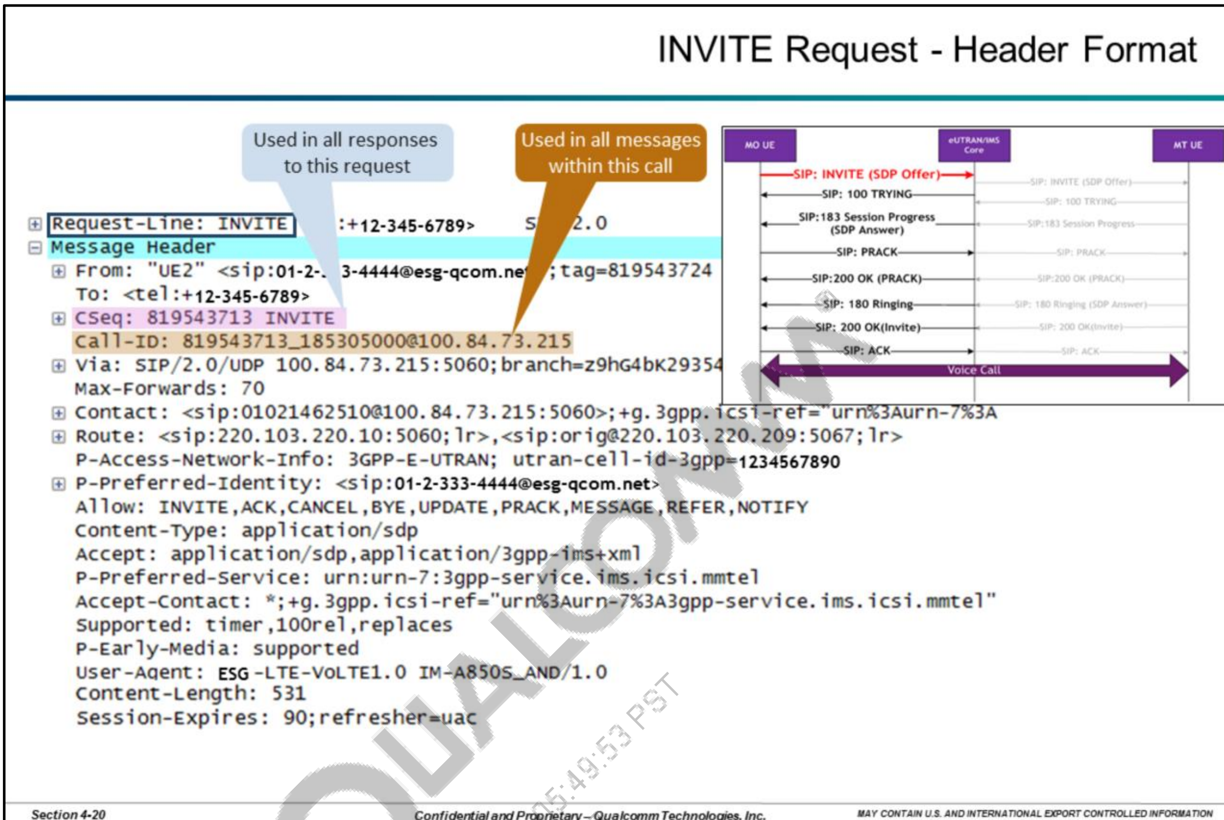
SIP INVITE with SDP (Session Description Protocol)

At minimum, SDP includes the following:

- origin – IP address, protocol and port number of session originator (owner)
- Media – media type, protocol and format
- Bandwidth – maximum bandwidth for RTP traffic and headers
- Attribute – encoder definition and sampling rate

Details of SDP are covered in the following RFCs:

1. RFC 4566 - SDP: Session Description Protocol
2. RFC 3264 - An Offer/Answer Model Session Description Protocol
3. RFC 5939 - Session Description Protocol (SDP) Media Capabilities Negotiation



INVITE Request – Header

From and **To**

These 2 fields (detailed in the next slide) are identical in all responses to this request, so the 'To' and 'From' fields are not reversed based on the direction of the message, whether request or response. The reason is that these fields are set based on the direction of the Request and not the direction of the message.

CSeq (Command Sequence)

CSeq is used to identify transactions. All responses to the current INVITE request will carry the same CSeq as the INVITE header (`819543713 INVITE`).

All subsequent requests from the same UE will carry a new CSeq, which is an incremented value of the current CSeq. Note that the next request from the MO UE (PRACK) carries a CSeq set to (`819543714 PRACK`).

INVITE Request – Header Details

Header Field (compact form)	Mandatory/ Optional	Description
From (f)	M	Identity of the initiator of the INVITE Request.
tag		Used for identification purposes
To (t)	M	Identity of the recipient of the INVITE request.
CSeq (Command Sequence)	M	CSeq consists of a sequence number and a method. The number is initialized at the start of a call and incremented for each new Request within the dialog. For this request, CSeq is set to `819543713 INVITE`
Call-ID (i)	M	Unique identifier used to identify messages belonging to the same call. All messages within this session will have the same Call-ID, regardless of the sender.

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INVITE Request – Header

For details, refer to RFC 3261; SIP: Session Initiation Protocol

INVITE Request – Header Details

Header Field (compact form)	Mandatory/ Optional	Description
Via (v)	M	Records the route taken by the request so the response can be tracked back to the originator. Format: SIP/2.0/UDP <IP address>:port; branch=<identifier> In this log: IP address → 100.84.73.215 Port → 5060 Identifier → z9hG4bK293549239 (responses to this request will have the same identifier)
Max-Forwards	M	Limit the number of hops a request can transit on the way to its destination and is decremented by one at each hop. This acts as a loop detector.
Contact (m)	M	IP address, port and unique device identifier where the request originator UE can be reached for further requests
Route	O	Used to force routing for a request through the listed set of proxies.

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INVITE Request – Header Details

Via: Each proxy on the route adds an entry to Via header field. This enables the response to follow the exact route back to the originator. The Via header field is the only field in the header where the order is significant.

Max-Forward: If the Max-Forwards value reaches 0 before the request reaches its destination, it will be rejected with a 483 (Too Many Hops) error response

Contact: Can also carry subscription information

Note that **Via** field is used to route the response, whereas **Route** field is used to route the request.

INVITE Request – Header Details

Header Field (compact form)	Mandatory/ Optional	Description
P-Access-Network-Info	O	Indicates the RAN technology used to send the request; 3GPP E-UTRA FDD in this log
P-Preferred-Identity	O	Used to carry the identity of the UE sending a SIP message as it was verified by authentication
Allow	O	Lists the SIP methods supported by the UE
Content-Type	O	Indicates the contents of the message body, SDP (Session Description Protocol), in this log
Accept	O	Lists the types of message bodies to be received in the response
Supported (k)	O	List of all the extensions supported by the UE • timer: The UE supports refreshes • 100rel : The UE will ACK 100-class responses • replaces: SIP Replaces header is supported

INVITE Request – Header Details

Supported: '100rel' extension indicates that MO UE will acknowledge 100-class responses (like 183 Session Progress) from MT UE. Without 100rel extension, MT UE, that sends 183 Session Progress, will not get any indication whether this response was received by MO UE or not.

The UE can also include the following extensions in the Supported header

- Preconditions – Indicates the support of preconditions framework as specified in 3GPP TS 24.299 and RFC 3312 (updated in RFC 4032)
- 199 – Indicates the support of the 199 response code (early dialog termination).

'Replaces' allows the UE to transfer the current dialog to a new entity

INVITE Request – Header Details

Header Field (compact form)	Mandatory/ Optional	Description
Session-Expires	O	The time limit of the current call, once established, without a RE-INVITE or an UPDATE. The value is given in seconds, with a minimum value of 90 seconds.
P-Early-Media	O	Indicated the support for early media such as pre-recorded announcements to be played prior to the call being answered
Content-Length (l)	O	The size of the message body, in bytes
P-Preferred-Service	O	Preferred communications service of the request, MMTel (multimedia telephony) for this request
Accept-Contact (a)	O	Allow the caller to set its preferences on the characteristics of the UE it is trying to reach
Accept	O	Indicates acceptable media types. In this log, UE initiating the request supports SDP and IMS XML

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INVITE Request – Header Details

Session-Expires

For details on Session-Expires, refer to RFC 4028; Session Timer

The inclusion of the *Session-Expires* indicates the UE wants to use session timer for the call being established. Notice it indicated 'timer' in the extensions in *Supported* header field.

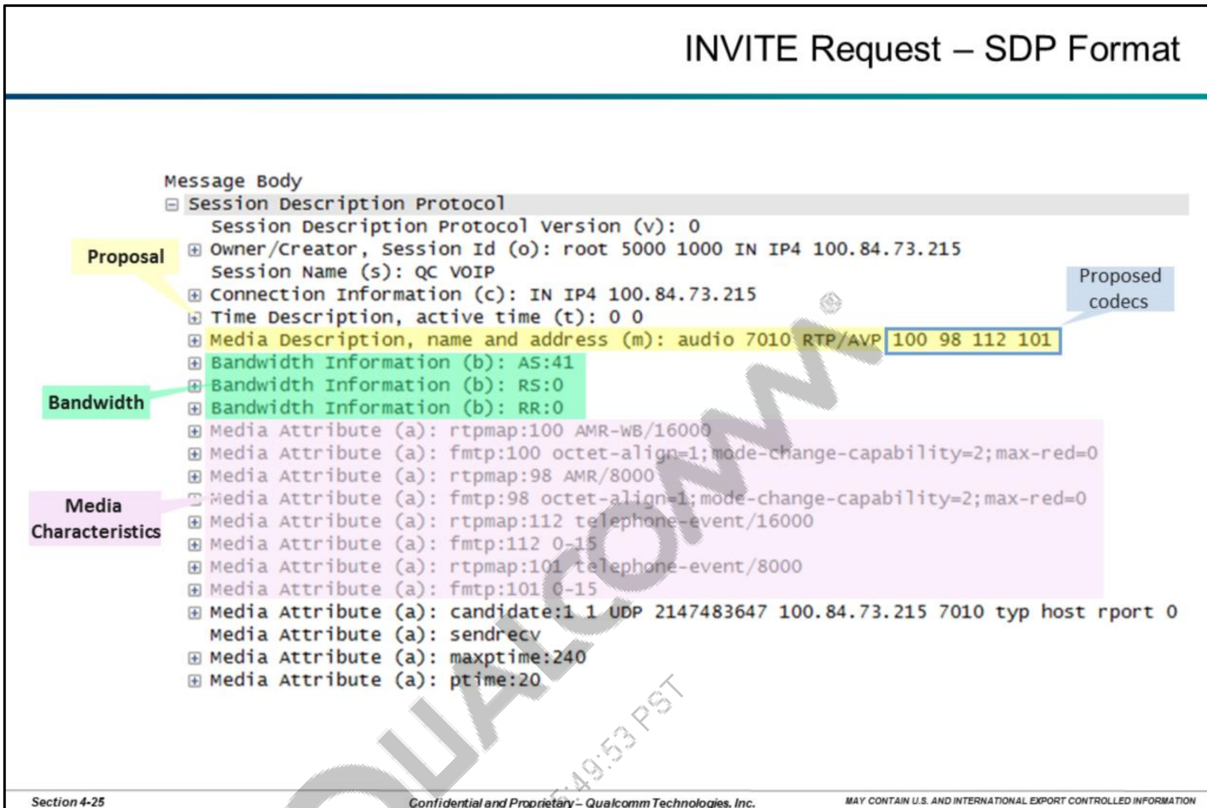
RFC 4028 offers the following explanation of the functionality of Session-Expires:

> From the Session-Expires header field in the response, both UAs know that a session timer is active, when it will expire, and who is refreshing. At some point before the expiration, the currently active refresher generates a session refresh request, which is a re-INVITE or UPDATE [3] request. If the refresher never gets a response to that session refresh request, it sends a BYE to terminate the session. Similarly, if the other side never gets the session refresh request before the session expires, it sends a BYE.

The *Session-Expires* header field differs from the *Expires* header field, had the latter existed in the log.

Expires header field in the INVITE request indicates the duration the request is valid. Expires is only valid till the call is established. In other words, *Expires* is only valid during call setup, but not after the call is established.

On the other hand, *Session-Expires* is only valid after the call is established.



INVITE Request – SDP Format

Message body of an INVITE request is composed of the SDP (Session Description Protocol)

SDP carries information about:

- Session originator
- Connection
- Media description

INVITE Request – SDP Details

SDP Field (compact form)	Description
Owner/Creator (o)	Information of the session owner: <username> <session id> <version> <network type> <address type> <address> • Username: `root` • Session ID: `5000` • Session version: `1000` • Network Type: `IN` → Internet • Address Type: `IP4` → IPv4 • Address: `100.84.73.215`
Connection Information (c)	Connection information to be established: <network type> <address type> <connection address> • Network Type: `IN` → Internet • Address Type: `IP4` → IPv4 • Connection Address: `100.84.73.215`
Time Description (t)	Time the session is active: <start time> <stop time> Both start time and stop time are set to '0' because there is no predetermined time for the session start or end. It starts when the called party picks up the phone and ends when either party terminates the call.

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INVITE Request – SDP Details

Owner/Creator

The session ID is typically set to the timestamp of the session origination or a random number.

Session version can also be a timestamp or another random number that is increase when the session changes.

Connection Information

The Connection Address refers to the IP address of the party to send media. In this log, it is set to the IP address of the session creator.

INVITE Request – SDP Media Description

SDP Field (compact form)	Description

Media Description (m)	This field includes information about the media session. Multiple media payload types are usually offered to give alternatives for the called party to choose from.
	Media Description =<media> <port> <transport protocol> <format>
	• Media: `audio`
	• Port: `7010`
	• Transport Protocol: `Real-time transport protocol (RTP)/audio video profile (AVP)`
	• Format, as defined in the media attributes (next slide)
	  • 100 → `AMR-WB`[1] `at 16kHz`
	  • 98 → `AMR at 8kHz`
	  • 112 → `telephone-events`, i.e., DTMF[2] at 16 kHz
	  • 101 → `telephone-events`, i.e., DTMF at 8 kHz

[1]AMR-WB: Adaptive MultiRate-Wide Band

[2]DTMF: Dual-Tone MultiFrequency

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INVITE Request – SDP Media Description

Media Description

<media> is the media type. Currently defined media are "audio", "video", "text", "application" and "message“

DTMF are not needed for VoLTE calls, but are still supported for applications that use DTMF for signaling, like telephone banking when a user enters an account number and a PIN using phone numbers.

INVITE Request – SDP Bandwidth Information

SDP Field (compact form)	Description
Bandwidth Information (b)	b = <modifier>:<bandwidth value>
Bandwidth Information (b): AS	"AS" indicates the application-specific bandwidth modifier (RTP session bandwidth) MO UE proposes the **highest bandwidth**, based on — Codec format (AMR-NB or AMR-WB) — Address type (IPv4 or IPv6) — Bandwidth efficient or octet-aligned AS → `41 kbps` (AMR-WB; IPv4; octet-aligned)
Bandwidth Information (b): RS Bandwidth Information (b): RR	RS (RTCP Sender) and RR (RTCP Receiver) define the RTCP bandwidth for the MO UE and MT UE, respectively. Setting both RS and RR bandwidth modifiers to 0 indicated no RTCP control is used.

INVITE Request – SDP

This table shows the bandwidth calculations for AMR-WB bandwidth efficient mode.

	Codec Mode								
	6.6	8.85	12.65	14.25	15.85	18.25	19.85	23.05	23.85
Speech Payload	132	177	253	285	317	365	397	461	477
AMR Header	12	15	11	11	11	11	11	11	11
IPv4 Header	320	320	320	320	320	320	320	320	320
IPv4 Packet Size	464	512	584	616	648	696	728	792	808
IPv4 BW (kbps)	**24**	**26**	**30**	**32**	**33**	**36**	**37**	**40**	**41**
IPv6 Header	480	480	480	480	480	480	480	480	480
IPv6 Packet Size	624	672	744	776	808	856	888	952	968
IPv6 BW (kbps)	**32**	**34**	**38**	**40**	**41**	**43**	**45**	**48**	**49**

For details of AS bandwidth calculations, refer to 26.114, IP Multimedia Subsystem (IMS); Multimedia Telephony; Media handling and interaction.

RTCP (Real Time Transport Control Protocol) is used to send control packets, mainly feedback on call statistics, latency and quality of service, to participants in the call.

For details of RTCP, refer to RFC 3550; RTP: A Transport Protocol for Real-Time Applications

INVITE Request – SDP Media Attributes

SDP Field (compact form)	Description
rtpmap	Defines the mappings from RTP payload types to encodings. In the log: `Media Attribute(a): rtpmap:100 AMR-WB/16000` Media format 100 maps to AMR-WB codec at 16 kHz sampling rate
fmtp (media)	Provides additional parameters of the media format. In the log: `Media Attribute (a): fmtp:100 octet-align=1;mode-change-capability=2;max-red=0`
octet-align	Setting this field to '1' indicates octet-aligned is used
mode-change-capability	A value of 1 indicates no restriction on the codec mode change is supported, and that the codec mode may be changed during the call
max-red	max-red is set to '0' indicating no redundancy will be used
fmtp (DTMF)	Provides additional parameters of the DTMF format. In the log: `Media Attribute (a): fmtp:112 0-15` UE supports DTMF payload type number 112, with DTMF tones events from 0 to 15

INVITE Request – SDP Media Attributes

octet-aligned

Permissible values for this field are 0 and 1.

- If 1, octet-aligned operation is be used.
- If 0 or if not present, bandwidth efficient operation is employed.

In the octet-aligned format, all the fields in a payload, including payload header, table of contents entries, and speech frames themselves, are individually aligned to octet boundaries to make implementations efficient. In the bandwidth efficient format only the full payload is octet aligned, so fewer padding bits are added.

For details of octet-aligned vs bandwidth efficient, refer to RFC 3267; RTP Payload Format for AMR and AMR-WB

max-red

Duration (ms) between the first transmission of a frame and any redundant transmission that the sender will use. Allowed values are integers between 0 (no redundancy will be used) and 65535.

INVITE Request – SDP Media Attributes

SDP Field (compact form)	Description
sendrecv	Indicate the request originator intends to send and receive media with the request terminator
ptime	<packet time>; media frame duration (ms). This is fixed at 20ms for VoLTE

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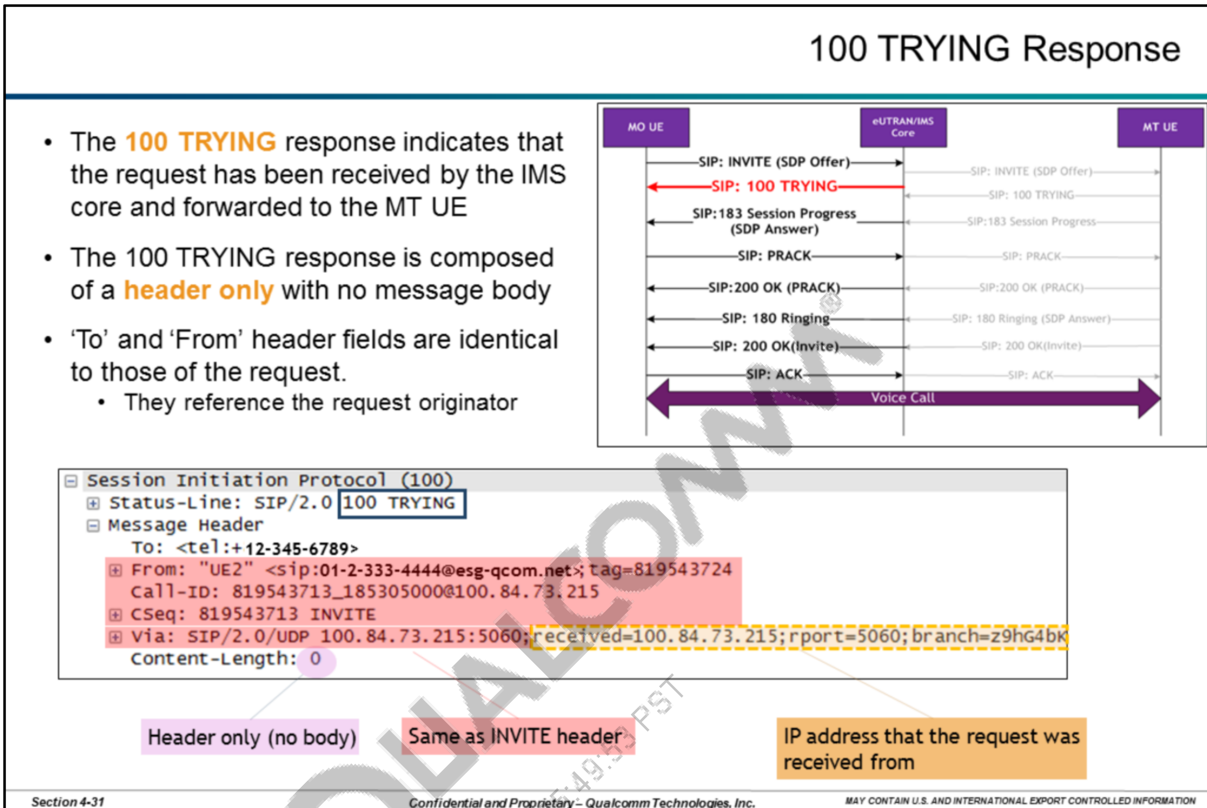
INVITE Request – SDP Media Attributes

sendrecv field can also be set to “recvonly” for receive-only mode or “sendonly” for send-only mode



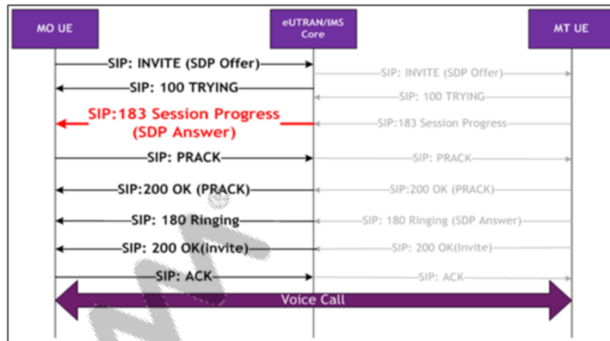
100 TRYING Response

The 'To' and 'From' header fields are identical in both requests and responses.

They refer to the originator and recipient of the request, rather than the sender and receiver of the current message.

183 SESSION PROGRESS Response

- MT UE sends **183 Session Progress** response with SDP, indicating the selected codec(s)
- IMS core forwards '183 Session Progress' to MO UE
- The network could use the '183 Session Progress' to initiate dedicated bearer establishment



- 183 Session Progress header includes:
  - **Require: 100rel**
    - MO UE must ACK this provisional response
  - **RSeq**
    - Provisional response sequence number, to be used by the MO UE in the ACK to this response

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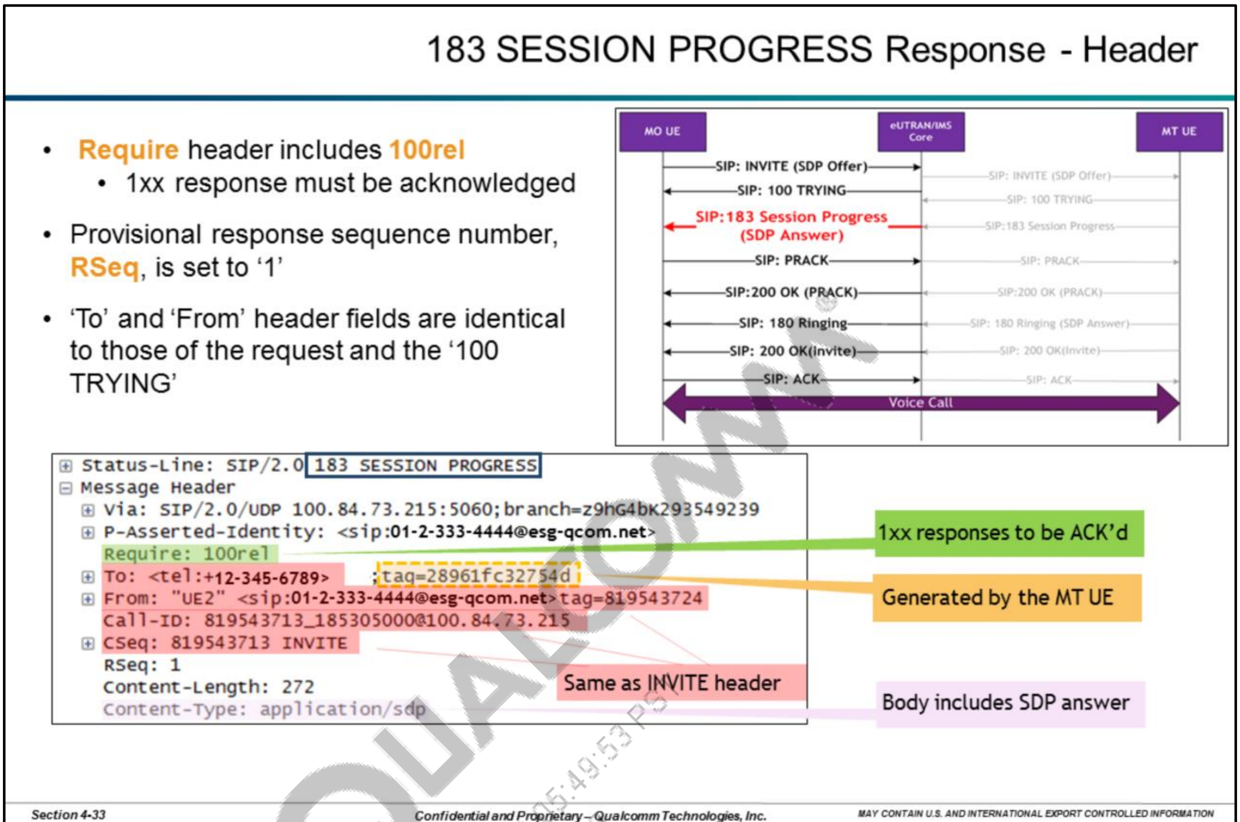
183 SESSION PROGRESS Response

- **Require: 100rel** Recall the MO UE included '100rel' in the *Supported* header field
- By default, provisional responses (i.e., 1xx responses) are not ACK'd. The inclusion of **Require: 100rel** in 183 SESSION PROGRESS requests the MO UE to ACK this response
- AN ACK of a provisional response is called a PRACK



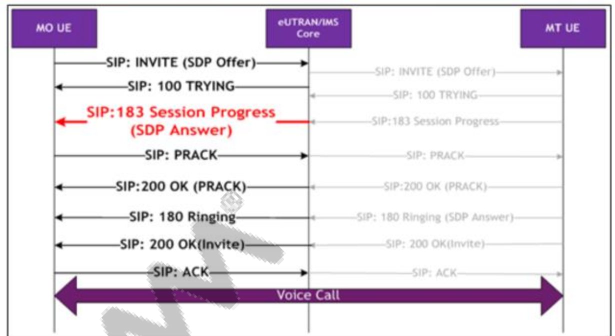
183 SESSION PROGRESS Response – Header

The 183 Session Progress response includes two sequence numbers:

1. **CSeq** (Command Sequence) which is identical to the CSeq of the INVITE request, indicating the 183 Session Progress is a response to the INVITE request
2. RSeq (Response Sequence) which will be included in the PRACK

183 SESSION PROGRESS Response – SDP

- The **183 Session Progress** response from the MT UE includes **two codecs, out of the four** that MO UE offered




```
Session Description Protocol
  Session Description Protocol Version (v): 0
⊞ Owner/Creator, Session Id (o): - 5001 1373346299 IN IP4 223.33.170.84
  Session Name (s): mrf
⊞ Connection Information (c): IN IP4 223.33.170.84
⊞ Time Description, active time (t): 0 0
⊞ Media Description, name and address (m): audio 11798 RTP/AVP 100 112
⊞ Media Attribute (a): rtpmap:100 AMR-WB/16000
⊞ Media Attribute (a): ptime:20
⊞ Media Attribute (a): maxptime:20
⊞ Media Attribute (a): fmtp:100 octet-align=1; mode-set=8
⊞ Media Attribute (a): rtpmap:112 telphone-event/16000
⊞ Media Attribute (a): fmtp:112 0-15
  Media Attribute (a): sendrecv
```

Accepted codecs

Attributes of accepted codecs

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Notes

183 SESSION PROGRESS Response – SDP

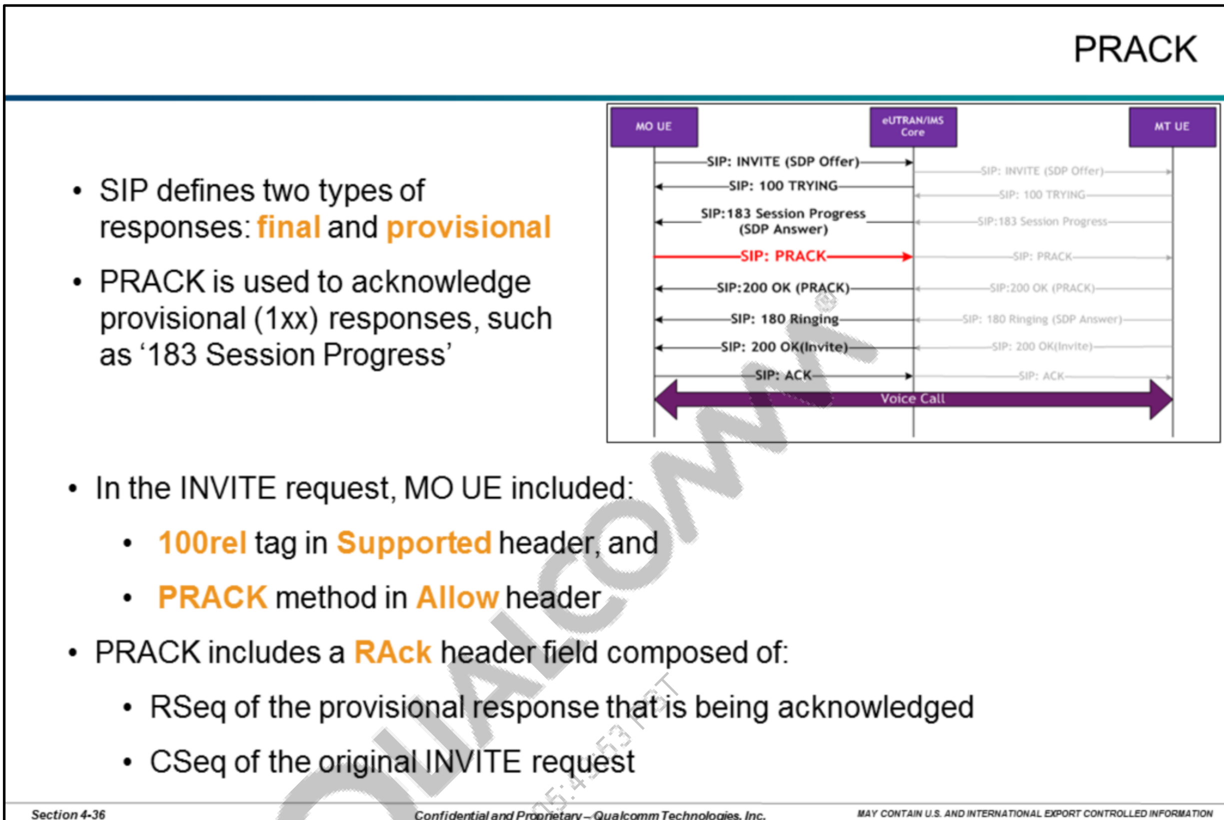
Message Body Field (compact format)	Description

Media Description (m)	Media Description =<media> <port> <transport protocol> <format>
	• Media: `audio`
	• Port: `11798`
	• Transport Protocol: `Real-time transport protocol (RTP)/audio video profile (AVP)`
	• Format, as defined in the media attributes
	  • 100 → `AMR-WB at 16000 Hz`
	  • 112 → `telephone-event`

- The **183 Session Progress** includes the SDP answer by MT UE. Only two of the four codecs offered by MO UE were accepted.

INVITE Request – SDP

Details of the Session Description Protocol (SDP) are covered in RFC4566

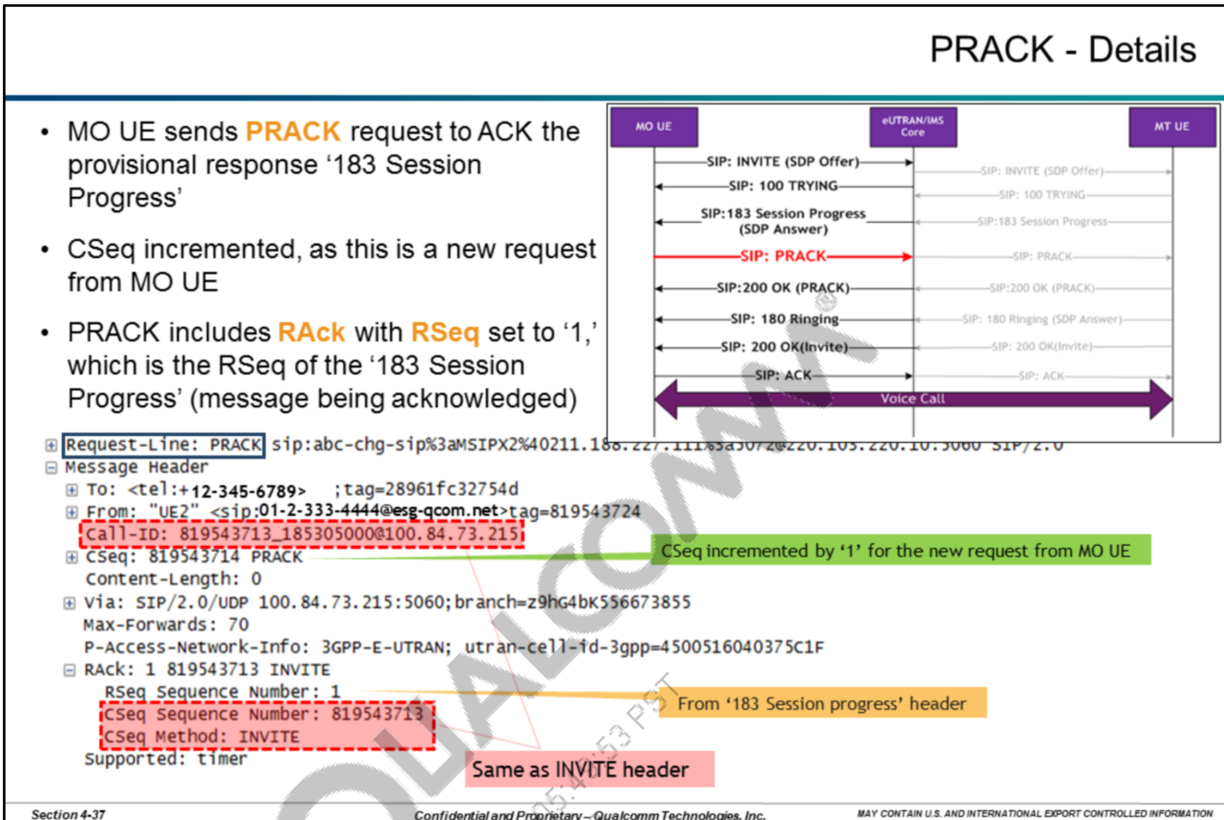


PRACK

For PRACK details, refer to "RFC 3262 Reliability of Provisional Responses in SIP"

The PRACK includes two CSeq values:

1. Header field PRACK CSeq which is an incremented value of the INVITE CSeq
2. INVITE CSeq, inside the RAck header field



PRACK - Details

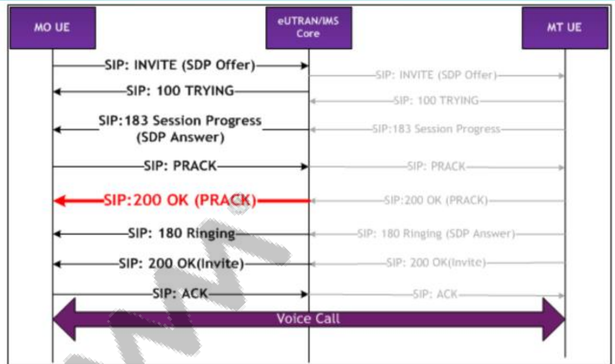
Each provisional response is given a sequence number, carried in the RSeq header field in the response (set to '1' in the log). The PRACK messages contain an RAck header field, which indicates the sequence number of the provisional response that is being acknowledged.

The RAck header is sent in a PRACK request to support reliability of provisional responses. It contains two numbers and a method tag.

- The first number is the value from the RSeq header in the provisional response that is being acknowledged. This is set to '1' in the above log.
- The second number, and the method, are copied from the CSeq in the response that is being acknowledged. These are set to '`819543713 INVITE`' in the above log.

SIP: 200 OK (PRACK)

- The PRACK, being a request, must get a response.
- MT UE sends **200 OK** as a response to the PRACK.
- SIP: 200 OK (PRACK) is a header-only message
- 200 OK includes the CSeq of the PRACK, not of the INVITE
  - Confirms it is a **response for the PRACK**




```
⊟ Session Initiation Protocol (200)
  ⊞ Status-Line: SIP/2.0 200 OK
  ⊟ Message Header
    ⊞ Via: SIP/2.0/UDP 100.84.73.215:5060;branch=z9hG4bK556673855
    ⊞ To: <tel:+12-1234567890>;tag=28961fc32754d
    ⊞ From: "UE2" <sip:01021462510@ESGims.net>;tag=819543724
      Call-ID: 819543713_1853050000@100.84.73.215
    ⊞ CSeq: 819543714 PRACK
    ⊞ Contact: <sip:MSIPX2@220.103.220.10:5060>
```

Does not change throughout the call

CSeq of PRACK (not CSeq of INVITE)

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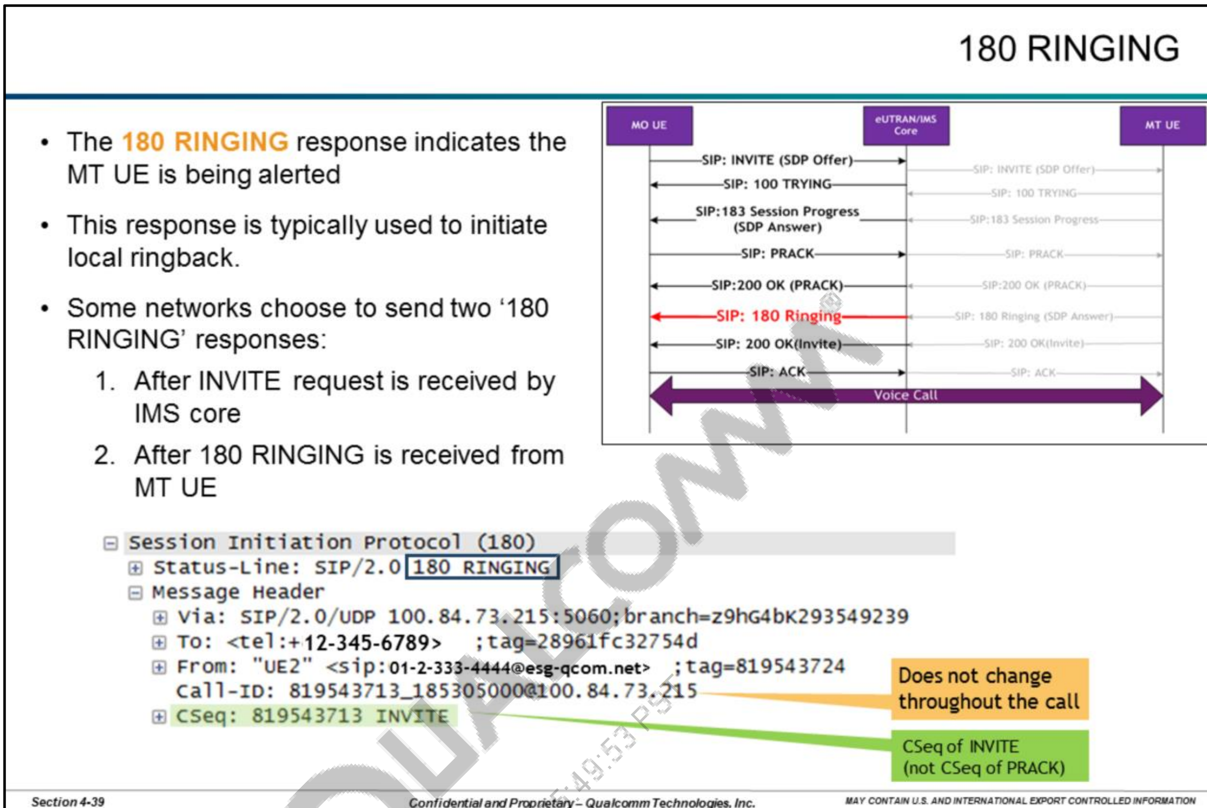
Notes

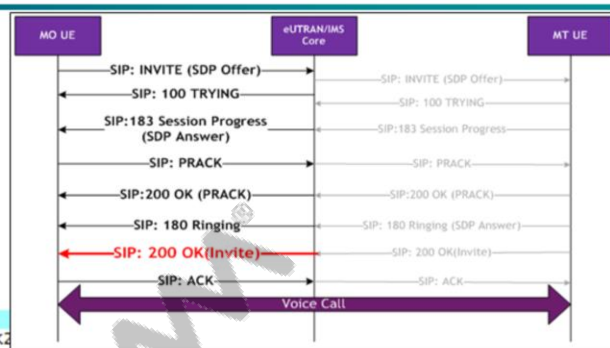


180 RINGING

- The 180 RINGING initiates the ringback tone, which played locally on the UE.
- Some operators send an early 180 RINGING to start the local ringback, following the INVITE request. The purpose of this early ringing is to present the calling party (MO UE user) with a better user experience. In this case, two 180 RINGING messages will be included in the call flow

200 OK (INVITE) Header

- The 200 OK is sent in response to the INVITE request.
  - CSeq of the INVITE request
- Session-Expires value accepted by MT

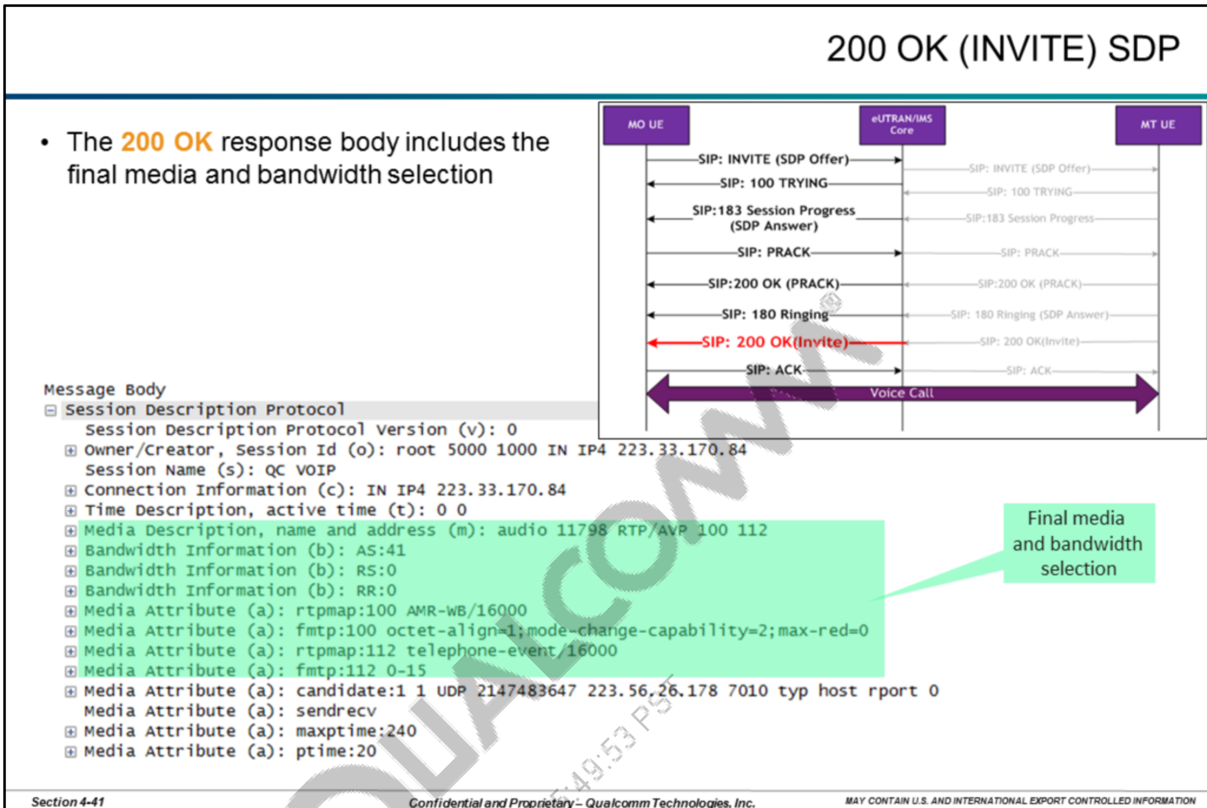



```
Message Header
⊞ Via: SIP/2.0/UDP 100.84.73.215:5060;branch=z9hG4bK2
⊞ P-Asserted-Identity: sip:01021462610@ESGims.net
⊞ From: "UE2" <sip:01021462510@ESGims.net>;tag=819543724
⊞ To: <tel:+12-1234567890>;tag=28961fc32754d
⊞ CSeq: 819543713 INVITE
  Call-ID: 819543713_185305000@100.84.73.215
  P-Access-Network-Info: 3GPP-E-UTRAN; utran-cell-id-3gpp=1234567890
⊞ P-ESG-MMTEL-Info: m_change
  Content-Length: 391
  User-Agent: ESG-LTE-VoLTE1.0 IM-A850S_AND/1.0
  Supported: 100rel
  Allow: INVITE,ACK,CANCEL,BYE,UPDATE,PRACK,MESSAGE,REFER,NOTIFY
  Require: timer
  Session-Expires: 90;refresher=uac
  Content-Type: application/sdp
⊞ Contact: <sip:abc-chg-sip%3aMSIPX2%40211.188.227.111%3a5072@220.103.220.10:5060>
⊞ P-Charging-Function-Addresses: ccf="aaa://imscg3.ESGims.net"; ccf="aaa://imscg4.ESGims.net"
```

CSeq of INVITE (not PRACK)

Session-Expires Accepted by MT

Notes


200 OK (INVITE) SDP
• The 200 OK response body includes the final media and bandwidth selection
MO UE
eUTRAN/IMS Core
MT UE
SIP: INVITE (SDP Offer)
SIP: 100 TRYING
SIP:183 Session Progress (SDP Answer)
SIP: PRACK
SIP:200 OK (PRACK)
SIP: 180 Ringing
SIP: 200 OK(Invite)
SIP: ACK
SIP: 180 Ringing (SDP Answer)
Voice Call
Message Body
Session Description Protocol
Session Description Protocol Version (v): 0
Owner/Creator, Session Id (o): root 5000 1000 IN IP4 223.33.170.84
Session Name (s): QC VOIP
Connection Information (c): IN IP4 223.33.170.84
Time Description, active time (t): 0 0
Media Description, name and address (m): audio 11798 RTP/AVP 100 112
Bandwidth Information (b): AS:41
Bandwidth Information (b): RS:0
Bandwidth Information (b): RR:0
Media Attribute (a): rtpmap:100 AMR-WB/16000
Media Attribute (a): fmtp:100 octet-align=1;mode-change-capability=2;max-red=0
Media Attribute (a): rtpmap:112 telephone-event/16000
Media Attribute (a): fmtp:112 0-15
Media Attribute (a): candidate:1 1 UDP 2147483647 223.56.26.178 7010 typ host rport 0
Media Attribute (a): sendrecv
Media Attribute (a): maxptime:240
Media Attribute (a): ptime:20
Final media and bandwidth selection
Section 4-41
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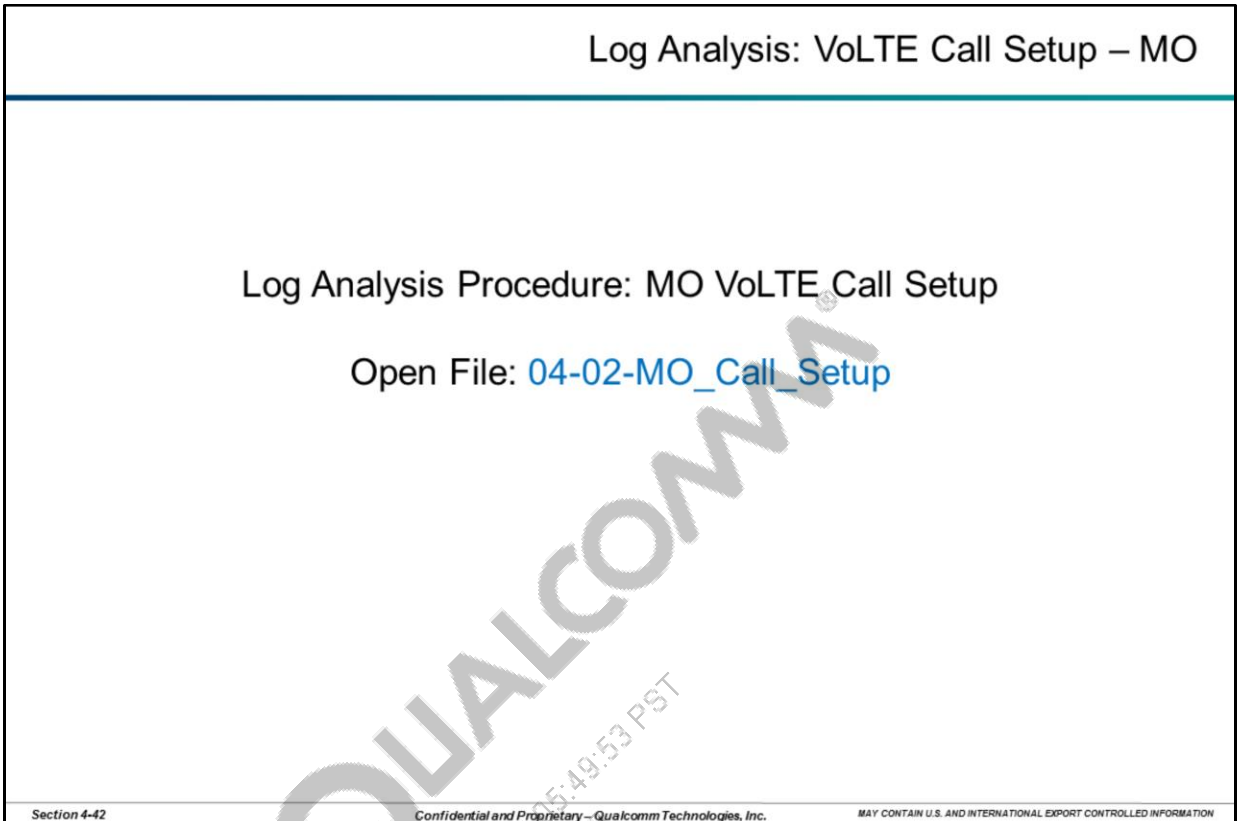
Notes


Log Analysis: VoLTE Call Setup – MO
Log Analysis Procedure: MO VoLTE Call Setup
Open File: 04-02-MO_Call_Setup
Section 4-42
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Notes

MO VoLTE Call Setup – Log Walk-Through

Step	Look for…	Timestamp	Verify…
1	SIP: INVITE	22:04:58.545	• Method set to INVITE in Request-Line. • 'From' and 'To' fields are populated properly • SDP includes the proposed codecs • Media attributes include 'sendrecv'
2	SIP: 100 TRYING	22:04:58.711	• '100 TRYING' in Status-Line • Same CSeq and Call-ID as the INVITE request
3	SIP: 183 SESSION PROGRESS	22:04:59.142	• 'From' and 'To' fields are identical to the INVITE request, with new tag for the 'To' field • Same CSeq and Call-ID as the INVITE request • Accepted codecs are a subset of the proposed codecs in the INVITE request • Media attributes include 'sendrecv'
4	SIP: PRACK	22:04:59.183	• Method set to PRACK in Request-Line • Call-ID identical to INVITE request • CSeq number is incremented
5	SIP: 200 OK (PRACK)	22:04:59.295	• '200 OK' in Status-Line • Call-ID identical to INVITE and PRACK requests • CSeq identical to PRACK request

Analysis Summary

The arrival of messages during logging could impact the order in which time stamps are shown.

If needed while analyzing a log file in the browser, use the menu "Edit" + "Find on this Page" to find a specific timestamp.

VoLTE Call Setup – Log Walk-Through

Step	Look for…	Timestamp	Verify…
6	SIP: 180 RINGING	22:05:05.798	• '180 RINGING' in Status-Line • Call-ID identical to INVITE and PRACK requests • CSeq identical to INVITE (not PRACK) request
7	SIP: 200 OK (INVITE)	22:05:06.000	• '200 OK' in Status-Line • Call-ID identical to INVITE and PRACK requests • CSeq identical to INVITE (not PRACK) request • SDP includes the same codecs accepted by the MT UE
8	ACK	22:05:06.035	• Method set to ACK in Request-Line • Call-ID and CSeq identical to INVITE request

Analysis Summary

The arrival of messages during logging could impact the order in which time stamps are shown.

If needed while analyzing a log file in the browser, use the menu "Edit" + "Find on this Page" to find a specific timestamp.

MO VoLTE Call Setup – Questions

Fill the blanks using the log file:

1. Does the MO UE accept early media ? ________, Where? ________________
2. What is the content of the INVITE message body? __________________
3. What is the CSeq of the INVITE request? ______________________
4. What is the CSeq of the PRACK? ______________________
5. What is the CSeq of the first 200 OK from the network? _____________________
6. What is the CSeq of the final 200 OK from the network? _____________________
7. What is the RSeq value of the 183 Session Progress? ___________
8. What are the components of the RACK in the PRACK message? ___________________________

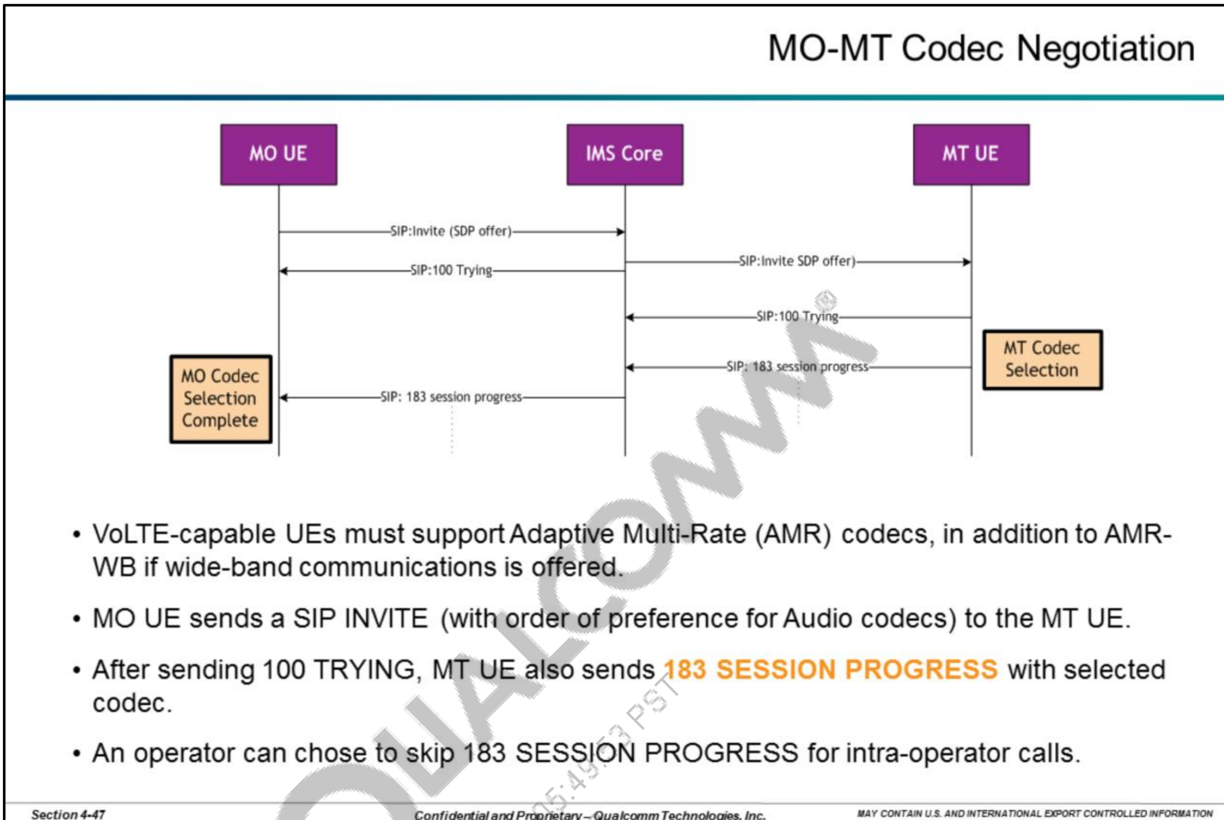
Notes

MO VoLTE Call Setup – Answers

Fill the blanks using the log file:

1. Does the MO UE accept early media ? Yes, Where? *P-Early-Media: supported*
2. What is the content of the INVITE message body? SDP
3. What is the CSeq of the INVITE request? 819543713 INVITE
4. What is the CSeq of the PRACK? 819543714 PRACK
5. What is the CSeq of the first 200 OK from the network? 819543714 PRACK
6. What is the CSeq of the final 200 OK from the network? 819543713 INVITE
7. What is the RSeq value of the 183 Session Progress? 1
8. What are the components of the RACK in the PRACK message? RSeq: 1; Cseq: 819543713 INVITE

Notes



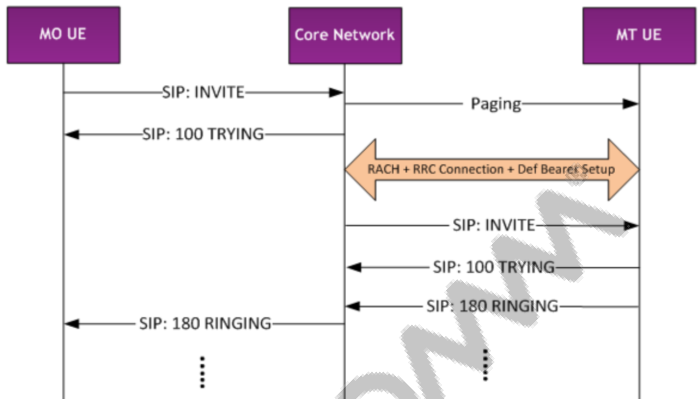
MO-MT Codec Negotiation

The modes of the AMR and AMR-WB codecs are listed below.

AMR CODEC Modes	4.75	5.15	5.90	6.70	7.40	7.95	10.20	12.20

AMR-WB CODEC Modes	6.60	8.85	12.65	14.25	15.85	18.25	19.85	23.05	23.85

MT Call Setup Call Flow



- Upon receiving SIP INVITE from MO UE, the network pages MT UE.
- Upon successful Page decode, MT UE will RACH and complete RRC connection procedure.
- The call setup will progress as outlined earlier.

MT Call Setup Call Flow

Call setup delay and call setup success statistics are typically estimated on the MO side.

This will include the RACH and RRC.

MT UE Call Setup from RRC IDLE

19:35:59.211	0xB0C0	LTE RRC OTA Packet	DL_DCCH
19:36:00.275	0xB0C0	LTE RRC OTA Packet	PCCH
19:36:07.965	0xB0C0	LTE RRC OTA Packet	PCCH
19:36:07.965	0xB0ED	LTE NAS EMM Plain OTA Outgoing Message	Service Request Msg
19:36:07.965	0xB0C0	LTE RRC OTA Packet	UL_CCCH
19:36:07.965	0xB061	LTE MAC Rach Trigger	
19:36:08.025	0xB167	LTE Random Access Request (MSG1) Report	
19:36:08.035	0xB168	LTE Random Access Response (MSG2) Report	
19:36:08.035	0xB169	LTE UE Identification Message (MSG3) Report	
19:36:08.055	0xB16A	LTE Contention Resolution Message (MSG4) R...	
19:36:08.055	0xB062	LTE MAC Rach Attempt	
19:36:08.055	0xB0C0	LTE RRC OTA Packet	DL_CCCH
19:36:08.058	0xB0C0	LTE RRC OTA Packet	UL_DCCH
19:36:08.113	0xB0C0	LTE RRC OTA Packet	DL_DCCH
19:36:08.114	0xB0C0	LTE RRC OTA Packet	UL_DCCH
19:36:08.140	0xB0C0	LTE RRC OTA Packet	DL_DCCH
19:36:08.140	0xB0C0	LTE RRC OTA Packet	UL_DCCH
19:36:08.188	0xB0C0	LTE RRC OTA Packet	DL_DCCH
19:36:08.215	0xB0C0	LTE RRC OTA Packet	UL_DCCH
19:36:08.281	0x156E	IMS SIP Message	
19:36:08.285	0x156E	IMS SIP Message	
19:36:13.075	0xB0C0	LTE RRC OTA Packet	PCCH
19:36:13.365	0x156E	IMS SIP Message	
19:36:13.444	0xB0C0	LTE RRC OTA Packet	DL_DCCH
19:36:13.445	0xB0C0	LTE RRC OTA Packet	UL_DCCH
19:36:13.445	0xB0E2	LTE NAS ESM Plain OTA Incoming Message	Activate dedicated EPS bearer context request Msg
19:36:13.446	0xB0E3	LTE NAS ESM Plain OTA Outgoing Message	Activate dedicated EPS bearer context accept Msg
19:36:13.449	0xB0C0	LTE RRC OTA Packet	UL_DCCH
19:36:13.630	0x156E	IMS SIP Message	
19:36:13.839	0x1568	IMS RTP SN and Payload	
19:36:13.846	0x1568	IMS RTP SN and Payload	
19:36:13.874	0x1568	IMS RTP SN and Payload	
19:36:13.894	0x1568	IMS RTP SN and Payload	
19:36:13.914	0x1568	IMS RTP SN and Payload	
19:36:13.934	0x1568	IMS RTP SN and Payload	
19:36:13.954	0x1568	IMS RTP SN and Payload	
19:36:13.974	0x1568	IMS RTP SN and Payload	
19:36:13.994	0x1568	IMS RTP SN and Payload	

RRC Release
Page
NAS Service Request
RRC Conn Establishment
SIP: INVITE
SIP: 100 TRYING
SIP: 200 OK (Invite)
Dedicated Bearer
SIP: ACK
Voice Traffic

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Notes

Log Analysis: VoLTE Call Setup – MT

Log Analysis Procedure: MT VoLTE Call Setup

Open File: 04-03-MT_Call_Setup

Notes

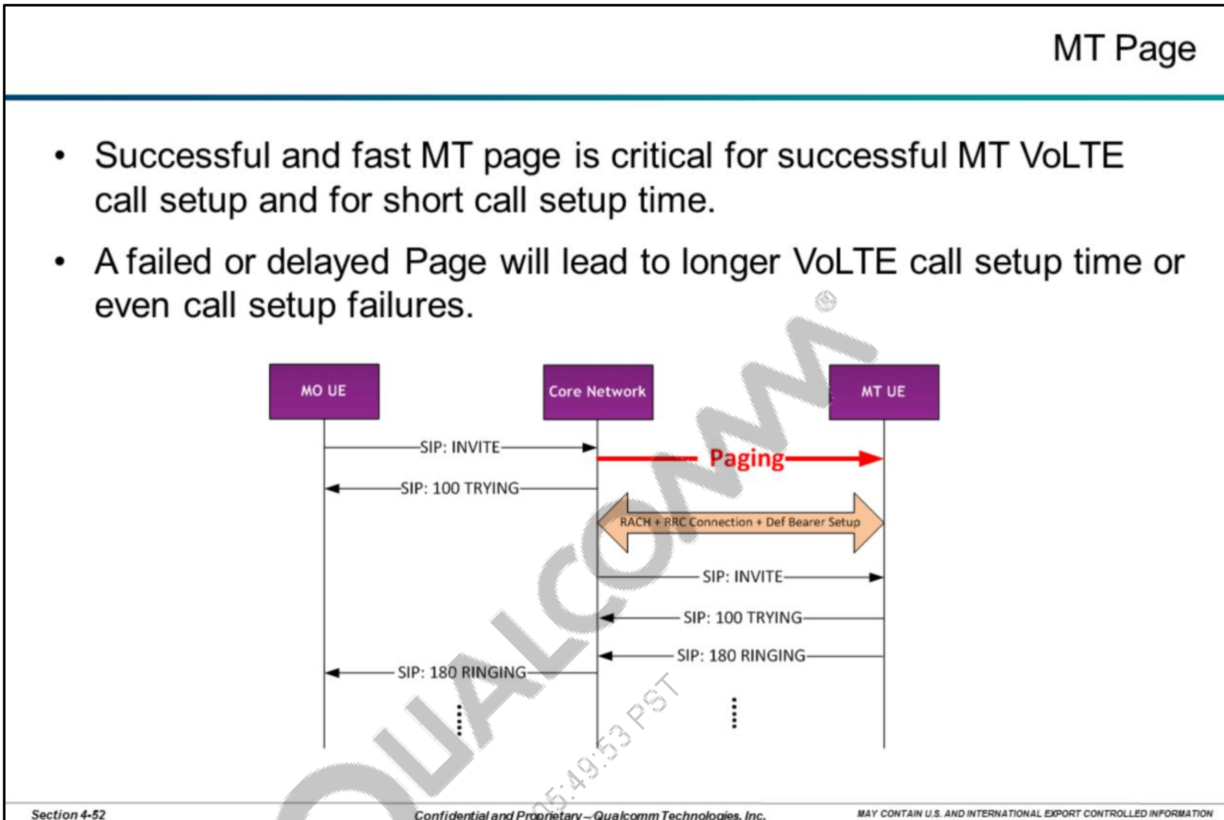
MT VoLTE Call Setup – Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	Page	0xB0C0	19:36:07.965	M-TMSI is correct. Should be identical to that in the rrcConnectionRequest
2	Service Request	0xB0ED	19:36:07.965	
3	RRC Connection Request	0xB0C0	19:36:07.965	M-TMSI identical to that of the Page establishmentCause mt-Access
4	RACH Procedure	0xB167 0xB168, 0xB169 0xB16A, 0xB062	19:36:08.025 Through 19:36:08.055	Successful RACH
5	ueCapabilityInformation	0xB0C0	19:36:08.140	RoHC profiles 1 and 2 are supported VoLTE FGI bits are set (bits 3,6,7,20,28,29)
6	VoLTE Call setup	0x156E	19:36:08.281 Through 19:36:13.365	IMS SIP INVITE to 200 OK (SIP INVITE)
7	RRC Connection Reconfiguration	0xB0C0	19:36:13.444	Dedicated bearer is configured after the call setup is progressing.
8	Dedicated bearer activation	0xB0E2, 0xB0E3	19:36:13.445	CQI = 1
9	IMS RTP SN and Payload	0x1568	19:36:13.839	Voice traffic flows after SIP ACK

Analysis Summary

The arrival of messages during logging could impact the order in which time stamps are shown.

If needed while analyzing a log file in the browser, use the menu “Edit” + “Find on this Page” (Ctrl+F) to find a specific timestamp.



MT Page

Main causes of failed Pages are:

1) Poor RF conditions leading to lost Pages or error decoding Pages

2) MT UE idle mobility (reselection) leading the network to page the MT UE on old serving cell

Specifications References

Specifications	Title
3GPP TS 36.331	E-UTRA Radio Resource Control (RRC); Protocol specification
3GPP TS 24.301	Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS)
3GPP TS 26.114	IP Multimedia Subsystem (IMS); Multimedia Telephony; Media handling and interaction
3GPP TS 23.228	IP Multimedia Subsystem (IMS)
RFC 3261	SIP: Session Initiation Protocol
RFC 4028	Session Timers in the Session Initiation Protocol (SIP)
RFC 4566	SDP: Session Description Protocol
RFC 3264	An Offer/Answer Model Session Description Protocol
RFC 5939	Session Description Protocol (SDP) Media Capabilities Negotiation
RFC 3550	RTP: A Transport Protocol for Real-Time Applications
RFC 3267	Real-Time Transport Protocol (RTP) Payload Format and File Storage Format for the Adaptive Multi-Rate (AMR) and Adaptive Multi-Rate Wideband (AMR-WB) Audio Codecs

Specifications References

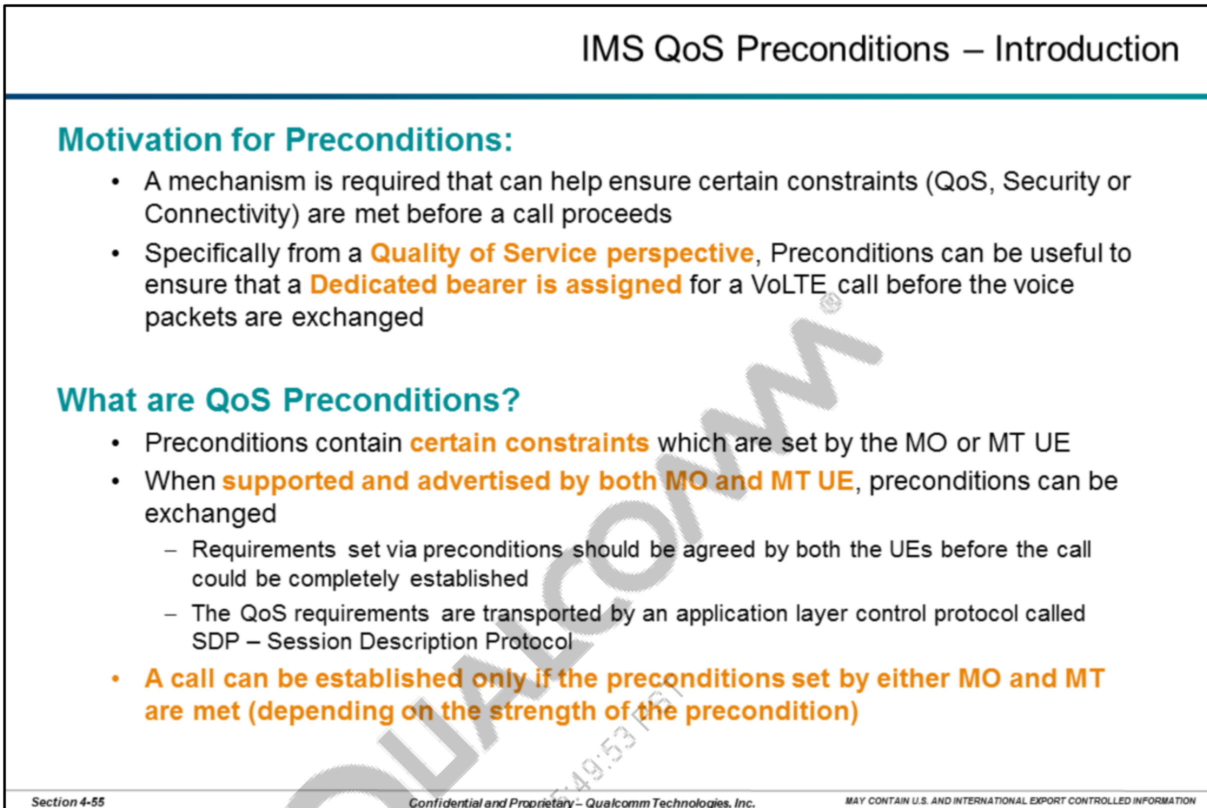
3GPP LTE specifications are available at www.3gpp.org

IETF RFCs are available at www.ietf.org

Topic Map

- Call Flow
- Dedicated Bearer Setup
- VoLTE Call Setup (MO / MT)
- **Preconditions**
- Call Setup Case Studies

Notes



IMS QoS Preconditions – Introduction

- Connectivity Precondition - A connectivity precondition can be used to delay session establishment or modification until media stream connectivity has been successfully verified.
- Security Precondition - Ensures the successful negotiation of media stream security parameters for a secure media stream prior to session establishment or modification.
- RFC 3312 - Note that use of a mandatory precondition requires the presence of a SIP "Require" header with the option tag "precondition".

Preconditions – QoS Selection Essentials

- Before the call could be initiated, both **MO and MT UE are unaware of each other's QoS availability**
- Two precondition QoS states are maintained by each UE
  - **Current-state(curr)** is the present state of the UE
  - **Desired-state(des)** is the target state of the UE

  Call is initiated only when **Current-state >= Desired-state**
- Each precondition QoS state is based on following tags:
  - **status-type** <segmented, end-to-end>
    - segmented – local-tag and remote-tag
  - **strength-tag** <mandatory, optional, none>
  - **direction-tag** <send, recv, sendrecv>
- **SIP INVITE, PROGRESS and UPDATE** messages are exchanged to reflect the current-state and desired-state of both UEs

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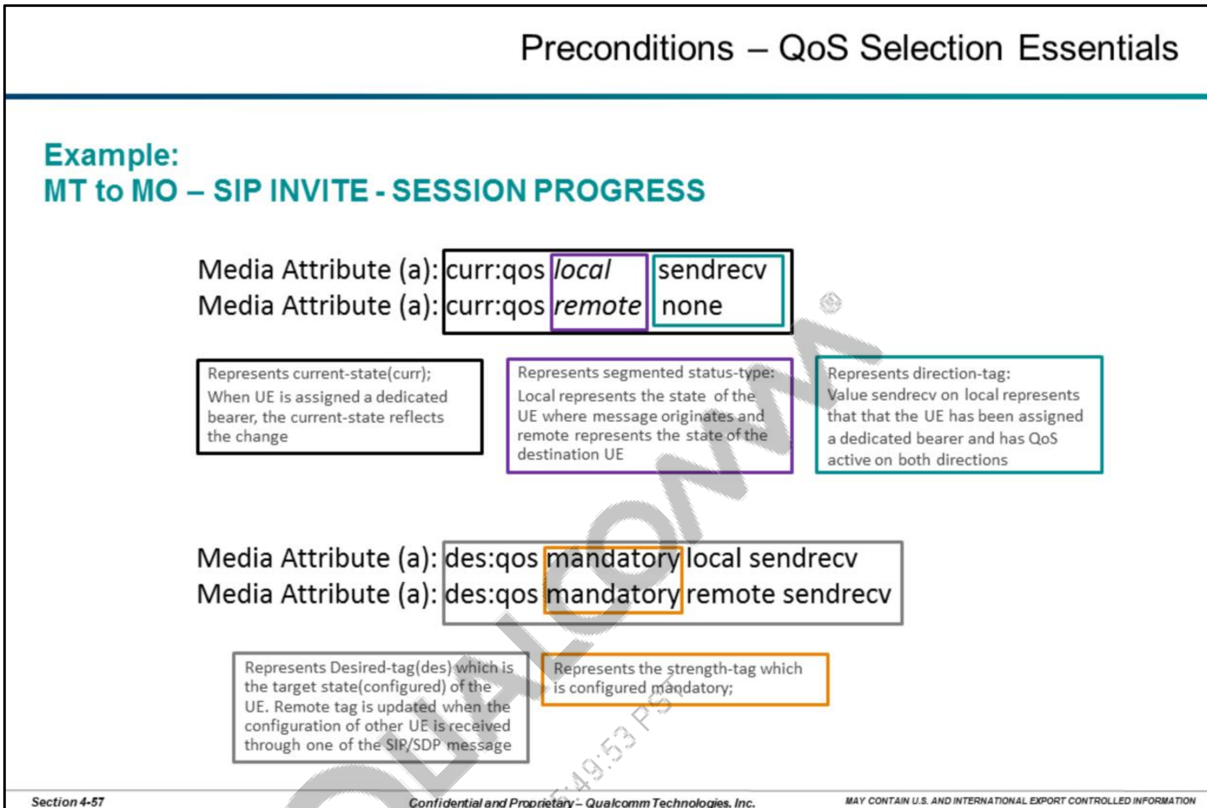
Notes



Preconditions – QoS Selection Essentials

- Local and remote represent the point of view of the entity generating the SDP description
- Slides explaining this concept are based on Mobile-to-Mobile VoLTE calls

Preconditions Case Studies

Case Study 1 - Preconditions Signaling in VoLTE

Case Study 2 - Preconditions Unavailability at the Network

Case Study 3 - UE QoS Configuration Timer Expiry

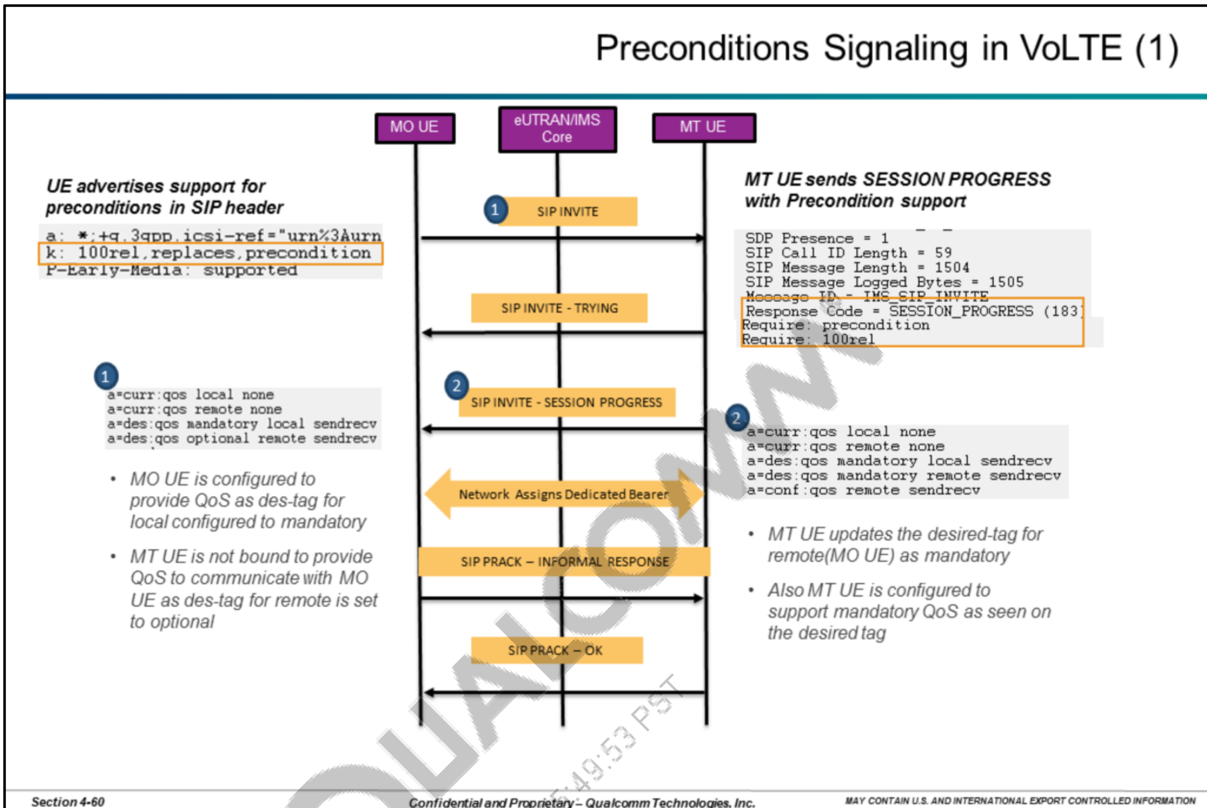
Notes

Analysis Example – Preconditions Signaling

Log Analysis Procedure: Preconditions Signaling

Open File: 04-04-Preconditions_Signaling

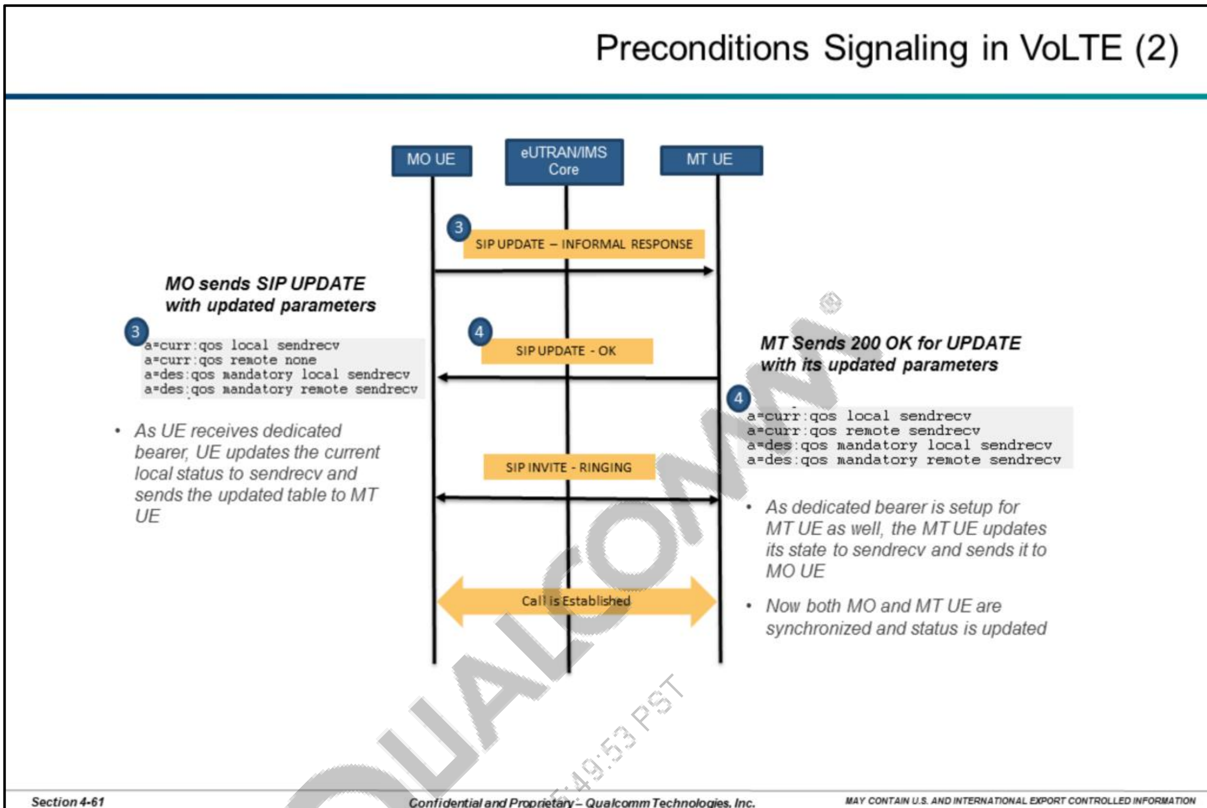
Notes



Preconditions Signaling in VoLTE

Step 1: UE initiates SIP INVITE after user attempts to make a call. If the UE is configured to support Preconditions, it would advertise its support "precondition" option tag in the Supported header. Based upon the configured settings, UE can set the strength tag as either mandatory or optional for local/remote.

Step 2: After MT UE sends SIP INVITE – TRYING, MT UE advertises its support for Preconditions(Using SIP INVITE – SESSION PROGRESS), updates MO with its Precondition information. MT UE can set the strength tag for itself as either optional or mandatory. After MO receives Session Progress it starts its QoS timer, which is run until the network assigns dedicated bearer resources to the UE.



Preconditions Signaling in VoLTE (2)

Step 3: After the dedicated bearers are assigned to MO UE (this represents that local reservation is complete), UE now updates the MT UE by sending SIP UPDATE.

Step 4: Similarly, MT UE in response to the last MO UE UPDATE sends 200 OK containing the updates SDP information.

Preconditions Signaling in VoLTE Network: Log Walk-Through

Step	Look for…	Timestamp	Verify…
1	SIP: INVITE	02:56:35.831	• MO UE advertises its support for preconditions • UE sets the curr and des state • 'des' state represents the configured settings in the UE • 'curr' state represents no QoS is assigned until now
2	SIP:SESSION PROGRESS	02:56:38.831	• MT UE sends Session Progress to MO UE and also advertises its support for preconditions • 'des' remote state is updated based on MO UEs configuration • 'des' local state is updated based on UEs configured setting
3	SIP: UPDATE	02:56:39.425	• MO UE updates the table as QoS has been assigned • 'curr' local state reflects the update due to QoS assignment
4	SIP: UPDATE OK	02:56:40.282	• 'curr' local state suggests QoS has been assigned to MT UE • 'curr' remote state represent the updated settings of the MO UE

Notes

Preconditions Case Studies

Case Study 1 - Preconditions Signaling in VoLTE

Case Study 2 - Preconditions Unavailability at the Network

Case Study 3 - UE QoS Configuration Timer Expiry

Notes

Preconditions Unavailability at the Network

- In this case study, both MO and MT UEs support Preconditions
- IMS network does not support Preconditions
  - MO UE initiates the call using IMS SIP INVITE with "preconditions" support
  - Network processes the message and strips the "preconditions" header and body before sending it to the destination UE
  - MT UE receives the IMS SIP INVITE which is sent by the MO UE without the preconditions content
- We examine how the call proceeds without Precondition support from the network

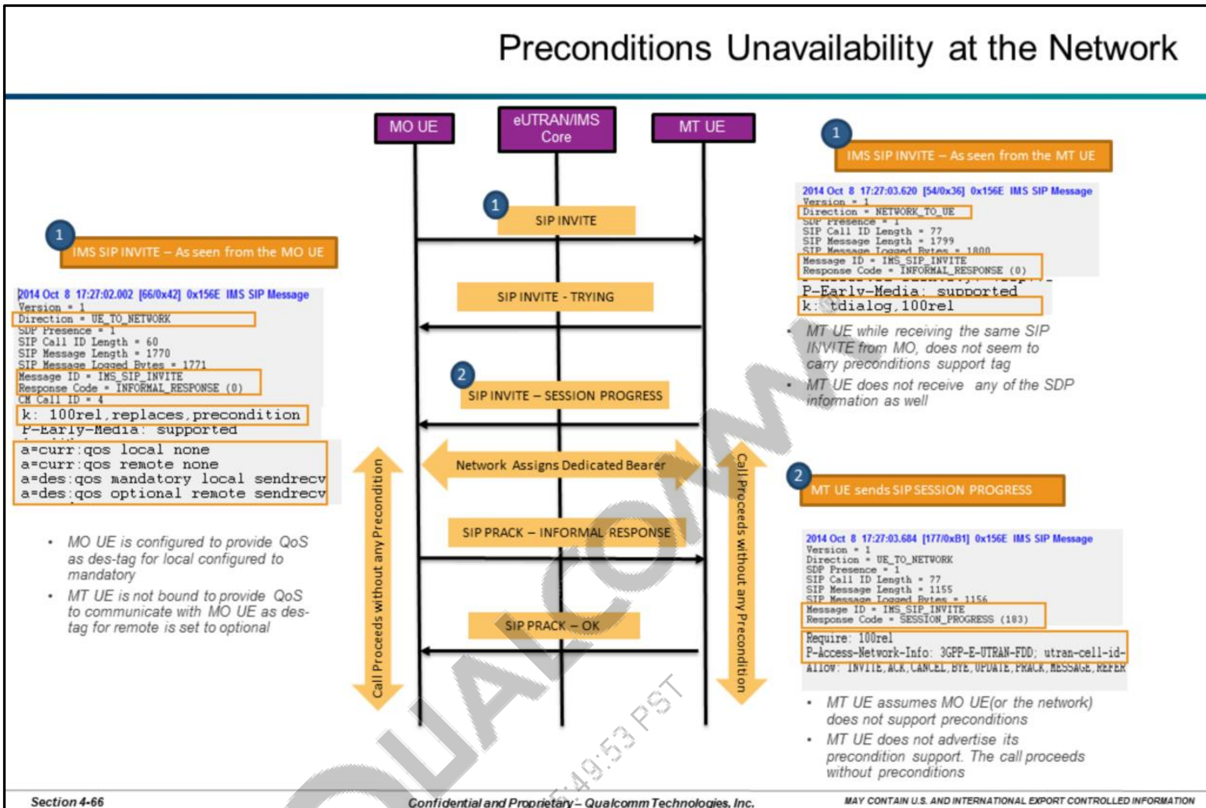
Notes

Analysis Example – Preconditions Unavailability at the Network

Log Analysis Procedure: Preconditions Unavailability at the Network

Open File: 04-05-Preconditions-Unavailabale

Notes


Preconditions Unavailability at the Network
MO UE
eUTRAN/IMS Core
MT UE
1
SIP INVITE
SIP INVITE - TRYING
2
SIP INVITE – SESSION PROGRESS
Network Assigns Dedicated Bearer
SIP PRACK – INFORMAL RESPONSE
SIP PRACK – OK
Call Proceeds without any Precondition
Call Proceeds without any Precondition
1
IMS SIP INVITE – As seen from the MO UE
2014 Oct 8 17:27:02.002 [66/0x42] 0x156E IMS SIP Message
Version = 1
Direction = UE_TO_NETWORK
SDP Presence = 1
SIP Call ID Length = 60
SIP Message Length = 1770
SIP Message Logged Bytes = 1771
Message ID = IMS_SIP_INVITE
Response Code = INFORMAL_RESPONSE (0)
CM Call ID = 4
k: 100rel,replaces,precondition
P-Early-Media: supported
a=curr:qos local none
a=curr:qos remote none
a=des:qos mandatory local sendrecv
a=des:qos optional remote sendrecv
• MO UE is configured to provide QoS as des-tag for local configured to mandatory
• MT UE is not bound to provide QoS to communicate with MO UE as des-tag for remote is set to optional
1
IMS SIP INVITE – As seen from the MT UE
2014 Oct 8 17:27:03.620 [54/0x36] 0x156E IMS SIP Message
Version = 1
Direction = NETWORK_TO_UE
SDP Presence = 1
SIP Call ID Length = 77
SIP Message Length = 1799
SIP Message Logged Bytes = 1800
Message ID = IMS_SIP_INVITE
Response Code = INFORMAL_RESPONSE (0)
P-Early-Media: supported
k: tdialog,100rel
• MT UE while receiving the same SIP INVITE from MO, does not seem to carry preconditions support tag
• MT UE does not receive any of the SDP information as well
2
MT UE sends SIP SESSION PROGRESS
2014 Oct 8 17:27:03.684 [177/0xB1] 0x156E IMS SIP Message
Version = 1
Direction = UE_TO_NETWORK
SDP Presence = 1
SIP Call ID Length = 77
SIP Message Length = 1155
SIP Message Logged Bytes = 1156
Message ID = IMS_SIP_INVITE
Response Code = SESSION_PROGRESS (183)
Require: 100rel
P-Access-Network-Info: 3GPP-E-UTRAN-FDD; utran-cell-id-
Allow: INVITE,ACK,CANCEL,BYE,UPDATE,PRACK,MESSAGE,REFER
• MT UE assumes MO UE(or the network) does not support preconditions
• MT UE does not advertise its precondition support. The call proceeds without preconditions
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Notes

Preconditions Unavailability at the Network: Log Walk-Through

Step	Look for...	Timestamp	Verify...
1	MO UE - SIP: INVITE	17:27:02.002	• MO UE advertises its support for preconditions • UE sets the 'curr' and 'des' state
2	MT UE - SIP: INVITE	17:27:03.620	• MT UE does not receive MO UEs advertised preconditions • Does not see any state information either
2	SIP:SESSION PROGRESS	17:27:03.684	• MT UE does not advertise precondition support as it now assumes that MO UE does not support it • Call proceeds without preconditions

Notes

Preconditions Case Studies

Case Study 1 - Preconditions Signaling in VoLTE

Case Study 2 - Preconditions Unavailability at the Network

Case Study 3 - UE QoS Configuration Timer Expiry

Notes

UE QoS Configuration Timer Expiry

Overview

- In this case study, we examine how failure in setting up the agreed QoS can lead to precondition failure
- MO and MT UE both support preconditions
- UE, while configured to support QoS, cannot wait for an indefinite amount of time to get the dedicated bearer setup from the network
  – During the preconditions exchange, the UE waits for a specified configured time to gets its dedicated bearer setup from the network

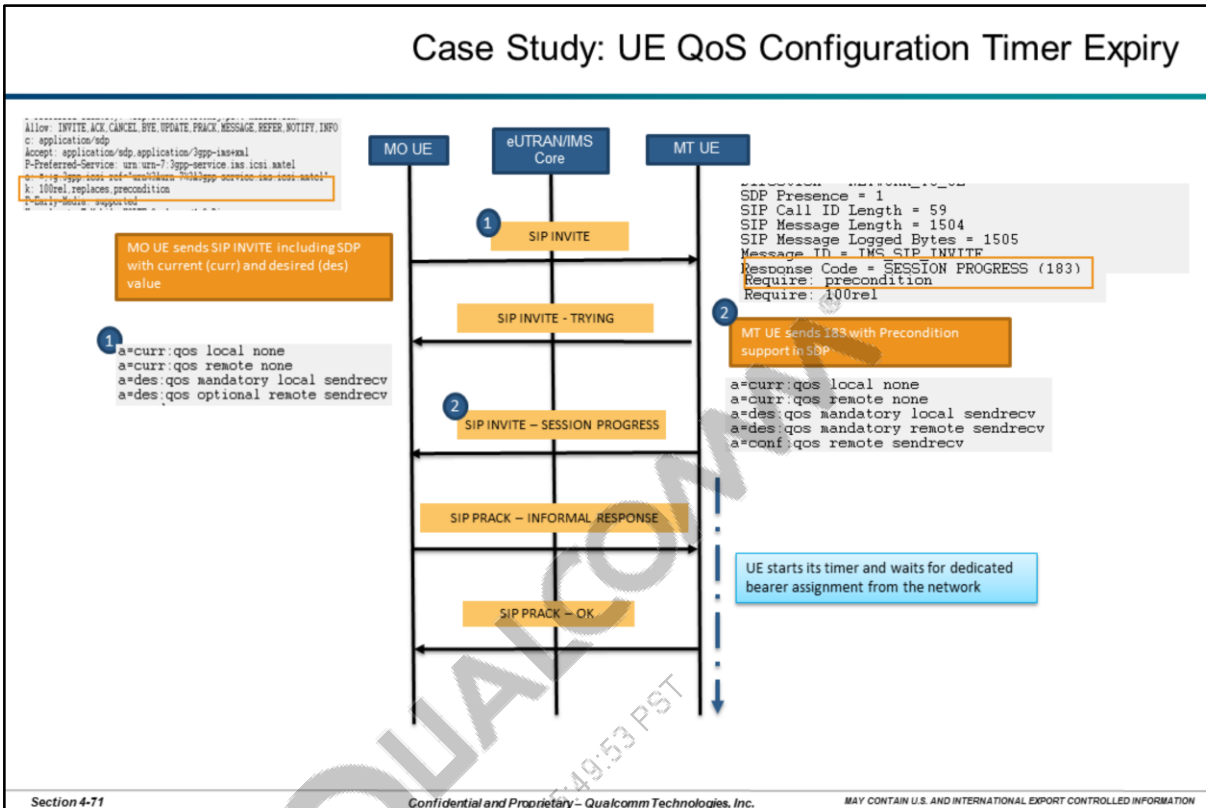
Notes

Analysis Example – UE QoS Configuration Timer Expiry

Log Analysis Procedure: QoS Timer Expiry

Open File: 04-06-QoS_Timer_Expiry

Notes


Case Study: UE QoS Configuration Timer Expiry
Allow: INVITE,ACK,CANCEL,BYE,UPDATE,PRACK,MESSAGE,REFER,NOTIFY,INFO
c: application/sdp
Accept: application/sdp,application/3gpp-ims+xml
P-Preferred-Service: urn:urn-7:3gpp-service.ims.icsi.mmtel
k: 100rel,replaces,precondition
MO UE
eUTRAN/IMS Core
MT UE
SDP Presence = 1
SIP Call ID Length = 59
SIP Message Length = 1504
SIP Message Logged Bytes = 1505
Response Code = SESSION PROGRESS (183)
Require: precondition
Require: 100rel
1
SIP INVITE
MO UE sends SIP INVITE including SDP with current (curr) and desired (des) value
SIP INVITE - TRYING
2
MT UE sends 183 with Precondition support in SDP
1
a=curr:qos local none
a=curr:qos remote none
a=des:qos mandatory local sendrecv
a=des:qos optional remote sendrecv
a=curr:qos local none
a=curr:qos remote none
a=des:qos mandatory local sendrecv
a=des:qos mandatory remote sendrecv
a=conf:qos remote sendrecv
2
SIP INVITE – SESSION PROGRESS
SIP PRACK – INFORMAL RESPONSE
UE starts its timer and waits for dedicated bearer assignment from the network
SIP PRACK – OK
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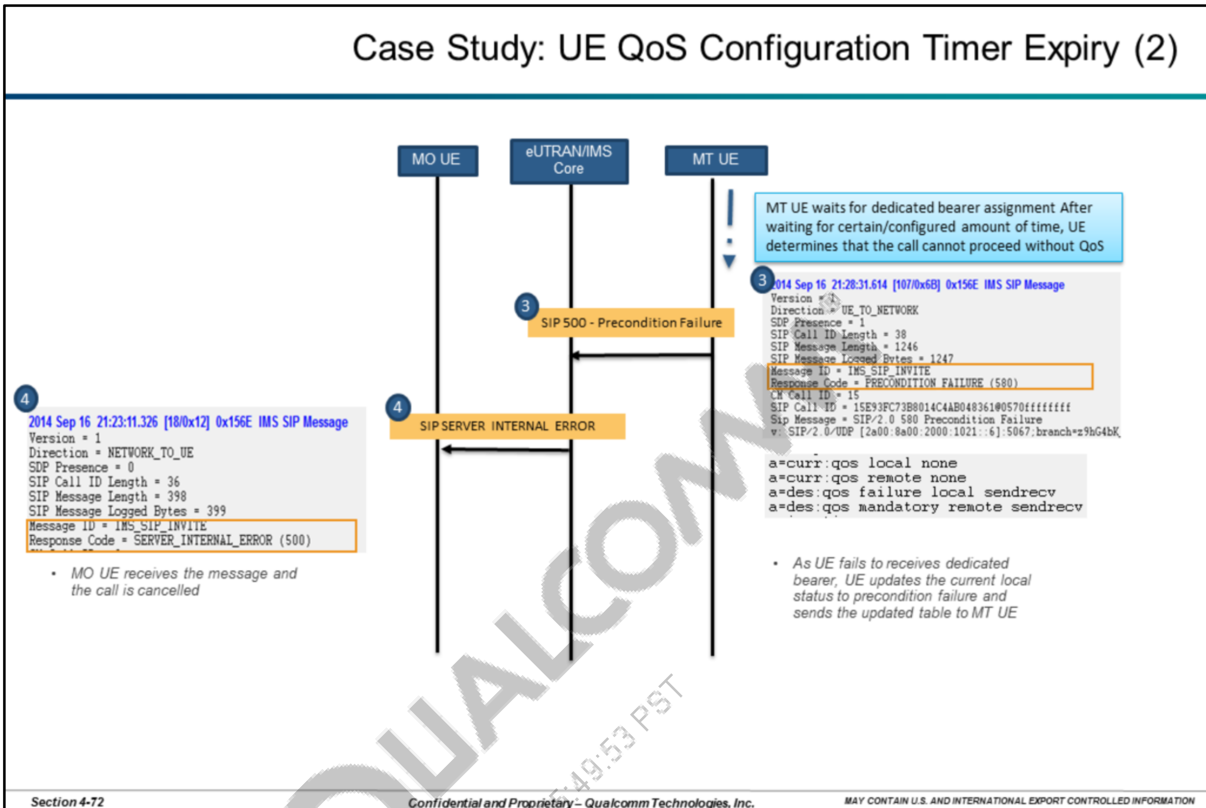
Notes



QOS Configuration Timer Expiry

QOS timer is set to 4sec (for Qualcomm UE) and it is configurable.

UE QoS Configuration Timer Expiry: Conclusion

- After timer expiry, the call was dropped because the UE was not able to satisfy the precondition criteria
- This occurred because the network did not assign the required QoS for the UE

Notes

UE QoS Configuration Timer Expiry : Log Walk-Through

Step	Look for…	Timestamp	Verify…
1	SIP: INVITE	02:56:35.831	• MO UE advertises its support for preconditions
2	SIP:SESSION PROGRESS	02:56:38.831	• MT UE sends Session Progress to MO UE and also advertises its support for preconditions
3	SIP: Precondition Failure	16:05:12.377	• UE declares precondition failure • UE updates the 'curr' state accordingly
4	SIP: SERVER INTERNAL ERROR	16:05:12.578	• UE receives the updated 'curr' and 'des' table • Call is cancelled

Notes

Topic Map

- Call Flow
- Dedicated Bearer Setup
- VoLTE Call Setup (MO / MT)
- Preconditions
- **Call Setup Case Studies**

Notes

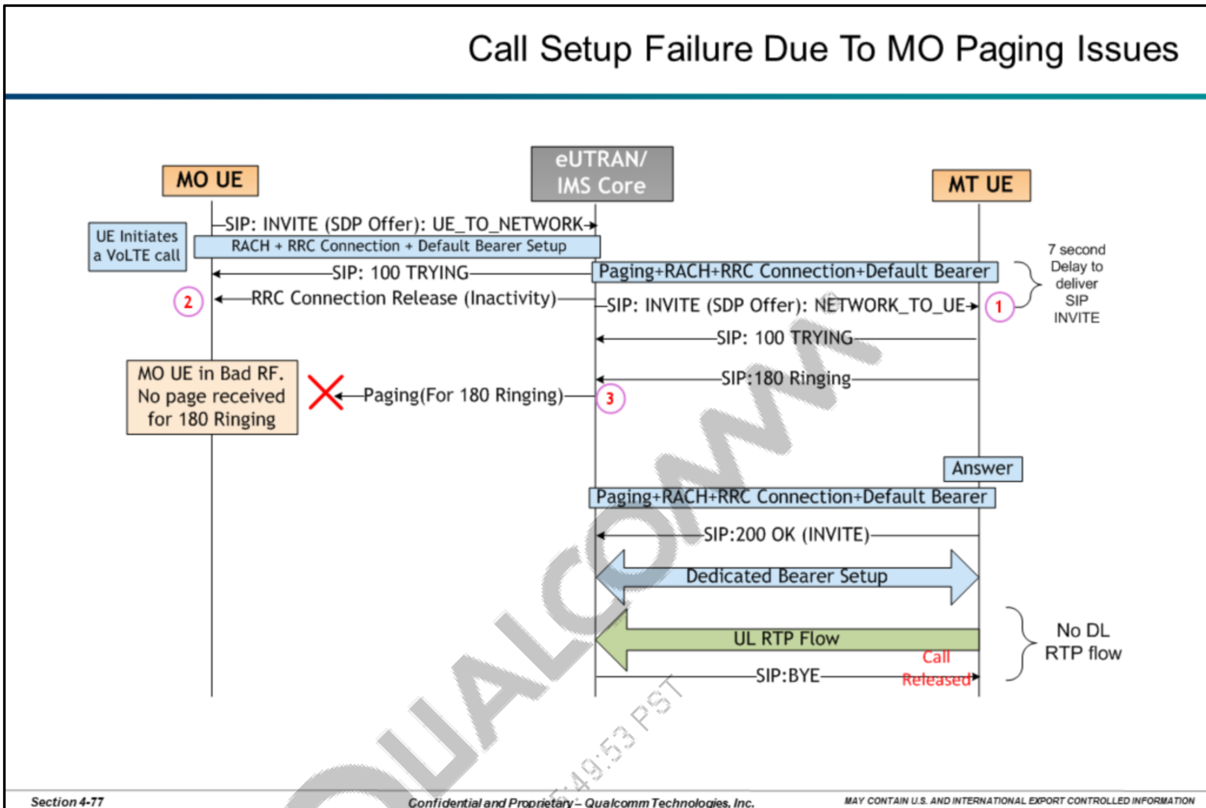
Call Setup Case Studies

Case Study 1 - Call Setup Failure Due to MO Paging Issues

Case Study 2 - Call Setup Delay Due to Short RRC Inactivity Timer Setting

Case Study 3 - Call Setup Failure Due to MO UE RLF

Notes



VoLTE call setup failure in this example is a combination of multiple issues listed below.

1) Delayed IMS SIP INVITE delivery by IMS Core Network

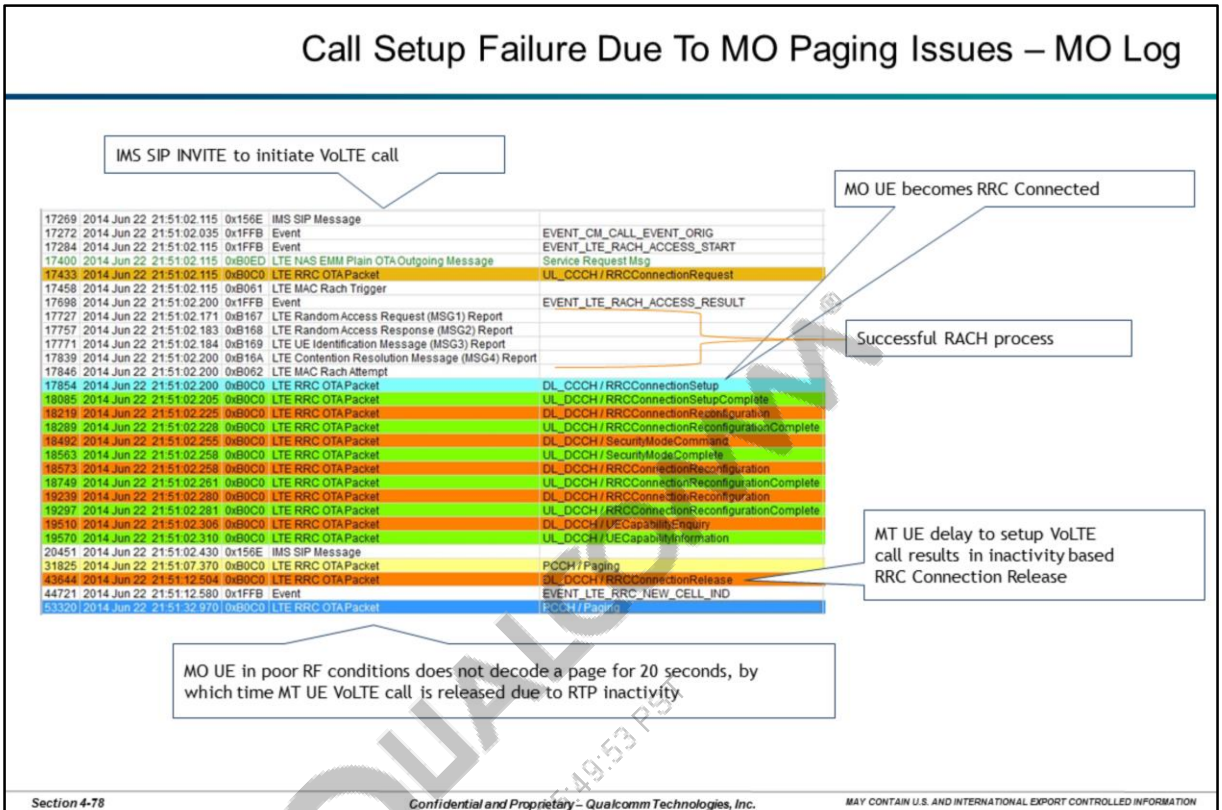
MO UE initiates a VoLTE call, performs RACH and becomes RRC connected on MO eNB. MO UE then forwards IMS SIP INVITE to IMS core network which responds back to MO UE with a SIP: 100 TRYING message. Now IMS core network pages the MT UE via target eNB. MT UE responds by performing RACH and setting up RRC connection on target eNB. At this point the IMS core network should have immediately delivered SIP INVITE message; instead it takes approximately 9 seconds to deliver this message.

2) Short RRC inactivity timer results in RRC connection release & subsequent RRC connection Setup again which increases call setup time

Delayed IMS SIP INVITE delivery on the MT side results in delayed TRYING (100) delivered to MO UE which by then expires RRC inactivity timer and subsequent RRC connection release. When the MT UE eventually receives IMS SIP INVITE, it then sends TRYING (100) followed by RINGING (180). In order to deliver RINGING (180) message to the MO UE, the network once again pages the MO UE to bring it back up into RRC Connected mode.

3) Paging to continue MO call setup fails under bad RF conditions which eventually leads to VoLTE call setup failure

Network tries paging the MO UE which went into RRC IDLE mode due to lack of activity due to delayed SIP INVITE delivery to MT UE. This Page fails multiple times under poor MO UE RF conditions. MO UE does not decode a Page for approximately 20 seconds. During this time MT UE has successfully setup dedicated QCI 1 bearer and started generating UL IMS RTP packets. Since MO UE has not yet setup a VoLTE call, there is no corresponding DL IMS RTP packets from the network. This lack of DL IMS RTP packets expires RTP inactivity timer at IMS core network which results in an IMS SIP BYE delivered to the MT UE to terminate the VoLTE call. Hence this M2M VoLTE call fails setup.


Call Setup Failure Due To MO Paging Issues – MO Log
IMS SIP INVITE to initiate VoLTE call
MO UE becomes RRC Connected
Successful RACH process
MT UE delay to setup VoLTE call results in inactivity based RRC Connection Release
17269 2014 Jun 22 21:51:02.115 0x156E IMS SIP Message
17272 2014 Jun 22 21:51:02.035 0x1FFB Event EVENT_CM_CALL_EVENT_ORIG
17284 2014 Jun 22 21:51:02.115 0x1FFB Event EVENT_LTE_RACH_ACCESS_START
17400 2014 Jun 22 21:51:02.115 0xB0ED LTE NAS EMM Plain OTA Outgoing Message Service Request Msg
17433 2014 Jun 22 21:51:02.115 0xB0C0 LTE RRC OTA Packet UL_CCCH / RRCConnectionRequest
17458 2014 Jun 22 21:51:02.115 0xB061 LTE MAC Rach Trigger
17698 2014 Jun 22 21:51:02.200 0x1FFB Event EVENT_LTE_RACH_ACCESS_RESULT
17727 2014 Jun 22 21:51:02.171 0xB167 LTE Random Access Request (MSG1) Report
17757 2014 Jun 22 21:51:02.183 0xB168 LTE Random Access Response (MSG2) Report
17771 2014 Jun 22 21:51:02.184 0xB169 LTE UE Identification Message (MSG3) Report
17839 2014 Jun 22 21:51:02.200 0xB16A LTE Contention Resolution Message (MSG4) Report
17846 2014 Jun 22 21:51:02.200 0xB062 LTE MAC Rach Attempt
17854 2014 Jun 22 21:51:02.200 0xB0C0 LTE RRC OTA Packet DL_CCCH / RRCConnectionSetup
18085 2014 Jun 22 21:51:02.205 0xB0C0 LTE RRC OTA Packet UL_DCCH / RRCConnectionSetupComplete
18219 2014 Jun 22 21:51:02.225 0xB0C0 LTE RRC OTA Packet DL_DCCH / RRCConnectionReconfiguration
18289 2014 Jun 22 21:51:02.228 0xB0C0 LTE RRC OTA Packet UL_DCCH / RRCConnectionReconfigurationComplete
18492 2014 Jun 22 21:51:02.255 0xB0C0 LTE RRC OTA Packet DL_DCCH / SecurityModeCommand
18563 2014 Jun 22 21:51:02.258 0xB0C0 LTE RRC OTA Packet UL_DCCH / SecurityModeComplete
18573 2014 Jun 22 21:51:02.258 0xB0C0 LTE RRC OTA Packet DL_DCCH / RRCConnectionReconfiguration
18749 2014 Jun 22 21:51:02.261 0xB0C0 LTE RRC OTA Packet UL_DCCH / RRCConnectionReconfigurationComplete
19239 2014 Jun 22 21:51:02.280 0xB0C0 LTE RRC OTA Packet DL_DCCH / RRCConnectionReconfiguration
19297 2014 Jun 22 21:51:02.281 0xB0C0 LTE RRC OTA Packet UL_DCCH / RRCConnectionReconfigurationComplete
19510 2014 Jun 22 21:51:02.306 0xB0C0 LTE RRC OTA Packet DL_DCCH / UECapabilityEnquiry
19570 2014 Jun 22 21:51:02.310 0xB0C0 LTE RRC OTA Packet UL_DCCH / UECapabilityInformation
20451 2014 Jun 22 21:51:02.430 0x156E IMS SIP Message
31825 2014 Jun 22 21:51:07.370 0xB0C0 LTE RRC OTA Packet PCCH / Paging
43644 2014 Jun 22 21:51:12.504 0xB0C0 LTE RRC OTA Packet DL_DCCH / RRCConnectionRelease
44721 2014 Jun 22 21:51:12.580 0x1FFB Event EVENT_LTE_RRC_NEW_CELL_IND
53320 2014 Jun 22 21:51:32.970 0xB0C0 LTE RRC OTA Packet PCCH / Paging
MO UE in poor RF conditions does not decode a page for 20 seconds, by which time MT UE VoLTE call is released due to RTP inactivity
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Notes

Call Setup Failure Due To MO Paging Issues – MT Log

6748	2014 Jun 22 21:51:03.125	0xB0C0	LTE RRC OTA Packet	PCCH / Paging
6889	2014 Jun 22 21:51:03.129	0xB0ED	LTE NAS EMM Plain OTA Outgoing Message	Service Request Msg
6904	2014 Jun 22 21:51:03.131	0xB0C0	LTE RRC OTA Packet	UL_CCCH / RRCConnectionRequest
7286	2014 Jun 22 21:51:03.131	0x1FFB	Event	EVENT_LTE_RACH_ACCESS_START
7295	2014 Jun 22 21:51:03.236	0x1FFB	Event	EVENT_LTE_RACH_ACCESS_RESULT
7364	2014 Jun 22 21:51:03.236	0xB0C0	LTE RRC OTA Packet	DL_CCCH / RRCConnectionSetup
7612	2014 Jun 22 21:51:03.243	0xB0C0	LTE RRC OTA Packet	UL_DCCH / RRCConnectionSetupComplete
7798	2014 Jun 22 21:51:03.275	0xB0C0	LTE RRC OTA Packet	DL_DCCH / RRCConnectionReconfiguration
7901	2014 Jun 22 21:51:03.280	0xB0C0	LTE RRC OTA Packet	UL_DCCH / RRCConnectionReconfigurationComplete
7912	2014 Jun 22 21:51:03.280	0xB0C0	LTE RRC OTA Packet	DL_DCCH / SecurityModeCommand
7995	2014 Jun 22 21:51:03.284	0xB0C0	LTE RRC OTA Packet	UL_DCCH / SecurityModeComplete
8007	2014 Jun 22 21:51:03.284	0xB0C0	LTE RRC OTA Packet	DL_DCCH / RRCConnectionReconfiguration
8236	2014 Jun 22 21:51:03.289	0xB0C0	LTE RRC OTA Packet	UL_DCCH / RRCConnectionReconfigurationComplete
8572	2014 Jun 22 21:51:03.316	0xB0C0	LTE RRC OTA Packet	DL_DCCH / RRCConnectionReconfiguration
8643	2014 Jun 22 21:51:03.317	0xB0C0	LTE RRC OTA Packet	UL_DCCH / RRCConnectionReconfigurationComplete
8799	2014 Jun 22 21:51:03.331	0xB0C0	LTE RRC OTA Packet	DL_DCCH / UECapabilityEnquiry
8859	2014 Jun 22 21:51:03.335	0xB0C0	LTE RRC OTA Packet	UL_DCCH / UECapabilityInformation
32574	2014 Jun 22 21:51:12.650	0x156E	IMS SIP Message	
32729	2014 Jun 22 21:51:12.657	0x156E	IMS SIP Message	
35480	2014 Jun 22 21:51:12.718	0x156E	IMS SIP Message	
50477	2014 Jun 22 21:51:17.749	0x156E	IMS SIP Message	
50974	2014 Jun 22 21:51:17.754	0x1FFB	Event	EVENT_CM_CALL_EVENT_CONNECT
51642	2014 Jun 22 21:51:17.793	0xB0C0	LTE RRC OTA Packet	DL_DCCH / RRCConnectionRelease
53815	2014 Jun 22 21:51:18.477	0xB0C0	LTE RRC OTA Packet	PCCH / Paging
53848	2014 Jun 22 21:51:18.480	0xB0ED	LTE NAS EMM Plain OTA Outgoing Message	Service Request Msg
53864	2014 Jun 22 21:51:18.482	0xB0C0	LTE RRC OTA Packet	UL_CCCH / RRCConnectionRequest
54435	2014 Jun 22 21:51:18.482	0x1FFB	Event	EVENT_LTE_RACH_ACCESS_START
54674	2014 Jun 22 21:51:18.526	0x1FFB	Event	EVENT_LTE_RACH_ACCESS_RESULT
54880	2014 Jun 22 21:51:18.526	0xB0C0	LTE RRC OTA Packet	DL_CCCH / RRCConnectionSetup
55196	2014 Jun 22 21:51:18.530	0xB0C0	LTE RRC OTA Packet	UL_DCCH / RRCConnectionSetupComplete
55589	2014 Jun 22 21:51:18.566	0xB0C0	LTE RRC OTA Packet	DL_DCCH / RRCConnectionReconfiguration
55691	2014 Jun 22 21:51:18.569	0xB0C0	LTE RRC OTA Packet	UL_DCCH / RRCConnectionReconfigurationComplete
55981	2014 Jun 22 21:51:18.584	0xB0C0	LTE RRC OTA Packet	DL_DCCH / SecurityModeCommand
56116	2014 Jun 22 21:51:18.586	0xB0C0	LTE RRC OTA Packet	UL_DCCH / SecurityModeComplete
56132	2014 Jun 22 21:51:18.586	0xB0C0	LTE RRC OTA Packet	DL_DCCH / RRCConnectionReconfiguration
56359	2014 Jun 22 21:51:18.590	0xB0C0	LTE RRC OTA Packet	UL_DCCH / RRCConnectionReconfigurationComplete
56990	2014 Jun 22 21:51:18.616	0xB0C0	LTE RRC OTA Packet	DL_DCCH / RRCConnectionReconfiguration
57055	2014 Jun 22 21:51:18.617	0xB0C0	LTE RRC OTA Packet	UL_DCCH / RRCConnectionReconfigurationComplete
57306	2014 Jun 22 21:51:18.640	0xB0C0	LTE RRC OTA Packet	DL_DCCH / UECapabilityEnquiry
57363	2014 Jun 22 21:51:18.643	0xB0C0	LTE RRC OTA Packet	UL_DCCH / UECapabilityInformation
66329	2014 Jun 22 21:51:19.759	0x156E	IMS SIP Message	
90062	2014 Jun 22 21:51:23.041	0xB0C0	LTE RRC OTA Packet	DL_DCCH / RRCConnectionReconfiguration
90238	2014 Jun 22 21:51:23.045	0xB0C0	LTE RRC OTA Packet	UL_DCCH / RRCConnectionReconfigurationComplete
90331	2014 Jun 22 21:51:23.046	0xB0E2	LTE NAS ESM Plain OTA Incoming Message	Activate dedicated EPS bearer context request Msg
90887	2014 Jun 22 21:51:23.053	0xB0E3	LTE NAS ESM Plain OTA Outgoing Message	Activate dedicated EPS bearer context accept Msg
91008	2014 Jun 22 21:51:23.056	0xB0C0	LTE RRC OTA Packet	UL_DCCH / ULInformationTransfer
91551	2014 Jun 22 21:51:23.054	0x1FFB	Event	EVENT_CM_CALL_EVENT_CONNECT
95901	2014 Jun 22 21:51:23.759	0x156E	IMS SIP Message	
124888	2014 Jun 22 21:51:28.357	0x156E	IMS SIP Message	
125301	2014 Jun 22 21:51:28.370	0x156E	IMS SIP Message	
125365	2014 Jun 22 21:51:28.392	0x1FFB	Event	EVENT_CM_CALL_EVENT_END
125585	2014 Jun 22 21:51:28.378	0x156E	IMS SIP Message	

Page to initiate MT VoLTE call

MT UE becomes RRC Connected

IMS SIP INVITE Delivery

MT UE generates RINGING (180)

MT UE answers VoLTE call with a 200 (OK)

Inactivity leads to an RRC Release before 200 (OK) could be sent OTA

Paging followed by fresh RRC Connection Setup to continue VoLTE call

QCI 1 dedicated bearer setup

Lack of DL RTP traffic results in network generated SIP BYE

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Notes

Log Analysis: Call Setup Failure Due To MO Paging Issues

Log Analysis Procedure: Call Setup Failure Due To MO Paging Issues

Open File: 04-07-Failure_MO_Paging_MO_UE
04-07-Failure_MO_Paging_MT_UE

Notes

Call Setup Failure Due To MO Paging Issues – MO UE Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	IMS_SIP_INVITE	0x156E	21:51:02.115	MO UE generates IMS SIP INVITE
2	RACH	0x1FFB	21:51:02.115 To 21:51:02.200	MO UE RACH process and reason/result for RACH
3	RRC Connection Setup Process	0xB0C0	21:51:02.115 To 21:51:02.205	MO UE becomes RRC connected to carry IMS SIP INVITE message
4	RRC Connection Release	0xB0C0	21:51:12.504	RRC Inactivity based Connection Release
5	Paging	0xB0C0	21:51:32.970	MO UE does not decode any page for 20 seconds by which time MT UE call is released

Analysis Summary

The arrival of messages during logging could impact the order in which time stamps are shown.

If needed while analyzing a log file in the browser, use the menu “Edit” + “Find on this Page” (Ctrl+F) to find a specific timestamp.

Call Setup Failure Due To MO Paging Issues – MT UE Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	Paging	0xB0C0	21:51:03.125	MT UE receives Page to setup a VoLTE call
2	RRC Connection Setup	0xB0C0	21:51:03.131 To 21:51:03.243	MT UE becomes RRC Connected
3	IMS SIP INVITE	0x156E	21:51:12.650	MT UE receives IMS SIP INVITE to setup a VoLTE call
4	RINGING (180)	0x156E	21:51:12.718	MT UE generates RINGING (180)
5	RRC Connection Release	0xB0C0	21:51:17.793	RRC inactivity after receiving IMS SIP INVITE causes RRC Connection release
6	RRC Connection Setup	0xB0C0	21:51:18.482 To 21:51:18.530	MT UE becomes RRC connected again to continue setting up VoLTE call
7	200 (OK)	0x156E	21:51:23.759	MT UE answers VoLTE call & generates 200 (OK)
8	IMS_SIP_BYE	0x156E	21:51:28.370	MT UE DL RTP inactivity timer expires triggering IMS SIP BYE from network

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Analysis Summary

The arrival of messages during logging could impact the order in which time stamps are shown.

If needed while analyzing a log file in the browser, use the menu “Edit” + “Find on this Page” (Ctrl+F) to find a specific timestamp.

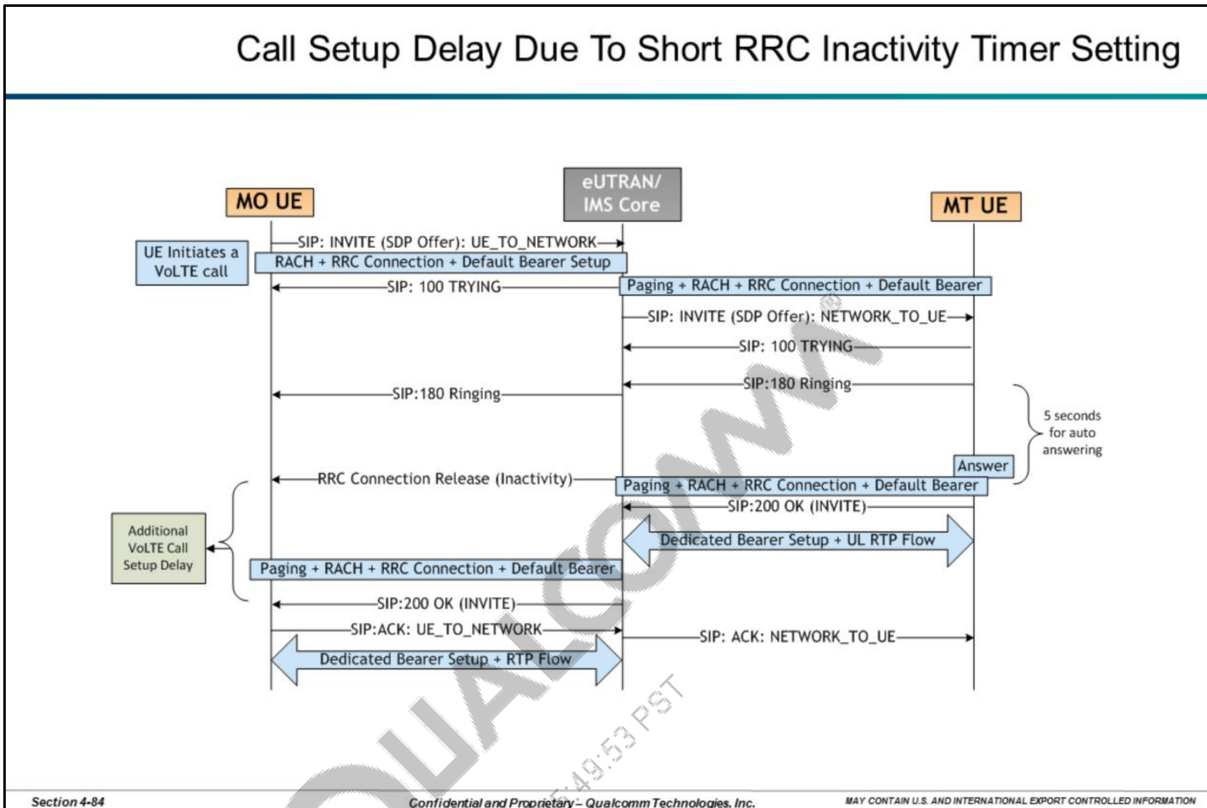
Call Setup Case Studies

Case Study 1 - Call Setup Failure Due to MO Paging Issues

Case Study 2 - Call Setup Delay due to Short RRC Inactivity Timer Setting

Case Study 3 - Call Setup Failure Due to MO UE RLF

Notes



Call Setup Delay

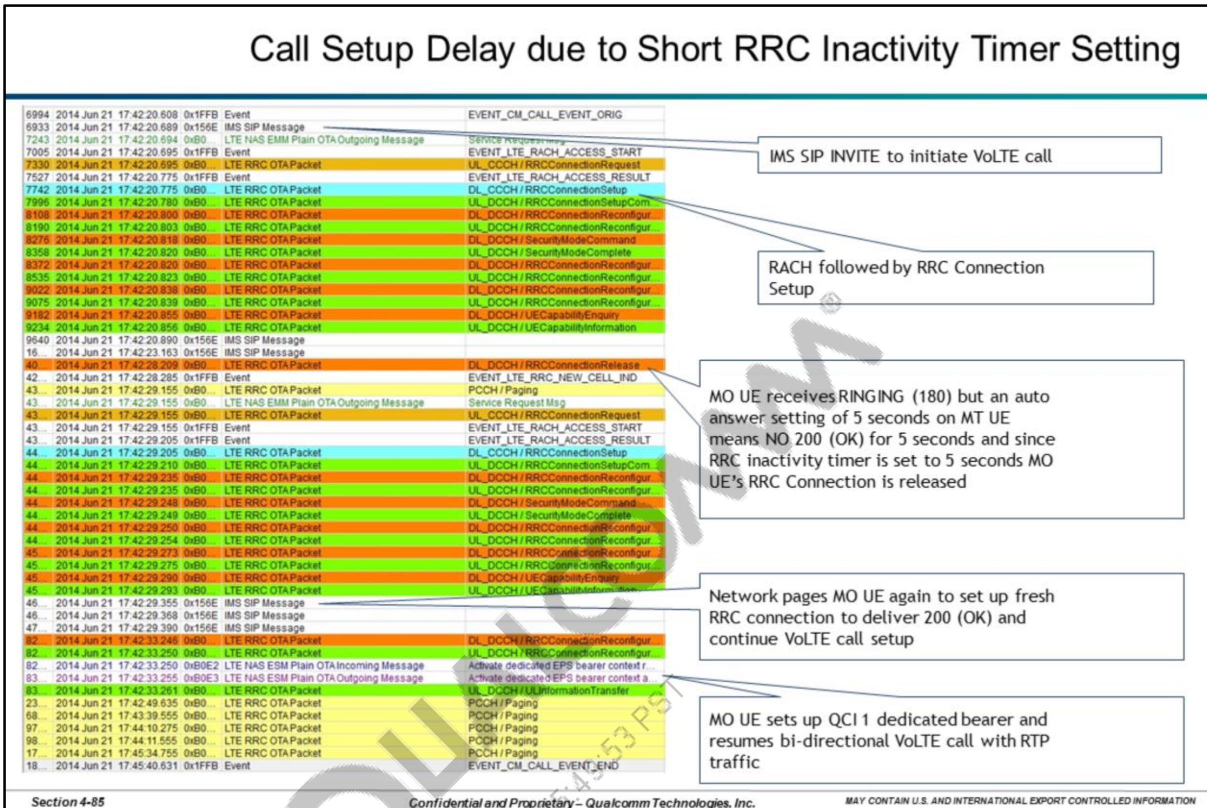
In this example VoLTE call setup delay is mainly due to improper RRC inactivity timer setting. MT UE auto answer was set to 5 seconds. In this VoLTE network RRC inactivity timer was set to 5 seconds.

MO UE generates IMS SIP INVITE to initiate VoLTE call. It performs RACH procedure followed by setting up RRC Connection on source eNB. It now delivers IMS SIP INVITE to IMS Core Network. The IMS Core Network now communicates with MT UE to continue setting up the M2M VoLTE call.

MT UE receives a page, performs RACH and becomes RRC connected to receive IMS SIP INVITE from IMS Core Network. It immediately generates RINGING (180) but its auto answer is set to 5 seconds. So MT UE waits 5 seconds, after which answers the incoming VoLTE call and generates 200 (OK).

By this time MO UE expires RRC inactivity timer (set to 5 seconds) and hence gets released from LTE network. IMS Core Network, in order to now deliver MT UE's 200 (OK), pages the MO UE who again preforms RACH and sets up a fresh RRC connection. These additional RACH and RRC Connection setup mechanisms add additional delay to VoLTE Call Setup Delay.

After a successful second RRC connection setup, MO UE receives 200 (OK), sets up QCI 1 dedicated bearer and continues VoLTE call.



6994	2014 Jun 21	17:42:20.608	0x1FFB	Event	EVENT_CM_CALL_EVENT_ORIG
6933	2014 Jun 21	17:42:20.689	0x156E	IMS SIP Message	
7243	2014 Jun 21	17:42:20.694	0xB0...	LTE NAS EMM Plain OTA Outgoing Message	Service Request Msg
7005	2014 Jun 21	17:42:20.695	0x1FFB	Event	EVENT_LTE_RACH_ACCESS_START
7330	2014 Jun 21	17:42:20.695	0xB0...	LTE RRC OTA Packet	UL_CCCH / RRCConnectionRequest
7527	2014 Jun 21	17:42:20.775	0x1FFB	Event	EVENT_LTE_RACH_ACCESS_RESULT
7742	2014 Jun 21	17:42:20.775	0xB0...	LTE RRC OTA Packet	DL_CCCH / RRCConnectionSetup
7996	2014 Jun 21	17:42:20.780	0xB0...	LTE RRC OTA Packet	UL_DCCH / RRCConnectionSetupCom...
8108	2014 Jun 21	17:42:20.800	0xB0...	LTE RRC OTA Packet	DL_DCCH / RRCConnectionReconfigur...
8190	2014 Jun 21	17:42:20.803	0xB0...	LTE RRC OTA Packet	UL_DCCH / RRCConnectionReconfigur...
8276	2014 Jun 21	17:42:20.818	0xB0...	LTE RRC OTA Packet	DL_DCCH / SecurityModeCommand
8358	2014 Jun 21	17:42:20.820	0xB0...	LTE RRC OTA Packet	UL_DCCH / SecurityModeComplete
8372	2014 Jun 21	17:42:20.820	0xB0...	LTE RRC OTA Packet	DL_DCCH / RRCConnectionReconfigur...
8535	2014 Jun 21	17:42:20.823	0xB0...	LTE RRC OTA Packet	UL_DCCH / RRCConnectionReconfigur...
9022	2014 Jun 21	17:42:20.838	0xB0...	LTE RRC OTA Packet	DL_DCCH / RRCConnectionReconfigur...
9075	2014 Jun 21	17:42:20.839	0xB0...	LTE RRC OTA Packet	UL_DCCH / RRCConnectionReconfigur...
9182	2014 Jun 21	17:42:20.855	0xB0...	LTE RRC OTA Packet	DL_DCCH / UECapabilityEnquiry
9234	2014 Jun 21	17:42:20.856	0xB0...	LTE RRC OTA Packet	UL_DCCH / UECapabilityInformation
9640	2014 Jun 21	17:42:20.890	0x156E	IMS SIP Message	
16...	2014 Jun 21	17:42:23.163	0x156E	IMS SIP Message	
40...	2014 Jun 21	17:42:28.209	0xB0...	LTE RRC OTA Packet	DL_DCCH / RRCConnectionRelease
42...	2014 Jun 21	17:42:28.285	0x1FFB	Event	EVENT_LTE_RRC_NEW_CELL_IND
43...	2014 Jun 21	17:42:29.155	0xB0...	LTE RRC OTA Packet	PCCH / Paging
43...	2014 Jun 21	17:42:29.155	0xB0...	LTE NAS EMM Plain OTA Outgoing Message	Service Request Msg
43...	2014 Jun 21	17:42:29.155	0xB0...	LTE RRC OTA Packet	UL_CCCH / RRCConnectionRequest
43...	2014 Jun 21	17:42:29.155	0x1FFB	Event	EVENT_LTE_RACH_ACCESS_START
43...	2014 Jun 21	17:42:29.205	0x1FFB	Event	EVENT_LTE_RACH_ACCESS_RESULT
44...	2014 Jun 21	17:42:29.205	0xB0...	LTE RRC OTA Packet	DL_CCCH / RRCConnectionSetup
44...	2014 Jun 21	17:42:29.210	0xB0...	LTE RRC OTA Packet	UL_DCCH / RRCConnectionSetupCom...
44...	2014 Jun 21	17:42:29.235	0xB0...	LTE RRC OTA Packet	DL_DCCH / RRCConnectionReconfigur...
44...	2014 Jun 21	17:42:29.235	0xB0...	LTE RRC OTA Packet	UL_DCCH / RRCConnectionReconfigur...
44...	2014 Jun 21	17:42:29.248	0xB0...	LTE RRC OTA Packet	DL_DCCH / SecurityModeCommand
44...	2014 Jun 21	17:42:29.249	0xB0...	LTE RRC OTA Packet	UL_DCCH / SecurityModeComplete
44...	2014 Jun 21	17:42:29.250	0xB0...	LTE RRC OTA Packet	DL_DCCH / RRCConnectionReconfigur...
44...	2014 Jun 21	17:42:29.254	0xB0...	LTE RRC OTA Packet	UL_DCCH / RRCConnectionReconfigur...
45...	2014 Jun 21	17:42:29.273	0xB0...	LTE RRC OTA Packet	DL_DCCH / RRCConnectionReconfigur...
45...	2014 Jun 21	17:42:29.275	0xB0...	LTE RRC OTA Packet	UL_DCCH / RRCConnectionReconfigur...
45...	2014 Jun 21	17:42:29.290	0xB0...	LTE RRC OTA Packet	DL_DCCH / UECapabilityEnquiry
45...	2014 Jun 21	17:42:29.293	0xB0...	LTE RRC OTA Packet	UL_DCCH / UECapabilityInformation
46...	2014 Jun 21	17:42:29.355	0x156E	IMS SIP Message	
46...	2014 Jun 21	17:42:29.368	0x156E	IMS SIP Message	
47...	2014 Jun 21	17:42:29.390	0x156E	IMS SIP Message	
82...	2014 Jun 21	17:42:33.246	0xB0...	LTE RRC OTA Packet	DL_DCCH / RRCConnectionReconfigur...
82...	2014 Jun 21	17:42:33.250	0xB0...	LTE RRC OTA Packet	UL_DCCH / RRCConnectionReconfigur...
82...	2014 Jun 21	17:42:33.250	0xB0E2	LTE NAS ESM Plain OTA Incoming Message	Activate dedicated EPS bearer context r...
83...	2014 Jun 21	17:42:33.255	0xB0E3	LTE NAS ESM Plain OTA Outgoing Message	Activate dedicated EPS bearer context a...
83...	2014 Jun 21	17:42:33.261	0xB0...	LTE RRC OTA Packet	UL_DCCH / ULInformationTransfer
23...	2014 Jun 21	17:42:49.635	0xB0...	LTE RRC OTA Packet	PCCH / Paging
68...	2014 Jun 21	17:43:39.555	0xB0...	LTE RRC OTA Packet	PCCH / Paging
97...	2014 Jun 21	17:44:10.275	0xB0...	LTE RRC OTA Packet	PCCH / Paging
98...	2014 Jun 21	17:44:11.555	0xB0...	LTE RRC OTA Packet	PCCH / Paging
17...	2014 Jun 21	17:45:34.755	0xB0...	LTE RRC OTA Packet	PCCH / Paging
18...	2014 Jun 21	17:45:40.631	0x1FFB	Event	EVENT_CM_CALL_EVENT_END

Notes

Log Analysis: Call Setup Delay due to Short RRC Inactivity Timer Setting

Log Analysis Procedure: Call Setup Delay due to Short RRC Inactivity Timer Setting

Open File: 04-08-Setup_Delay_RRC_Inactivity

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Notes

Call Setup Delay Due To Short RRC Inactivity Timer Setting

Step	Look for	Log Packet	Time Stamp	Verify
1	IMS_SIP_INVITE	0x156E	17:42:20.689	MO UE initiates VoLTE call by generating IMS SIP INVITE
2	RACH Process	0x1FFB	17:42:20.695 To 17:42:20.775	MO UE successfully performs RACH
3	RRC Connection Setup	0xB0C0	17:42:20.695 To 17:42:20.780	MO UE sets up RRC Connection
4	RRC Connection Release	0xB0C0	17:42:28.209	Auto answer delay of 5 seconds causes RRC inactivity on MO UE which expires RRC inactivity timer leading to a connection release
5	Second RRC Connection Setup	0xB0C0	17:42:29.155 To 17:42:29.205	Network pages MO UE which sets up RRC Connection again to continue with the VoLTE call
6	OK (200)	0x156E	17:42:29.293	MO UE receives MT UE's OK (200)
7	Dedicated Bearer Setup	0xB0E2/0xB0E3	17:42:33.250 To 17:42:33.255	MO UE sets up QCI 1 dedicated bearer to start sending and receiving IMS RTP packets

Analysis Summary

The arrival of messages during logging could impact the order in which time stamps are shown.

If needed while analyzing a log file in the browser, use the menu "Edit" + "Find on this Page" (Ctrl+F) to find a specific timestamp.

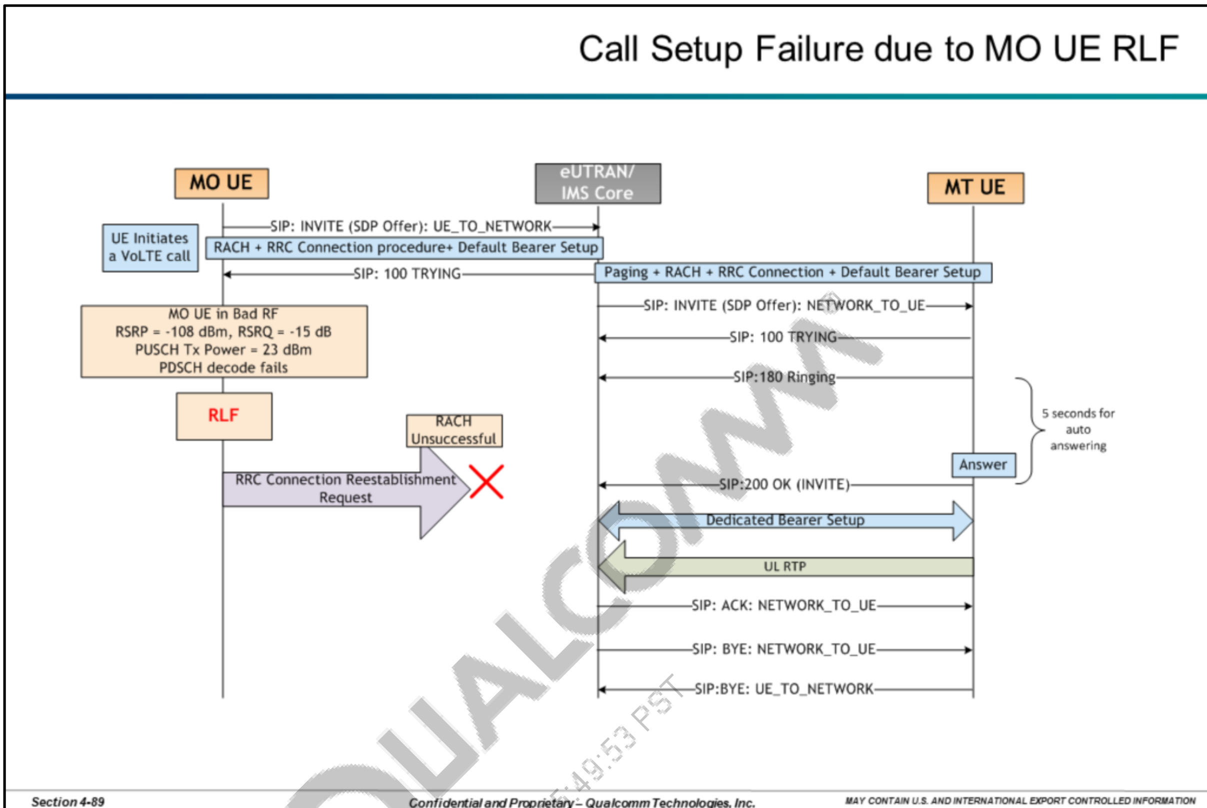
Call Setup Case Studies

Case Study 1 - Call Setup Failure Due to MO Paging Issues

Case Study 2 - Call Setup Delay Due to Short RRC Inactivity Timer Setting

Case Study 3 - Call Setup Failure Due to MO UE RLF

Notes



VoLTE Call Setup Failure

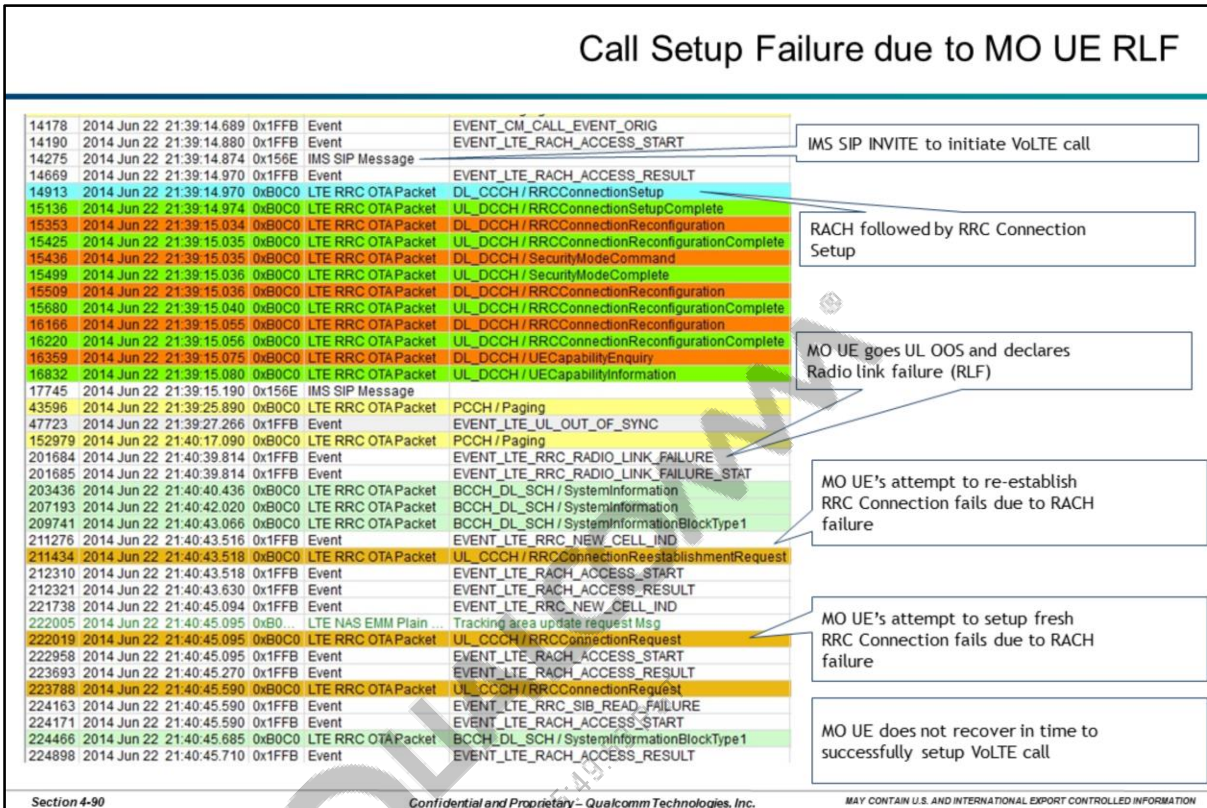
VoLTE call setup failure in this example is due to radio link failure on MO UE while setting up the VoLTE call.

MO UE initiates a VoLTE call and generates IMS SIP INVITE. In order to send out this IMS SIP INVITE message, MO UE begins RACH and becomes RRC connected on source eNB. Now the MO UE delivers IMS SIP INVITE to IMS core network.

Upon receiving IMS SIP INVITE from MO UE, IMS core network pages MT UE which performs RACH and becomes RRC connected on target eNB to continue setting up the VoLTE call. Now IMS core network delivers IMS SIP INVITE message to MT UE. In response, MT UE generate RINGING (180) followed by 200 (OK) when MT UE answers VoLTE call.

However, within this time, MO UE in bad RF conditions (RSRP = -108dBm, RSRQ = -15dB, PUSCH Tx Power = 23dBm) undergoes radio link failure and loses RRC Connection. Subsequent attempt by MO UE to re-establish RRC connection fails due to several unsuccessful RACH attempts.

While the MO UE is struggling to reconnect and re-setup RRC connection, MT UE has already setup dedicated QCI 1 bearers and started generating UL RTP packets. Since MO UE is still connected to continue VoLTE call, there are no DL RTP packets delivered to MT UE. This expires RTP inactivity timer at the network which sends an IMS SIP BYE to MT UE to discontinue and release VoLTE call. Hence VoLTE call setup failure primarily due to MO UE RLF.


Call Setup Failure due to MO UE RLF
14178 2014 Jun 22 21:39:14.689 0x1FFB Event EVENT_CM_CALL_EVENT_ORIG
14190 2014 Jun 22 21:39:14.880 0x1FFB Event EVENT_LTE_RACH_ACCESS_START
14275 2014 Jun 22 21:39:14.874 0x156E IMS SIP Message
14669 2014 Jun 22 21:39:14.970 0x1FFB Event EVENT_LTE_RACH_ACCESS_RESULT
14913 2014 Jun 22 21:39:14.970 0xB0C0 LTE RRC OTA Packet DL_CCCH / RRCConnectionSetup
15136 2014 Jun 22 21:39:14.974 0xB0C0 LTE RRC OTA Packet UL_DCCH / RRCConnectionSetupComplete
15353 2014 Jun 22 21:39:15.034 0xB0C0 LTE RRC OTA Packet DL_DCCH / RRCConnectionReconfiguration
15425 2014 Jun 22 21:39:15.035 0xB0C0 LTE RRC OTA Packet UL_DCCH / RRCConnectionReconfigurationComplete
15436 2014 Jun 22 21:39:15.035 0xB0C0 LTE RRC OTA Packet DL_DCCH / SecurityModeCommand
15499 2014 Jun 22 21:39:15.036 0xB0C0 LTE RRC OTA Packet UL_DCCH / SecurityModeComplete
15509 2014 Jun 22 21:39:15.036 0xB0C0 LTE RRC OTA Packet DL_DCCH / RRCConnectionReconfiguration
15680 2014 Jun 22 21:39:15.040 0xB0C0 LTE RRC OTA Packet UL_DCCH / RRCConnectionReconfigurationComplete
16166 2014 Jun 22 21:39:15.055 0xB0C0 LTE RRC OTA Packet DL_DCCH / RRCConnectionReconfiguration
16220 2014 Jun 22 21:39:15.056 0xB0C0 LTE RRC OTA Packet UL_DCCH / RRCConnectionReconfigurationComplete
16359 2014 Jun 22 21:39:15.075 0xB0C0 LTE RRC OTA Packet DL_DCCH / UECapabilityEnquiry
16832 2014 Jun 22 21:39:15.080 0xB0C0 LTE RRC OTA Packet UL_DCCH / UECapabilityInformation
17745 2014 Jun 22 21:39:15.190 0x156E IMS SIP Message
43596 2014 Jun 22 21:39:25.890 0xB0C0 LTE RRC OTA Packet PCCH / Paging
47723 2014 Jun 22 21:39:27.266 0x1FFB Event EVENT_LTE_UL_OUT_OF_SYNC
152979 2014 Jun 22 21:40:17.090 0xB0C0 LTE RRC OTA Packet PCCH / Paging
201684 2014 Jun 22 21:40:39.814 0x1FFB Event EVENT_LTE_RRC_RADIO_LINK_FAILURE
201685 2014 Jun 22 21:40:39.814 0x1FFB Event EVENT_LTE_RRC_RADIO_LINK_FAILURE_STAT
203436 2014 Jun 22 21:40:40.436 0xB0C0 LTE RRC OTA Packet BCCH_DL_SCH / SystemInformation
207193 2014 Jun 22 21:40:42.020 0xB0C0 LTE RRC OTA Packet BCCH_DL_SCH / SystemInformation
209741 2014 Jun 22 21:40:43.066 0xB0C0 LTE RRC OTA Packet BCCH_DL_SCH / SystemInformationBlockType1
211276 2014 Jun 22 21:40:43.516 0x1FFB Event EVENT_LTE_RRC_NEW_CELL_IND
211434 2014 Jun 22 21:40:43.518 0xB0C0 LTE RRC OTA Packet UL_CCCH / RRCConnectionReestablishmentRequest
212310 2014 Jun 22 21:40:43.518 0x1FFB Event EVENT_LTE_RACH_ACCESS_START
212321 2014 Jun 22 21:40:43.630 0x1FFB Event EVENT_LTE_RACH_ACCESS_RESULT
221738 2014 Jun 22 21:40:45.094 0x1FFB Event EVENT_LTE_RRC_NEW_CELL_IND
222005 2014 Jun 22 21:40:45.095 0xB0... LTE NAS EMM Plain ... Tracking area update request Msg
222019 2014 Jun 22 21:40:45.095 0xB0C0 LTE RRC OTA Packet UL_CCCH / RRCConnectionRequest
222958 2014 Jun 22 21:40:45.095 0x1FFB Event EVENT_LTE_RACH_ACCESS_START
223693 2014 Jun 22 21:40:45.270 0x1FFB Event EVENT_LTE_RACH_ACCESS_RESULT
223788 2014 Jun 22 21:40:45.590 0xB0C0 LTE RRC OTA Packet UL_CCCH / RRCConnectionRequest
224163 2014 Jun 22 21:40:45.590 0x1FFB Event EVENT_LTE_RRC_SIB_READ_FAILURE
224171 2014 Jun 22 21:40:45.590 0x1FFB Event EVENT_LTE_RACH_ACCESS_START
224466 2014 Jun 22 21:40:45.685 0xB0C0 LTE RRC OTA Packet BCCH_DL_SCH / SystemInformationBlockType1
224898 2014 Jun 22 21:40:45.710 0x1FFB Event EVENT_LTE_RACH_ACCESS_RESULT
IMS SIP INVITE to initiate VoLTE call
RACH followed by RRC Connection Setup
MO UE goes UL OOS and declares Radio link failure (RLF)
MO UE's attempt to re-establish RRC Connection fails due to RACH failure
MO UE's attempt to setup fresh RRC Connection fails due to RACH failure
MO UE does not recover in time to successfully setup VoLTE call
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Notes

Log Analysis: Call Setup Failure due to MO UE RLF

Log Analysis Procedure: Call Setup Failure due to MO UE RLF

Open File: 04-09_Failure_MO_RLF

Notes

Call Setup Failure Due to MO UE RLF – Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	IMS SIP INVITE	0x156E	21:39:14.874	MO UE generates IMS SIP INVITE to initiate VoLTE call
2	RRC Connection Setup	0xB0C0	21:39:14.970 To 21:39:14.974	MO UE preforms RACH and sets up RRC Connection
3	Radio Link Failure	0x1FFB	21:40:39.814	MO UE under poor RF conditions declares Radio Link Failure
4	Reestablishment Request	0xB0C0	21:40:43.518	MO UE tries to re-establish RRC Connection to continue VoLTE call
5	Unsuccessful RACH	0x1FFB	21:40:43.518 To 21:40:43.630	MO UE aborts RACH due to multiple RACH failure
6	Multiple RRC Connection Requests	0xB0C0	21:40:45.095 To 21:41:06.503	MO UE tries fresh RRC connection setup multiple times to continue VoLTE call however it takes approximately 27 seconds to recover from radio link failure by which time MT UE VoLTE call was released leading to M2M call setup failure

Analysis Summary

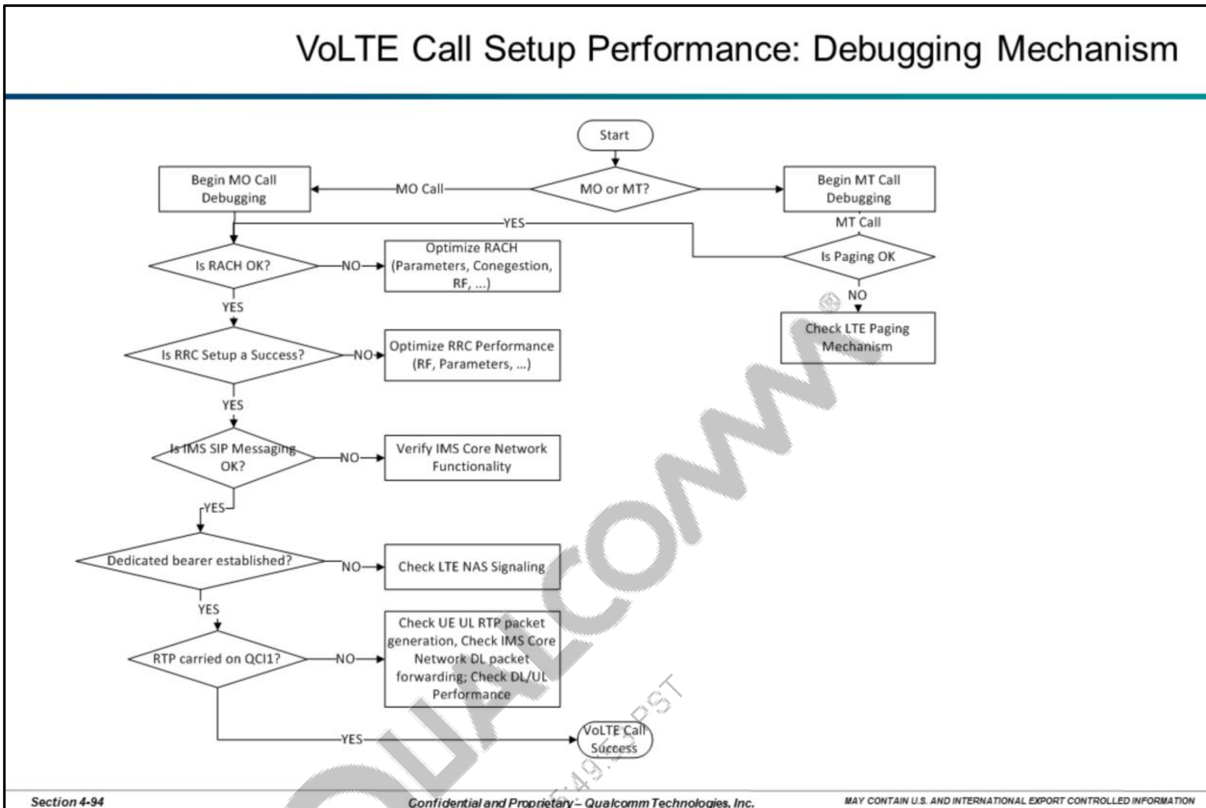
The arrival of messages during logging could impact the order in which time stamps are shown.

If needed while analyzing a log file in the browser, use the menu “Edit” + “Find on this Page” (Ctrl+F) to find a specific timestamp.

VoLTE Call Setup Performance: Recommendations

- RF and paging algorithms should be optimized for VoLTE
- Optimized RRC inactivity timer settings are critical for good VoLTE call setup performance
- Efficient IMS functionality is essential

Notes



VoLTE Call Setup Debugging Mechanism

1) Identify if the VoLTE call is MO or MT, based on which debugging can proceed.

2) If MT call, first check if Paging is OK; if not, LTE paging mechanism must be evaluated. From this point on both MO and MT debugging steps are similar.

3) Check RACH performance; if RACH issues are noticed, RACH optimization has to be performed.

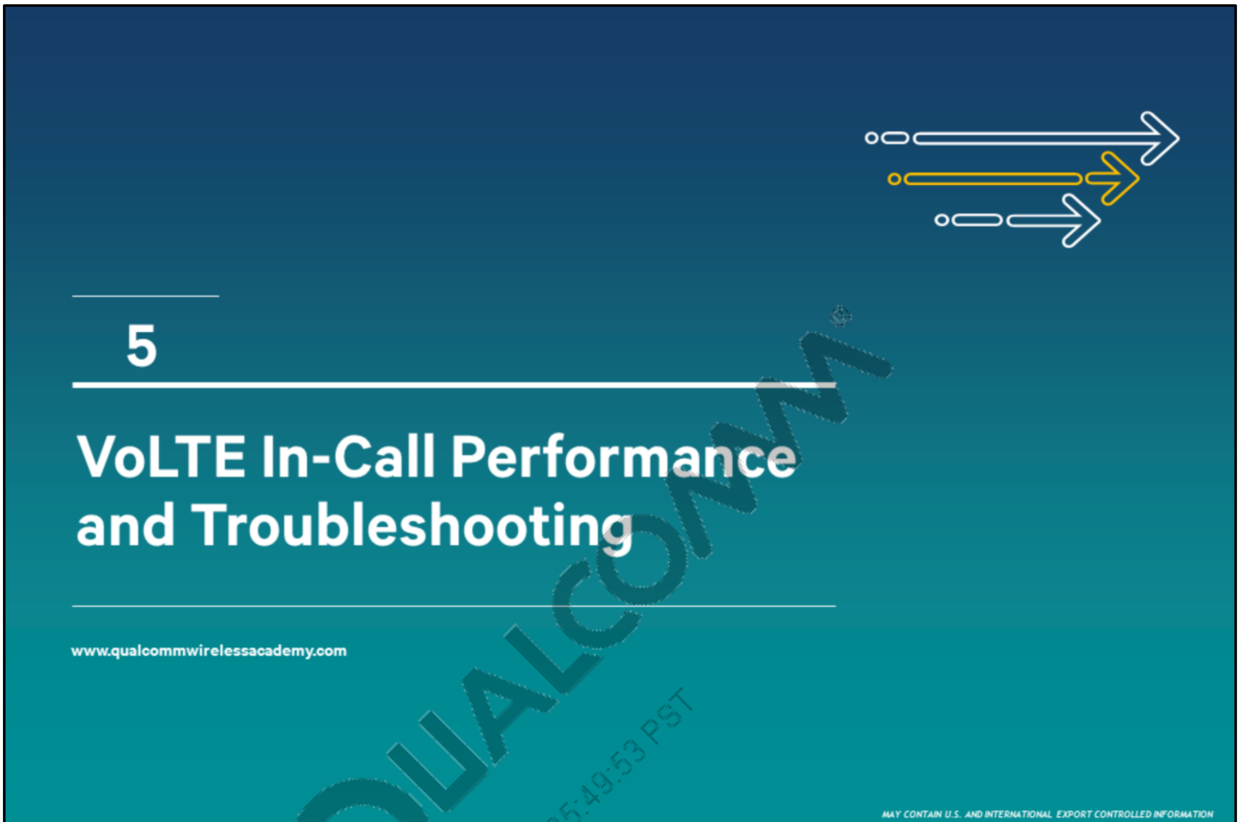
4) Next step would be to check RRC connection performance and related optimization. Specifically check for RACH and RRC parameter settings which must be optimized for VoLTE traffic.

5) IMS Signaling related performance needs to be evaluated. Related to this, core network functionality needs to be verified and optimized.

6) LTE bearer establishment is very important. If it fails, related LTE NAS signaling performance needs optimization.

7) QCI 1 bearer establishment and subsequent RTP traffic carried on this bearer is vital. Multiple issues could affect this performance. In general RTP packet generation, IMS core network packet forwarding, and LTE performance all need to be checked to improve overall VoLTE performance.

8) If everything above works well, the VoLTE call would work well.


5
VoLTE In-Call Performance and Troubleshooting
www.qualcommwirelessacademy.com
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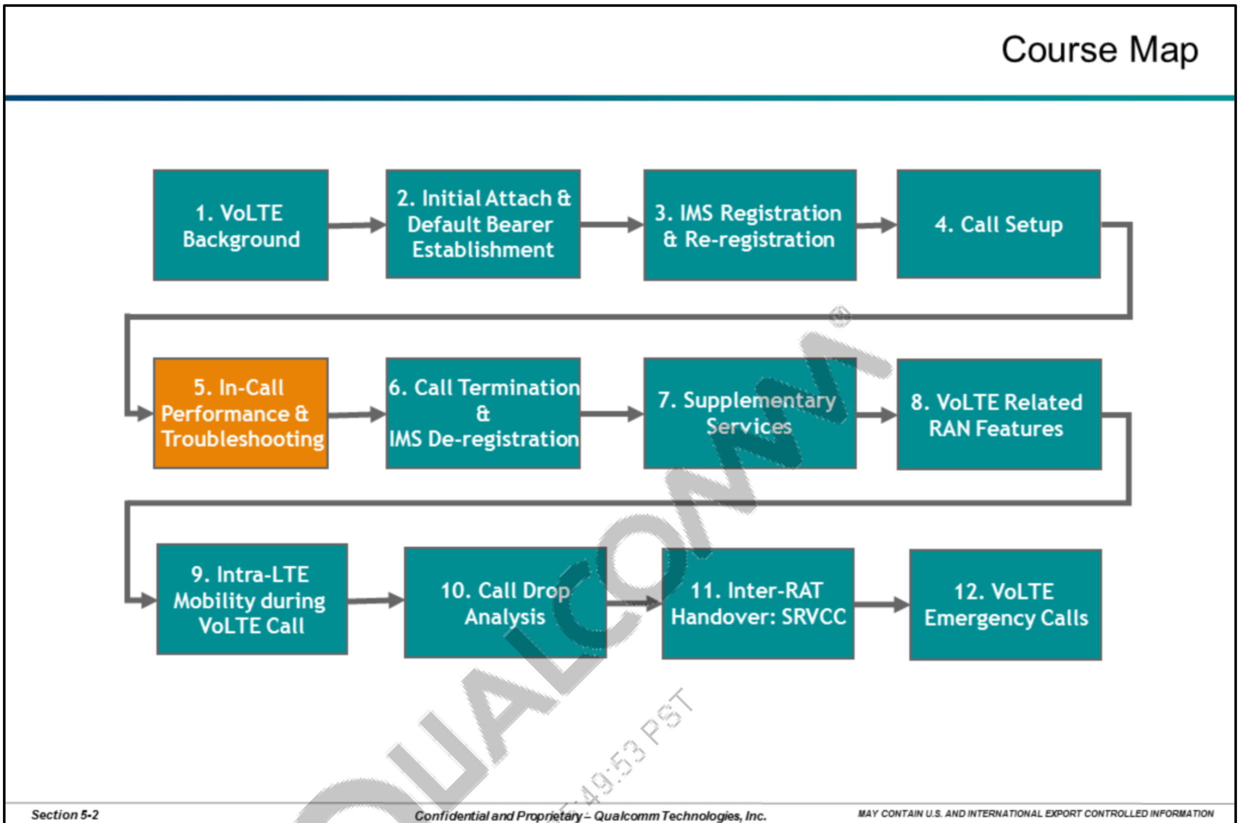
Course Map
1. VoLTE Background
2. Initial Attach & Default Bearer Establishment
3. IMS Registration & Re-registration
4. Call Setup
5. In-Call Performance & Troubleshooting
6. Call Termination & IMS De-registration
7. Supplementary Services
8. VoLTE Related RAN Features
9. Intra-LTE Mobility during VoLTE Call
10. Call Drop Analysis
11. Inter-RAT Handover: SRVCC
12. VoLTE Emergency Calls
Section 5-2
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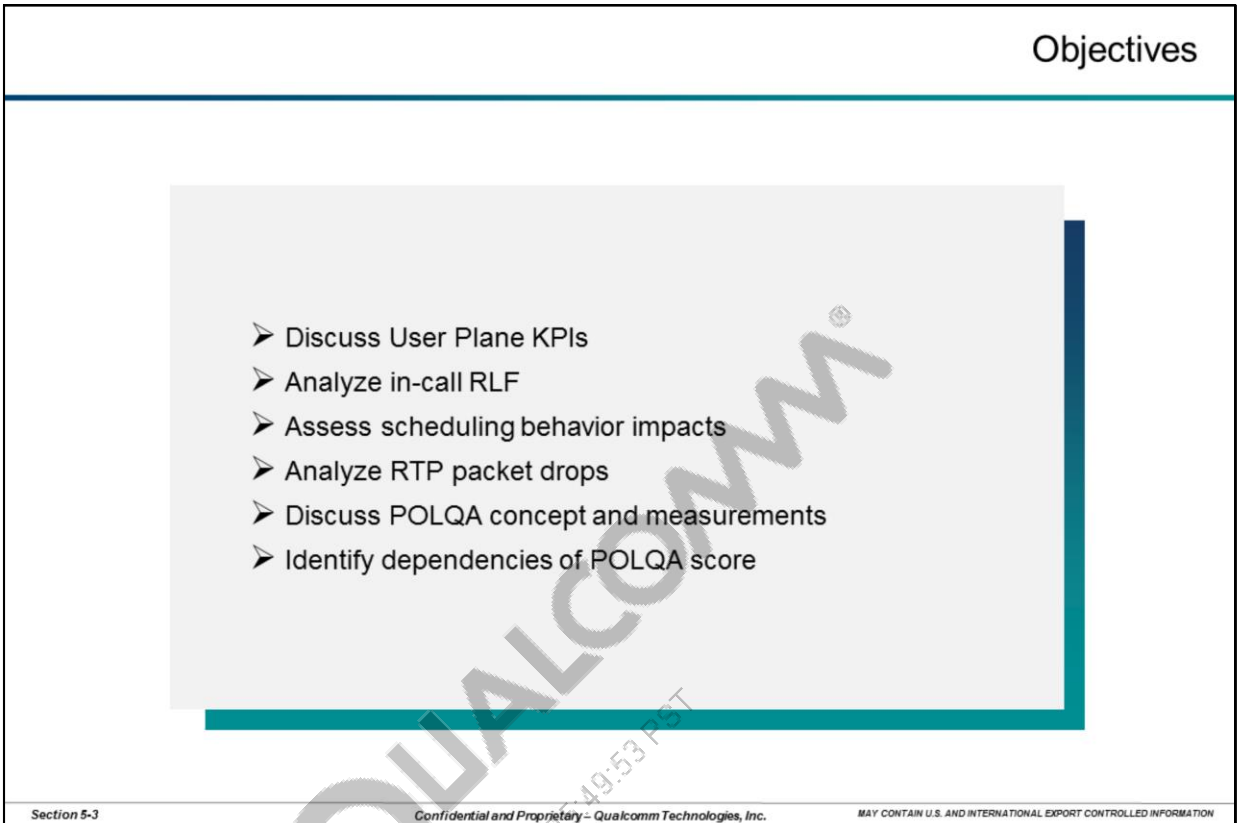
Objectives
Discuss User Plane KPIs
Analyze in-call RLF
Assess scheduling behavior impacts
Analyze RTP packet drops
Discuss POLQA concept and measurements
Identify dependencies of POLQA score
Section 5-3
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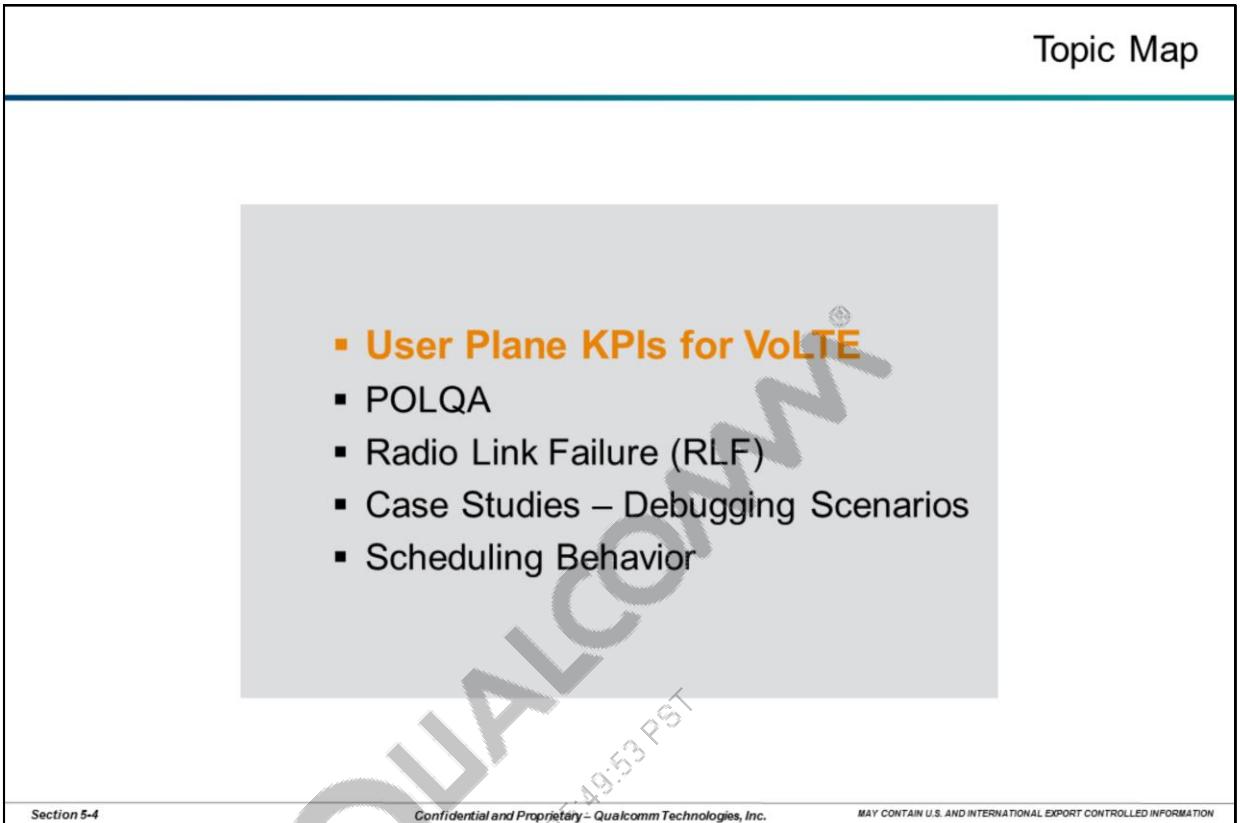
Notes


Topic Map
User Plane KPIs for VoLTE
POLQA
Radio Link Failure (RLF)
Case Studies – Debugging Scenarios
Scheduling Behavior
Section 5-4
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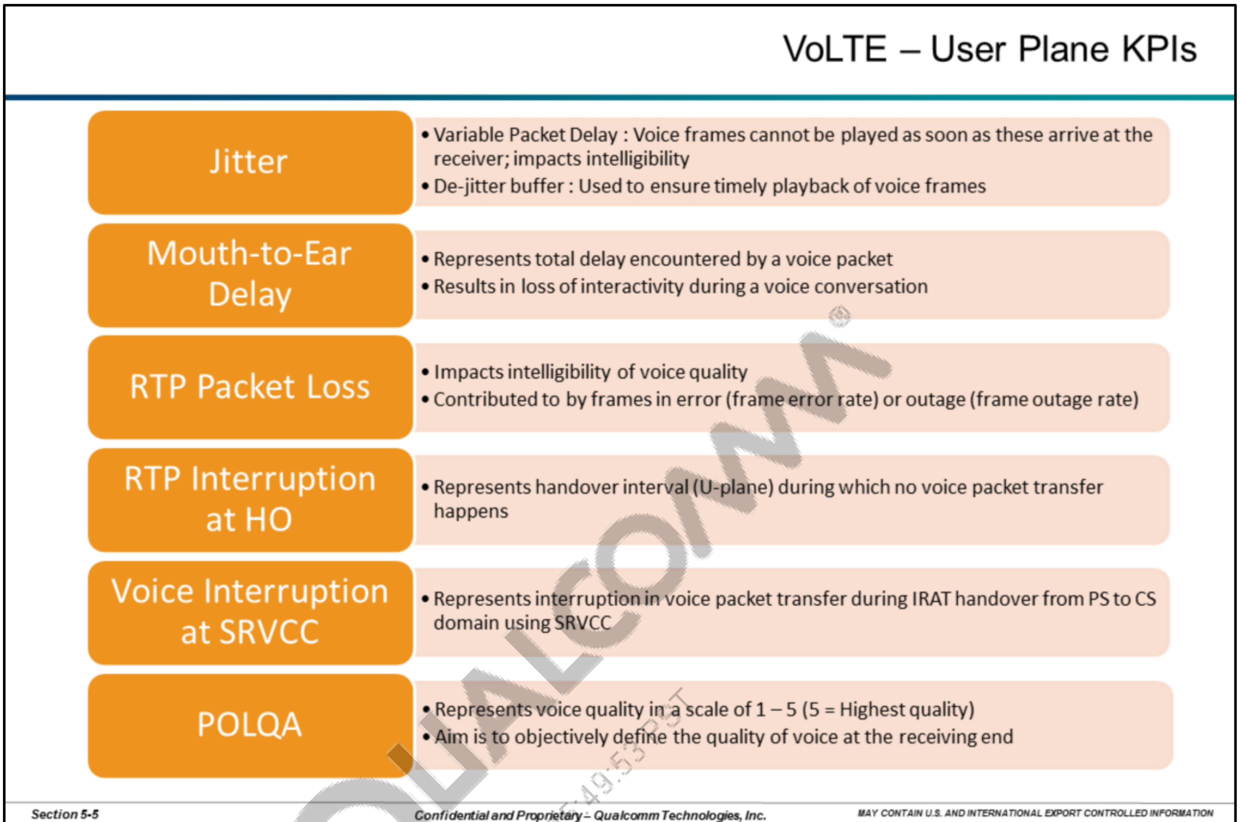
Notes


VoLTE – User Plane KPIs
Jitter
• Variable Packet Delay : Voice frames cannot be played as soon as these arrive at the receiver; impacts intelligibility
• De-jitter buffer : Used to ensure timely playback of voice frames
Mouth-to-Ear Delay
• Represents total delay encountered by a voice packet
• Results in loss of interactivity during a voice conversation
RTP Packet Loss
• Impacts intelligibility of voice quality
• Contributed to by frames in error (frame error rate) or outage (frame outage rate)
RTP Interruption at HO
• Represents handover interval (U-plane) during which no voice packet transfer happens
Voice Interruption at SRVCC
• Represents interruption in voice packet transfer during IRAT handover from PS to CS domain using SRVCC
POLQA
• Represents voice quality in a scale of 1 – 5 (5 = Highest quality)
• Aim is to objectively define the quality of voice at the receiving end
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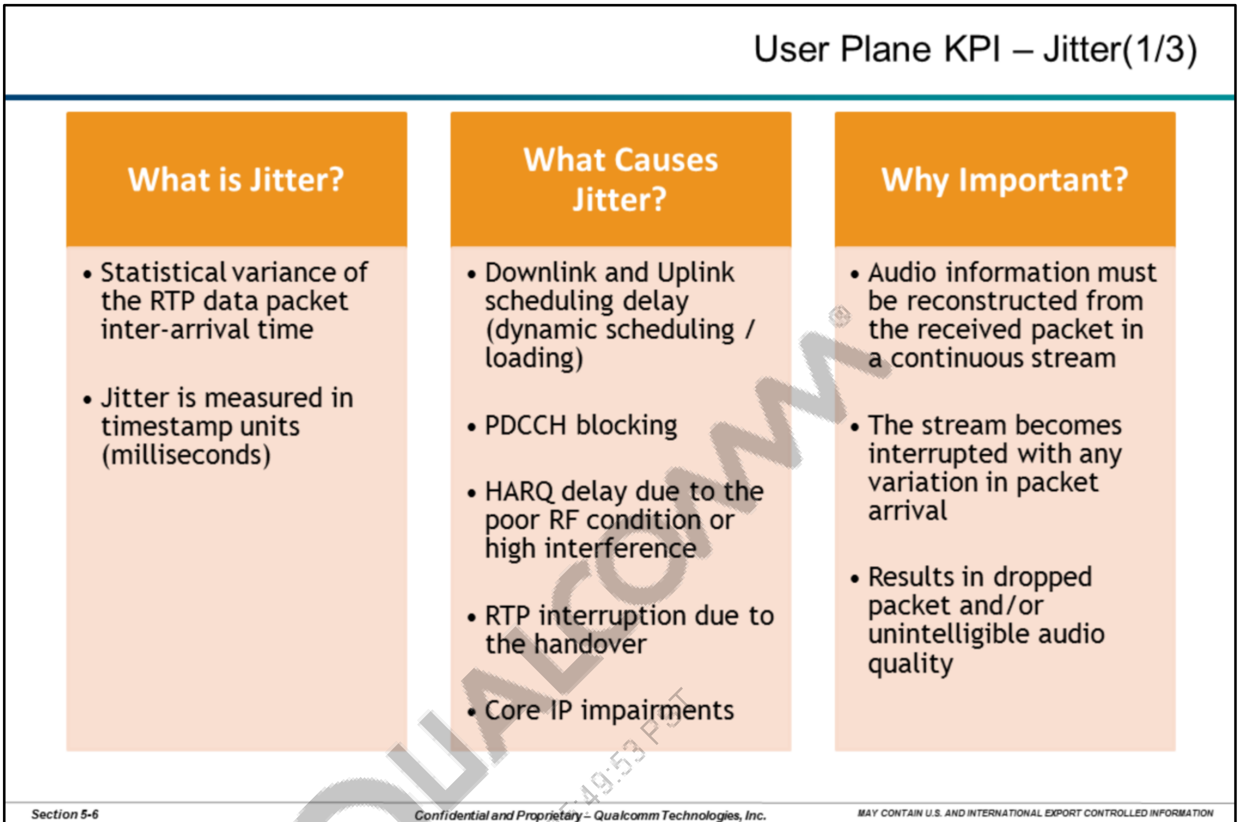
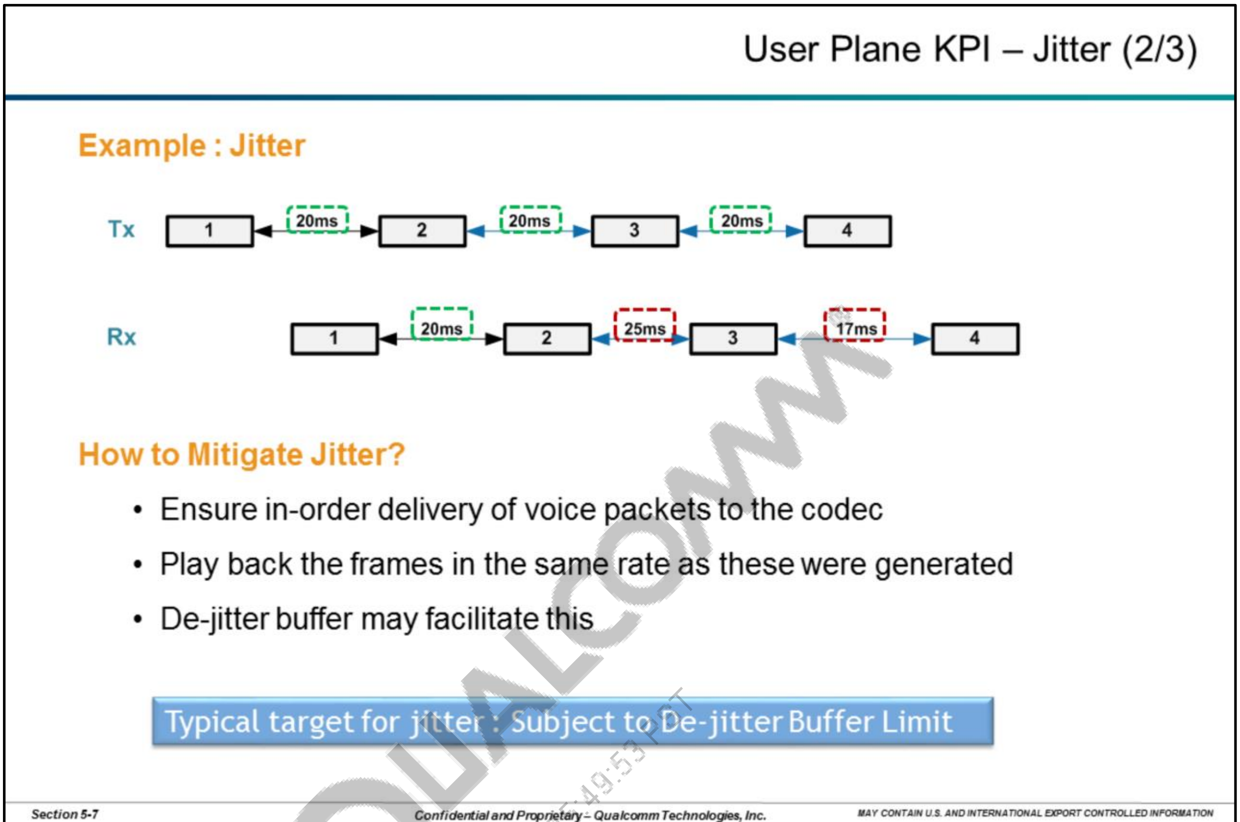
Notes



User Plane KPI - Jitter

LTE RAN or LTE core may cause different latencies on different RTP packets resulting in the variation of the inter-arrival time of RTP packets.

- RTP packets with jitters larger than the de-jitter buffer length will be discarded by de-jitter buffer, resulting in poor voice quality.



The formula for estimating jitter is as follows (https://www.ietf.org/rfc/rfc3550.txt):

$J(i) = J(i-1) + (|D(i-1,i)| - J(i-1))/16$ where,

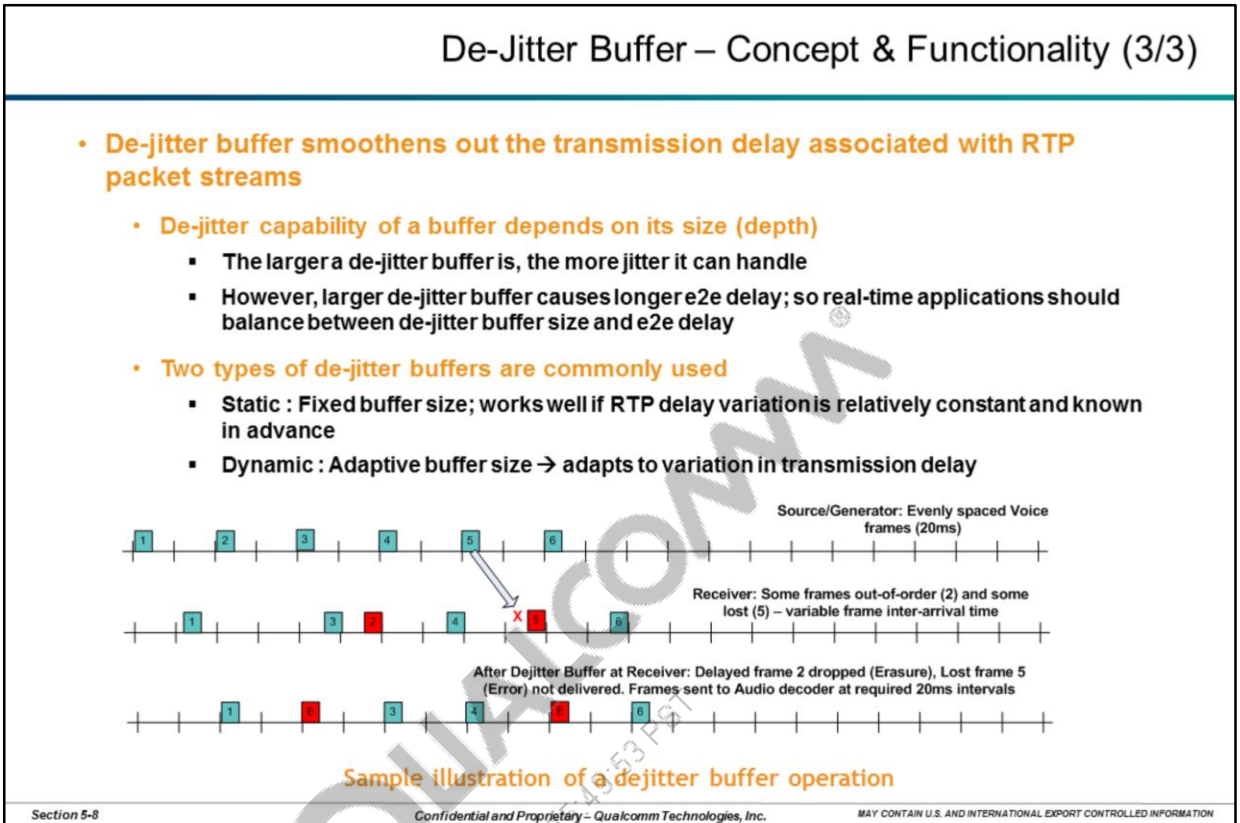
i : i-th packet

J : Jitter

D (i-1,i) : The difference of relative transit times for the two consecutive packets. The difference is computed as

$D(i-1,i) = Ri - Si - (Ri-1 - Si-1)$

i	Si	Ri	|Di-1,i|	Ji
1	0	8	0	0.00
2	20	28	0	0.00
3	40	46	2	0.13
4	60	74	8	0.62
5	80	91	3	0.77
6	100	112	1	0.78
7	120	133	1	0.79
8	140	149	4	0.99
9	160	171	2	1.06
10	180	192	1	1.05



Dejitter Buffer Concepts Timing jitters can be controlled by dejitter buffers, which receive a stream of packets and effectively render these packets by controlling the rate at which packets are output from the buffer. Dejitter buffers may be used in the terminal equipment/device itself (for example, VoIP devices). Larger dejitter buffers enable the system to be more tolerant to jitter. However, a buffer will increase end-to-end latency (or delay), a major transmission impairment.

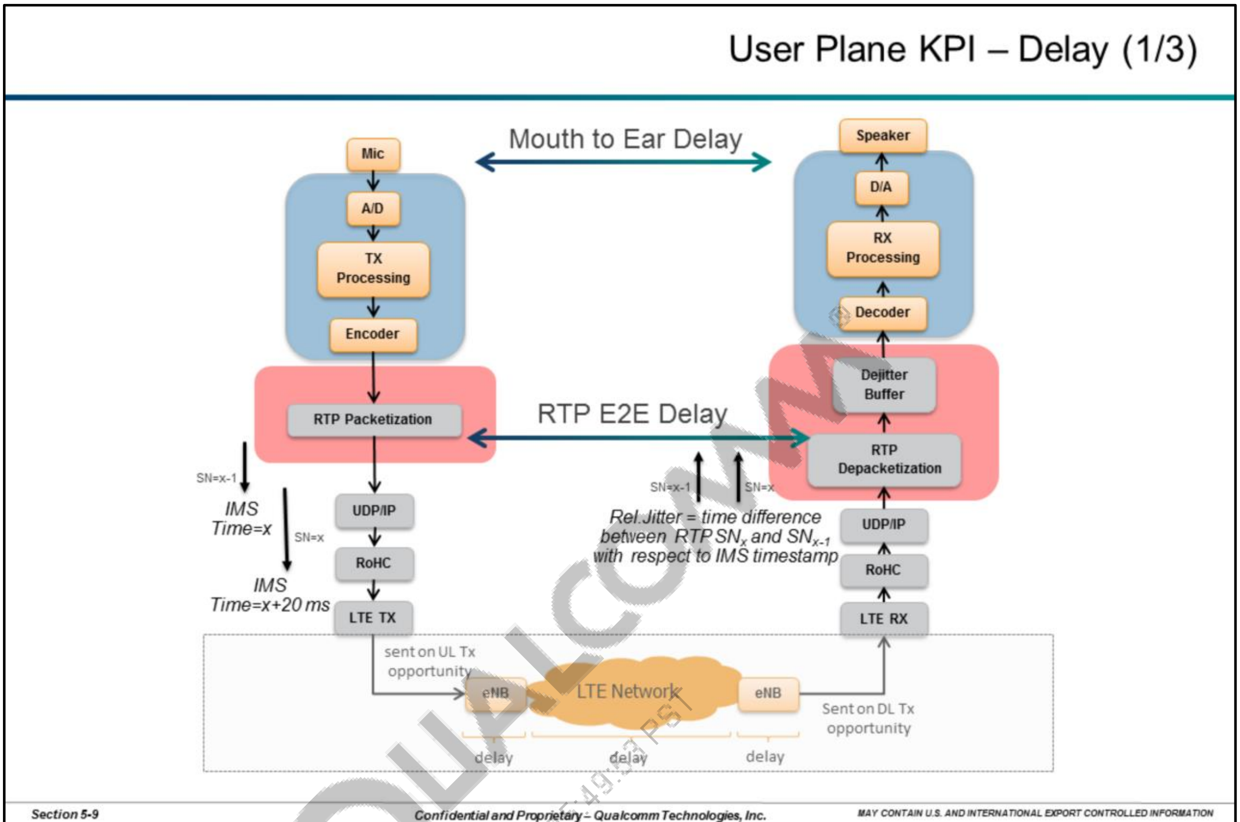
The goal of a dejitter buffer is to provide a smooth supply of audio/video frames to the decoder.

This smooth supply is accomplished by buffering a number of audio/video frames (buffer length) before resuming playback. Some dejitter buffers are static, with a fixed processing window. Others are dynamic and can alter the size of the window to adapt to network conditions. There is a balance between the size of the dejitter buffer and overall delay. Even with a dejitter buffer, some packets may arrive outside the window of the buffer. These packets cannot be processed and will be lost or discarded; interpolation may be used to maintain signal integrity. Dynamic (or adaptive) dejitter buffers can change the buffer length in response to the characteristics of the communication channel. Buffer length selection must consider the trade-off between additional end-to-end delay and frame erasure rate. Proprietary dynamic dejitter buffer algorithms can be implemented.

In the diagram above, the voice frames are generated at the source every 20 ms. After traversing the wireless channel, some frames (RTP packets) at the receiver may be delayed and received out of order (such as 2) and some may be lost due to errors (such as 5). These frames at the receiver are stored in the dejitter buffer, which may drop frames that are delayed significantly (such as 2) causing erasure and while delivering all other frames received successfully (except 5) as per the required 20 ms timing to the vocoder at the receiver.

Adaptive Dejitter buffer: Dynamically changes the dejitter buffer depth according to the channel/network conditions to reduce the end-to-end delay, when possible.

Time-warping: Dynamically compresses or expands packets being played out from the dejitter buffer, without changing their pitch.

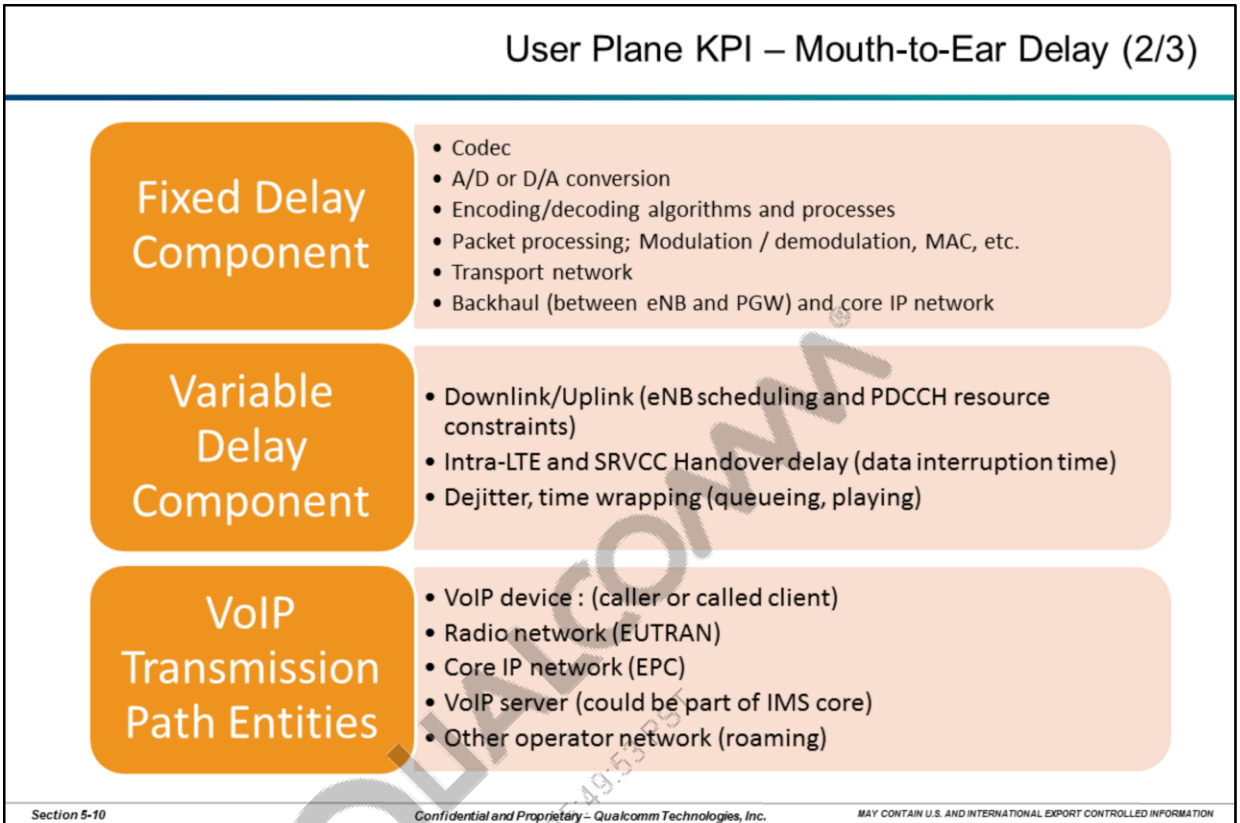


User Plane KPI - Delay

As the RTP packet flows on UL from the speaker to the DL at the listener, Air Interface delays become important. Any delays in scheduling on either UL (from speaker) or DL (at listener) may increase jitter.

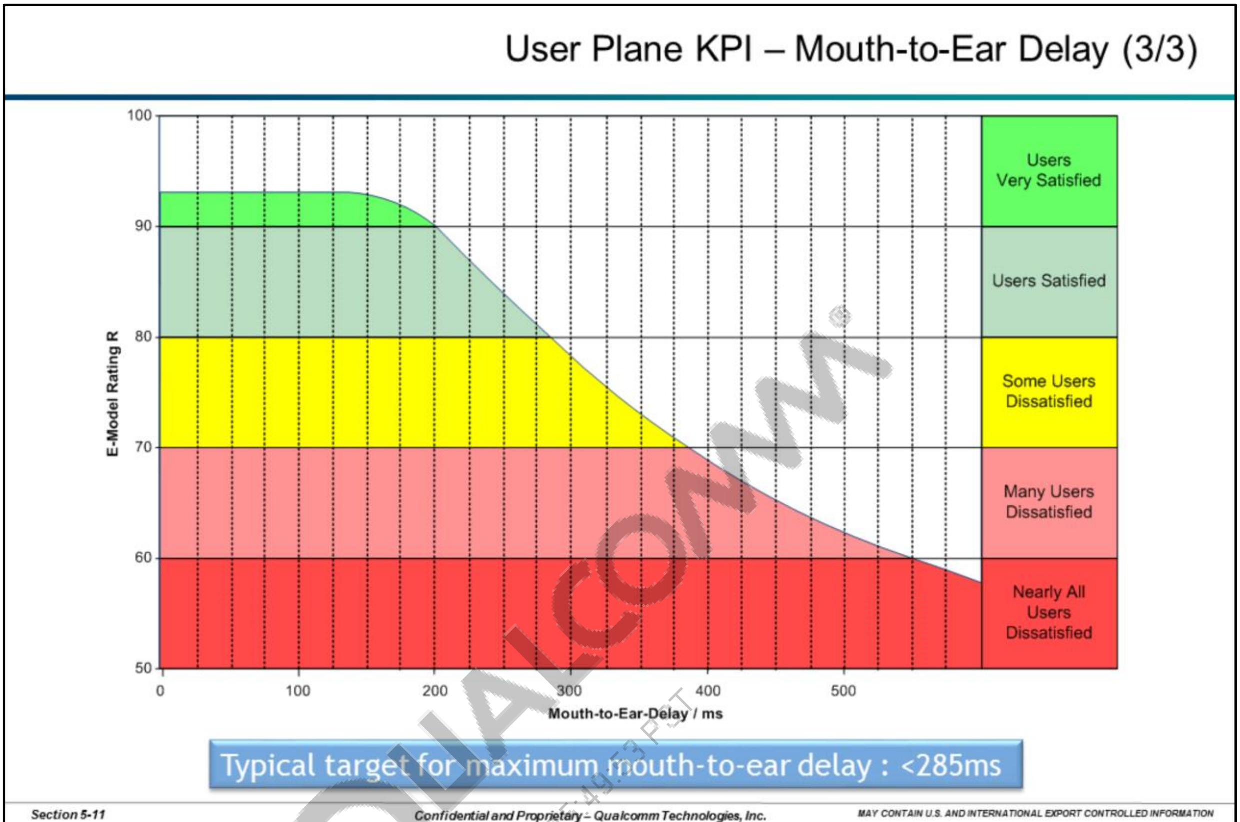
- Jitter increase can therefore increase the adaptive DJ buffer level, increasing end to end delay

Next slide discusses the components contributing to e2e delay.



End-to-End (E2E) Delay Components Different system components contribute to the end-to-end delay:

- At the source, the voice codec (also called the vocoder) collects speech samples, then processes data to produce speech frames. This generates a very small delay.
- Packet processing at various network nodes and propagation delay over wireline links also contribute to end-to-end delay—also quite small.
- On the wireless links (both Uplink and Downlink) each voice frame can experience a different amount of delay due to queuing, scheduling, and over-the-air transmission (e.g., H-ARQ). This is a major component of delay.
- At the receiver, just before the vocoder, an adaptive dejitter buffer must be used to buffer and remove the delay jitter. This is the second major component of delay.
- Finally, the voice codec will decode the voice frames and then play-out the speech frames. This generates a small amount of delay.



Recommendation for Mouth-to-Ear Delay

See International Telecommunication Union ITU-T G.114, "One-way Transmission Time", May 2003.

http://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-G.114-200305-I!!PDF-E&type=items

For user satisfaction, the maximum acceptable end-to-end delay is 285 ms.

- Commercial CDMA2000 1X/WCDMA/GSM networks have 260-270 ms delay.
- Packet switched networks allow for capacity/delay trade-off optimization.

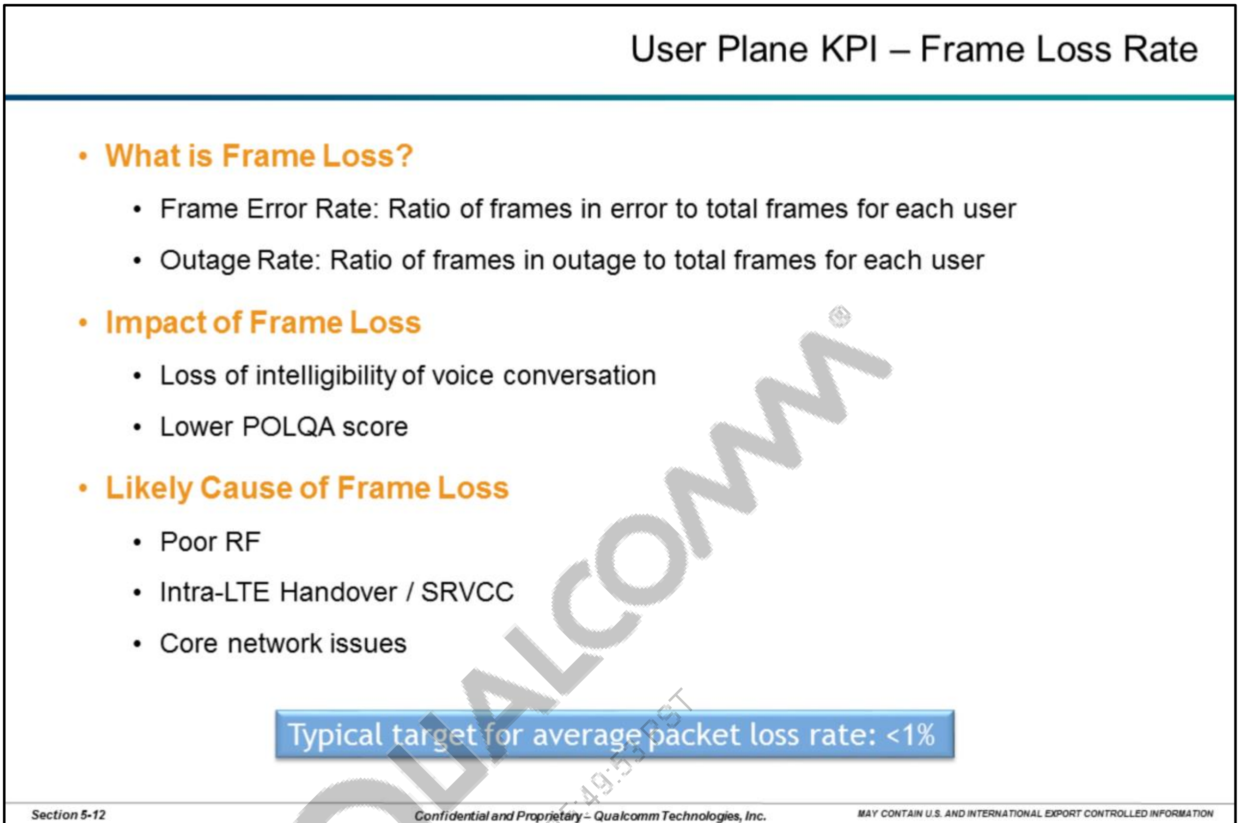
For VoIP capacity analysis, mouth-to-ear delay is analyzed in comparison to ITU recommendations.

Note that the ITU-T G.114 recommendations are for circuit switched networks. However, it does include (in the Appendix) some discussion on packetization delay in IP networks, the impact of dejitter buffers, as well as some guidance on one-way delays for VoIP network planning to ensure acceptable mouth-to-ear delays.

MOS Score E-Model Rating R is a measure of the MOS – a measure of voice quality. The transmission rating factor R can be in the range of 0 to 100, where R = 0 represents extremely bad quality and R = 100 represents very high quality. The E-model provides a statistical estimation of quality measures.

An estimated Mean Opinion Score for the conversational situation on the scale of 1 to 5 can be obtained from the R-factor, using specific formulae. Additional details can be found in ITU-T G.107, "The E-model - A computational model for use in transmission planning".

Note: In 2011, the ITU-T published P.863 : Perceptual objective listening quality assessment (POLQA). POLQA represents the next-generation of voice quality testing technology for fixed, mobile and IP-based networks and can be applied to HD Voice, 3G and 4G/LTE and is considered a successor to PESQ. The ITU-T document describes an objective method for predicting overall listening speech quality from narrowband (300 to 3400 Hz) to super-wideband (50 to 14'000 Hz) telecommunication scenarios as perceived by the user in a P.800 or P.830 ACR listening only test. P.863 supports two operational modes, one for narrowband and one for super-wideband. The document presents a high-level description of the method, advice on how to use it, and part of the results from a Study Group 12 benchmark carried out in the period 2006-2010. For more information, please refer http://www.itu.int/rec/T-REC-P.863/en



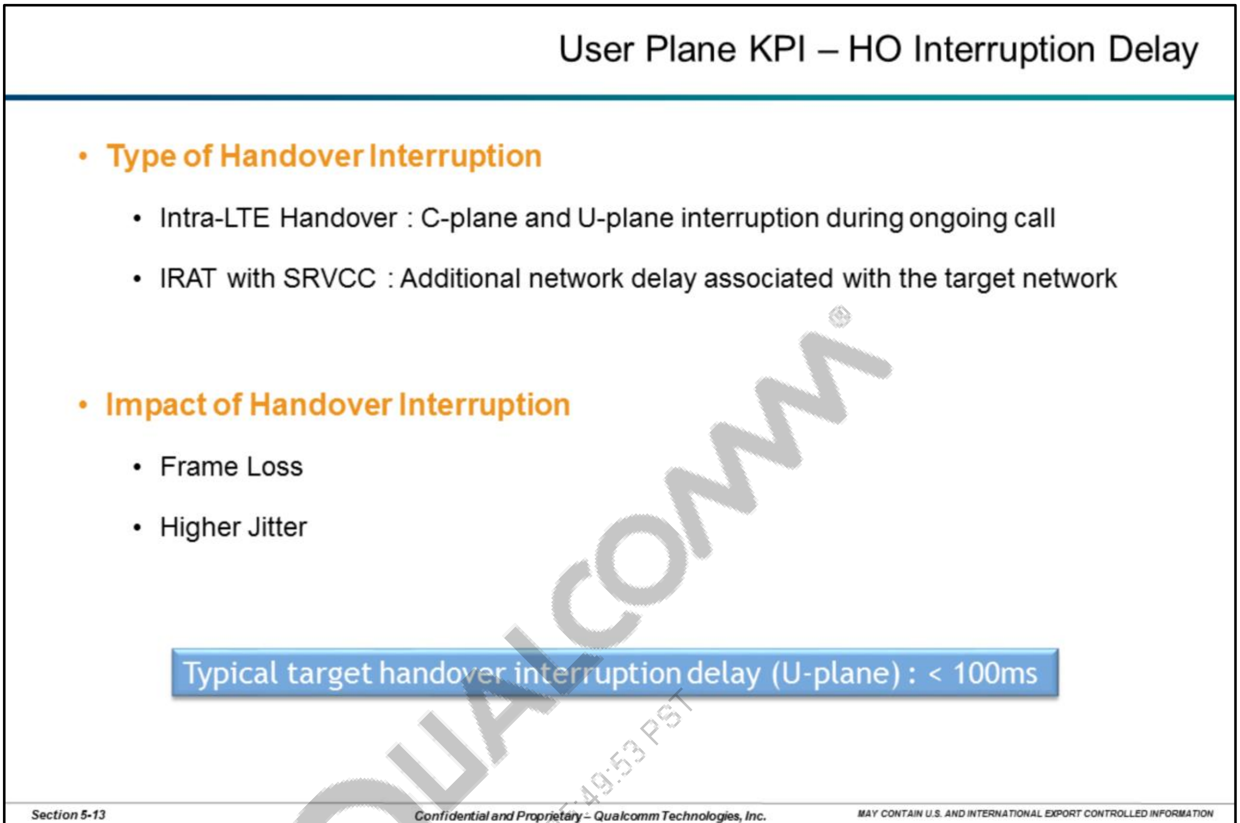
User Plane KPI – Frame Loss Rate

The packet loss rate is typically controlled by the link-adaptation algorithms to statistically ensure that the VoIP packets are successfully transmitted within the pre-defined loss targets.

Frame Error Rate = 100 x (Total transmitted frames – Frames received without error) / Total transmitted frames

Frame Outage Rate = 100 x Frames in outage / Total transmitted frames

Frame Loss Rate = Frame Error Rate + Frame Outage Rate



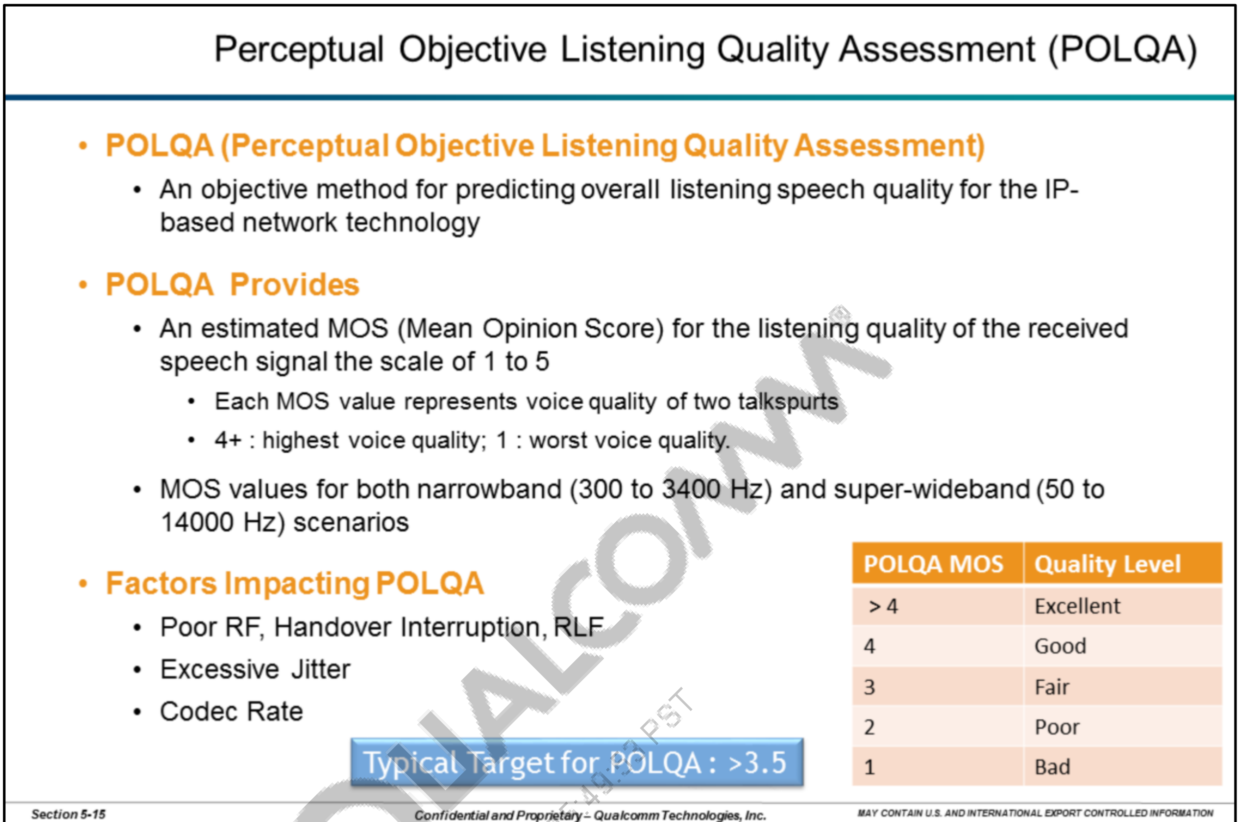
User Plane KPI – HO Interruption Delay

The packet loss rate is typically controlled by the link-adaptation algorithms to statistically ensure that the VoIP packets are successfully transmitted within the pre-defined loss targets.

Topic Map

- User Plane KPIs for VoLTE
- **POLQA**
- Radio Link Failure (RLF)
- Case Studies – Debugging Scenarios
- Scheduling Behavior

Notes



MOS Score

E-Model Rating R is a measure of the MOS – a measure of voice quality. The transmission rating factor R can be in the range of 0 to 100, where R = 0 represents extremely bad quality and R = 100 represents very high quality. The E-model provides a statistical estimation of quality measures. An estimated Mean Opinion Score(MOS) for the conversational situation on the scale of 1 to 5 can be obtained from the R-factor, using specific formula. Additional details can be found in ITU-T G.107, "The E-model - A computational model for use in transmission planning".

Note: In 2011, the ITU-T published P.863 : Perceptual objective listening quality assessment (POLQA). POLQA represents the next-generation of voice quality testing technology for fixed, mobile and IP-based networks and can be applied to HD Voice, 3G and 4G/LTE and is considered a successor to PESQ.

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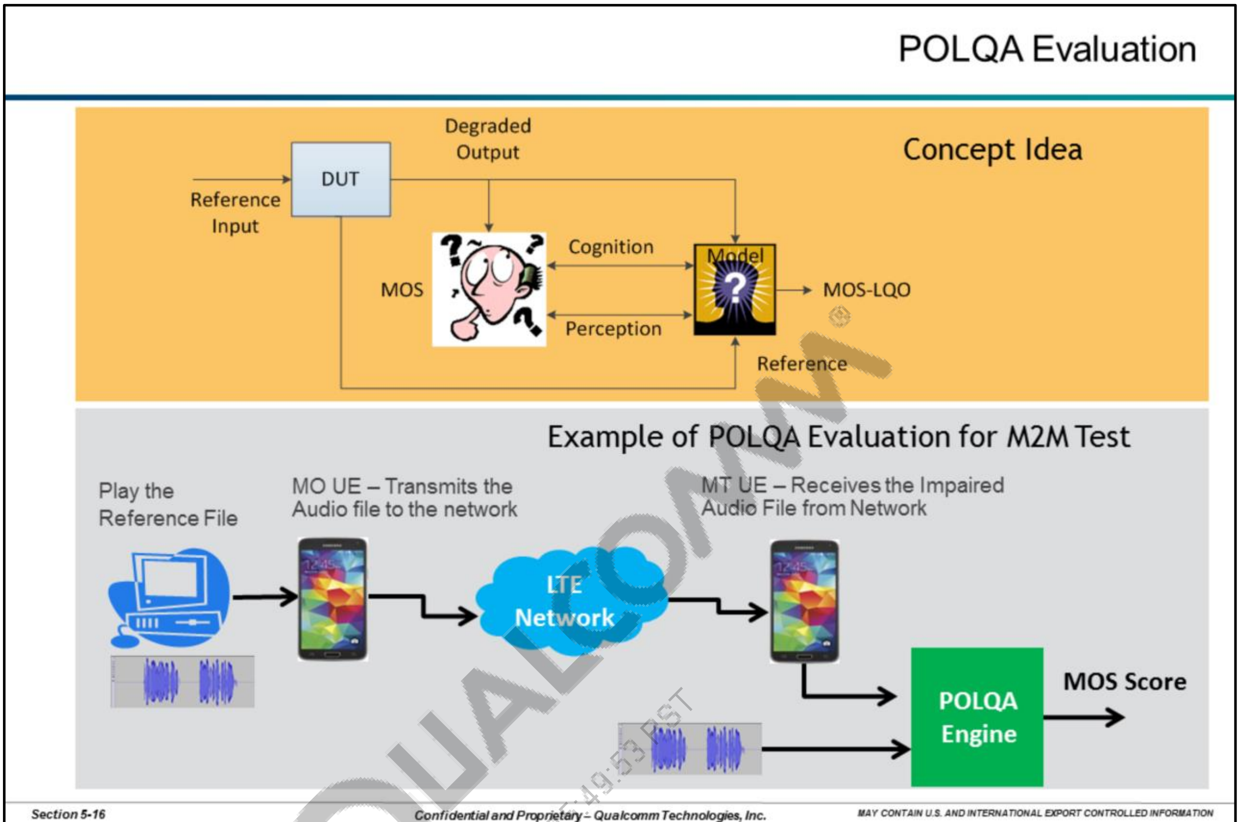
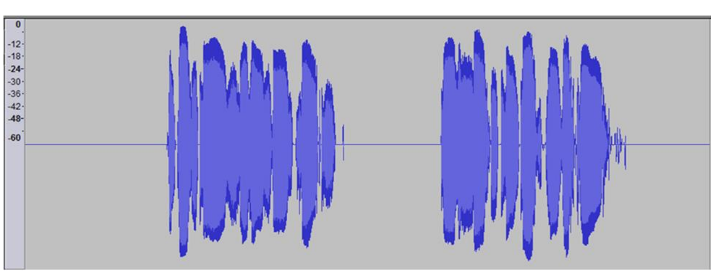


According to ITU-T P.863

The inputs to the POLQA engine are two waveforms represented by two data vectors containing 16 bit PCM samples. The first vector contains the samples of the (undistorted) reference signal, whereas the second vector contains the samples of the degraded signal. The POLQA algorithm consists of a temporal alignment block, a sample rate estimator of a sample rate converter, which is used to compensate for differences in the sample rate of the input signals, and the actual core model, which performs the MOS calculation.

According to ITU T P.863, the reference speech signal for POLQA analysis should satisfy the following characterization:

- The reference speech signal for POLQA testing should contain two sentences (talkspurts) separated by a gap with the length of 1sec to 2sec.
- The first talkspurt starts between 0.5 and 2 sec, where the last talkspurt ends between 0.5 and 2.5 s before the end of reference signal.
- The entire reference signal length has to be between 8 and 12.
- The speech activity factor calculated over the entire file has to be between 35% and 65% (ITU-T P.56).



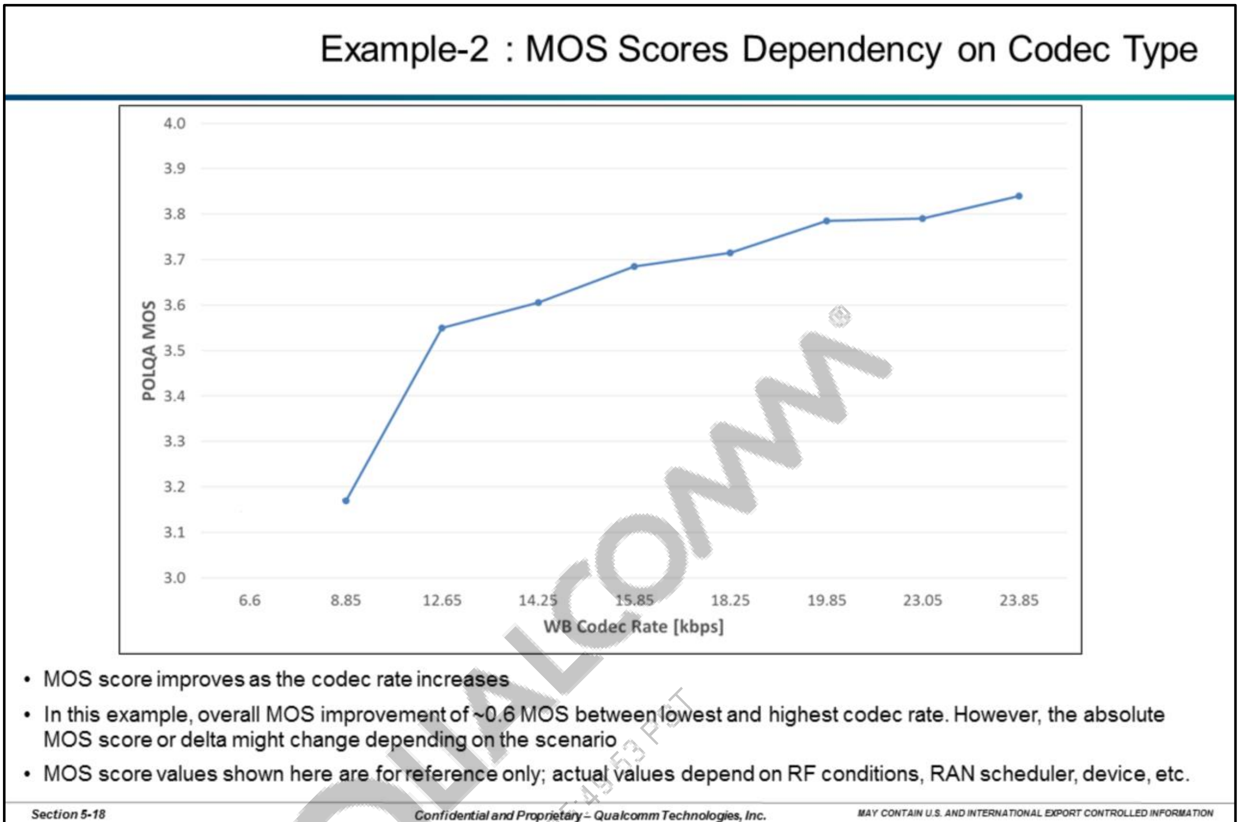
Test Assumptions

- LTE band 20 (800 MHz)
- No TTI bundling is enabled. Enabling TTI-Bundling may improve UL performance.
- Wideband voice sample (300 – 8000 Hz) with 16 kHz sampling frequency
- Voice codec: WB-AMR-23.85
- Mobile-to-mobile (M2M) VoLTE call

The figure shows the MOS score as a function of pathloss for both DL and UL. The MOS score is reflecting the end-to-end perception.

The MO pathloss is calculated as follows:

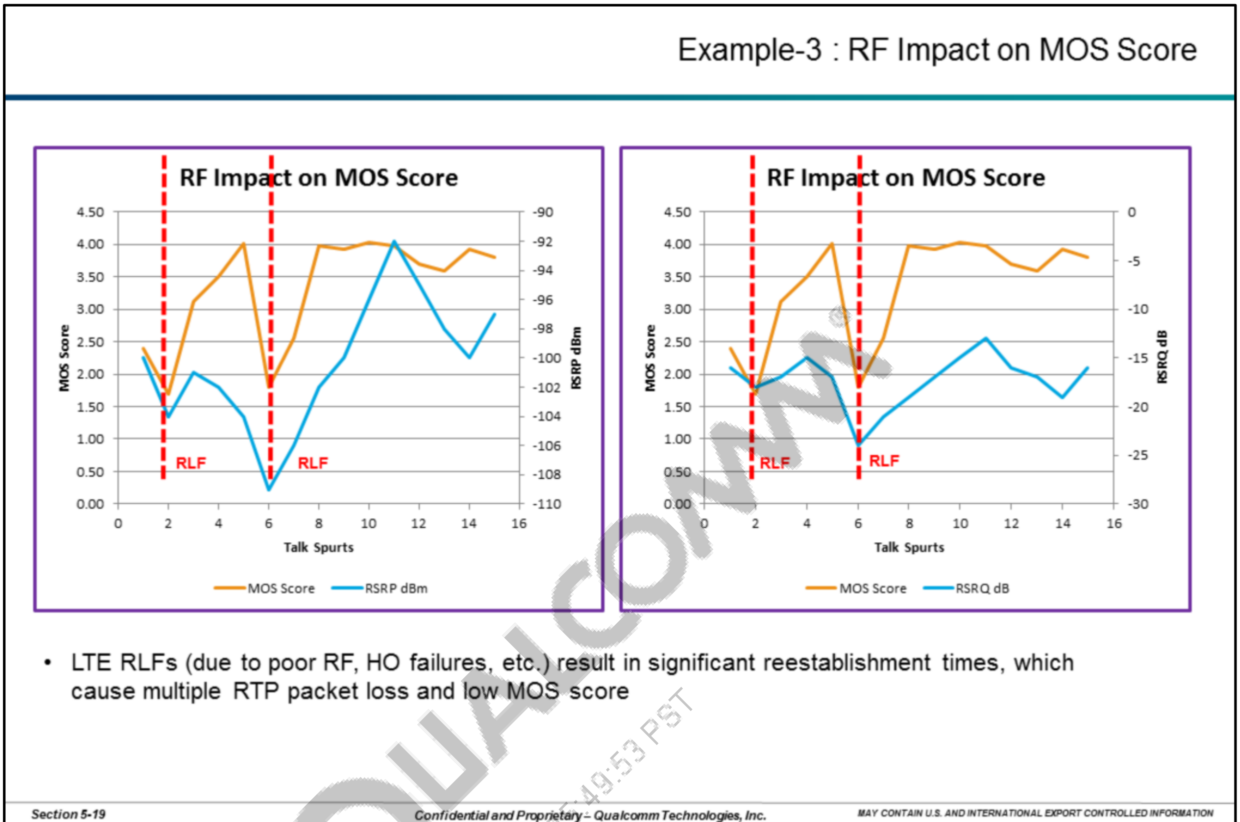
[RS_signal_strength_dBm – RSRP_dBm] [dB].



Bandwidth Calculations

This table shows the bandwidth calculations for AMR-WB bandwidth efficient mode.

	Codec Mode								
	6.6	8.85	12.65	14.25	15.85	18.25	19.85	23.05	23.85
Speech Payload	132	177	253	285	317	365	397	461	477
AMR Header	12	15	11	11	11	11	11	11	11
IPv4 Header	320	320	320	320	320	320	320	320	320
IPv4 Packet Size	464	512	584	616	648	696	728	792	808
IPv4 BW (kbps)	**24**	**26**	**30**	**32**	**33**	**36**	**37**	**40**	**41**
IPv6 Header	480	480	480	480	480	480	480	480	480
IPv6 Packet Size	624	672	744	776	808	856	888	952	968
IPv6 BW (kbps)	**32**	**34**	**38**	**40**	**41**	**43**	**45**	**48**	**49**



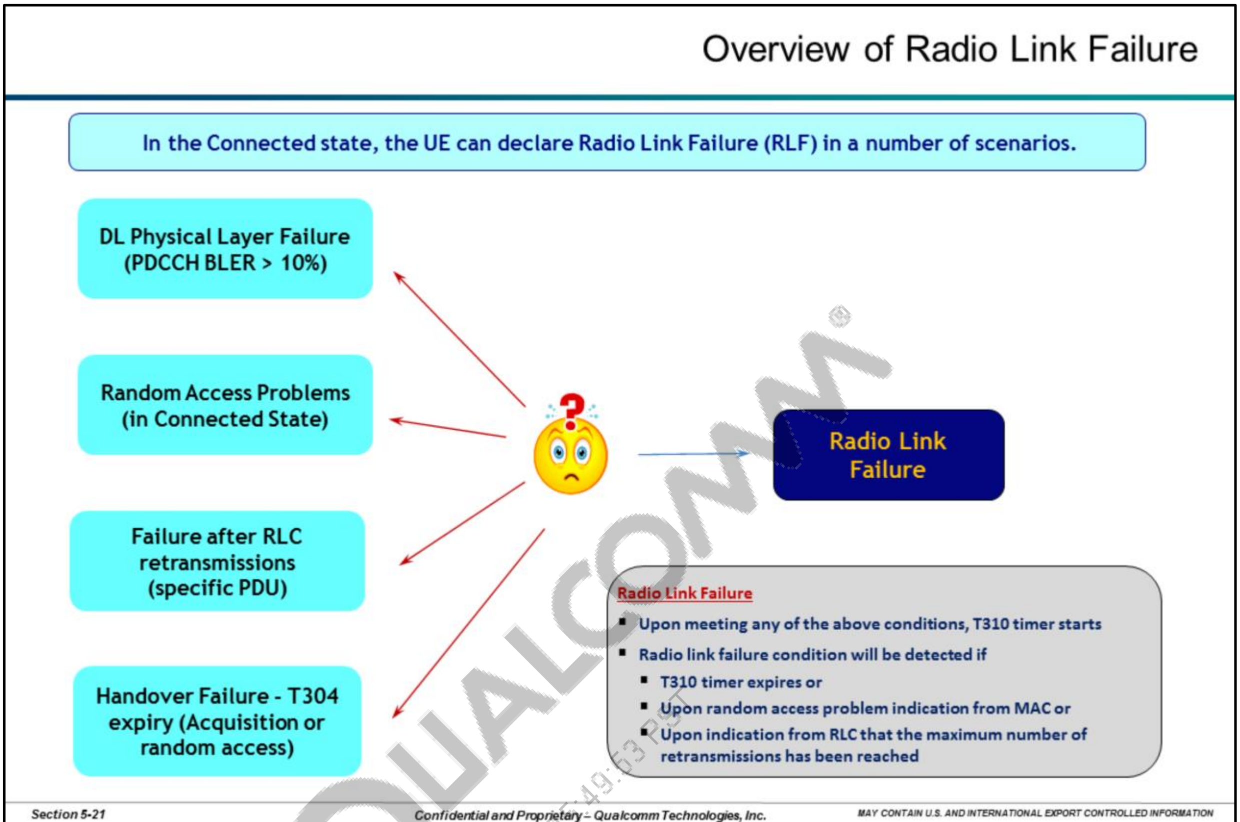
RF Impact on MOS Score

This slide compares the MOS score with the RF condition (RSRP/RSRQ) for different voice chunks. Each chunk contains two talkspurts with the duration of 8s.

Topic Map

- User Plane KPIs for VoLTE
- POLQA
- **Radio Link Failure (RLF)**
- Case Studies – Debugging Scenarios
- Scheduling Behavior

Notes



Detection of physical layer problems in RRC_CONNECTED

The UE shall:

- Upon receiving N310 consecutive "out-of-sync" indications from lower layers while neither T300, T301, T304 or T311 is running:
- Start timer T310

Detection of radio link failure

The UE shall:

- Upon T310 expiry; or
- Upon random access problem indication from MAC while neither T300, T301, T304 nor T311 is running; or
- Upon indication from RLC that the maximum number of retransmissions has been reached

Consider radio link failure to be detected

If AS security has not been activated:

- UE will perform the actions upon leaving RRC_CONNECTED, with release cause 'other'

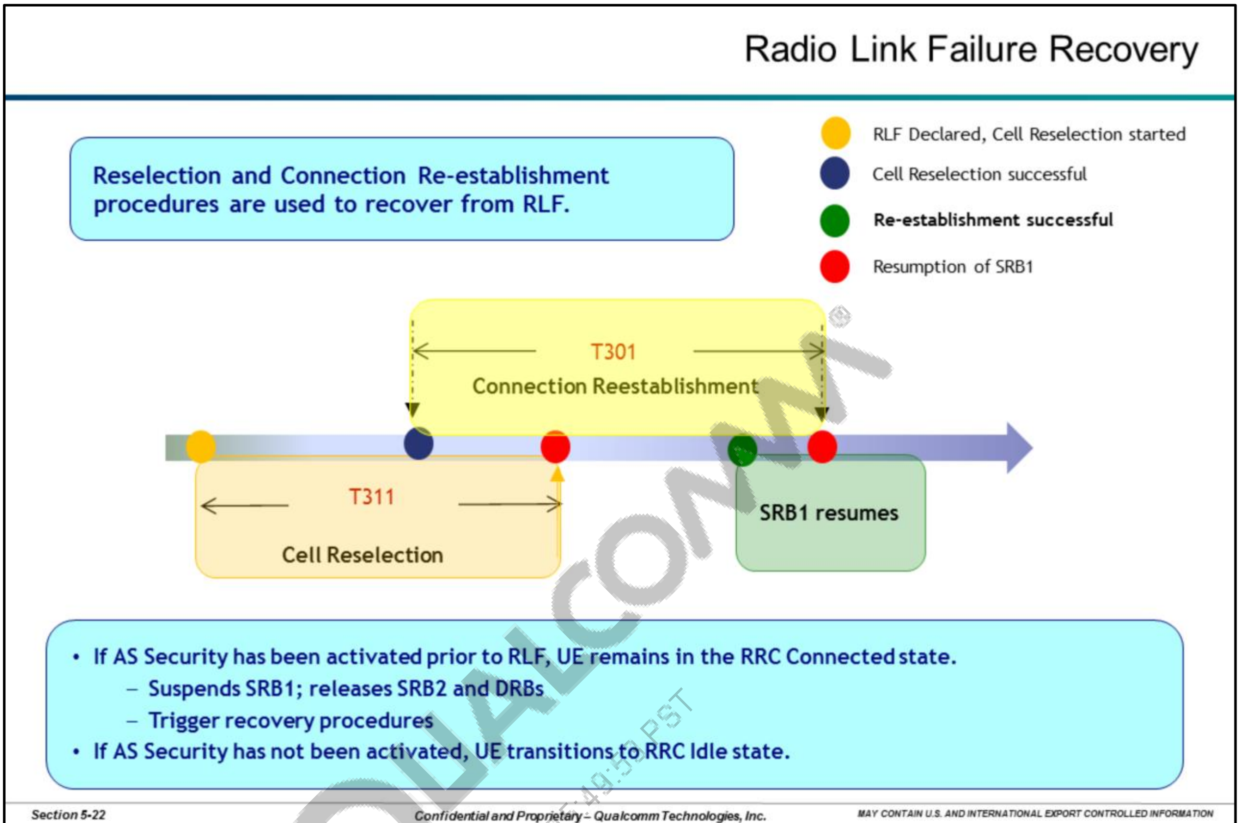
Else:

- Initiate the connection re-establishment procedure

Measurement can be done at : eNB

Level of Measurement : User, Cell, cluster, market, network

Related 3GPP specifications : 3GPP TS 36.331 V9.3.0 (2010-06) section 5.3.10.7



Recovery from RLF – Overview

This procedure is utilized to enable recovery from a radio link failure. Once an RLF has been declared, the timer T311 is started. This is only possible if AS security was activated prior to the RLF. In this case SRB1 is suspended, and SRB2 and all DRBs are released. If AS security was not activated, the UE transitions directly to idle mode.

Upon commencement of T311, the UE attempts cell reselection. If unsuccessful before the expiration of T311, the UE transitions to idle mode. If successful, the UE starts the timer T301 and begins the connection reestablishment procedure with the selected cell. If T301 expires without successful reestablishment, the UE transitions to idle mode. If successful, SRB1 resumes and the recovery mechanism is complete. SRB2 and any DRB can then be established.

Impact of Radio Link Failure on VoLTE

- **Impact of Radio Link Failure**
  - Disruption of U-plane data transfer
  - For VoLTE, this results into RTP packet loss for the duration until RRC connection is reestablished
  - Loss of RTP packet also impacts voice intelligibility (reduces POLQA score)
- **Summary**
  - RLF → RRC Reestablishment Success
    - Not treated as user-perceived call drop, only degrades voice quality
  - RLF → RRC Reestablishment Failure → RTP timeout
    - Treated as user-perceived call drop

Typical target for RLF : <2%
Typical target for RRC Reestablishment Success Rate : >98%
Typical target Call drop rate : <1% (RTP Timeout Timer : 10s)

Notes

Topic Map

- User Plane KPIs for VoLTE
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- Radio Link Failure (RLF)
- **Case Studies – Debugging Scenarios**
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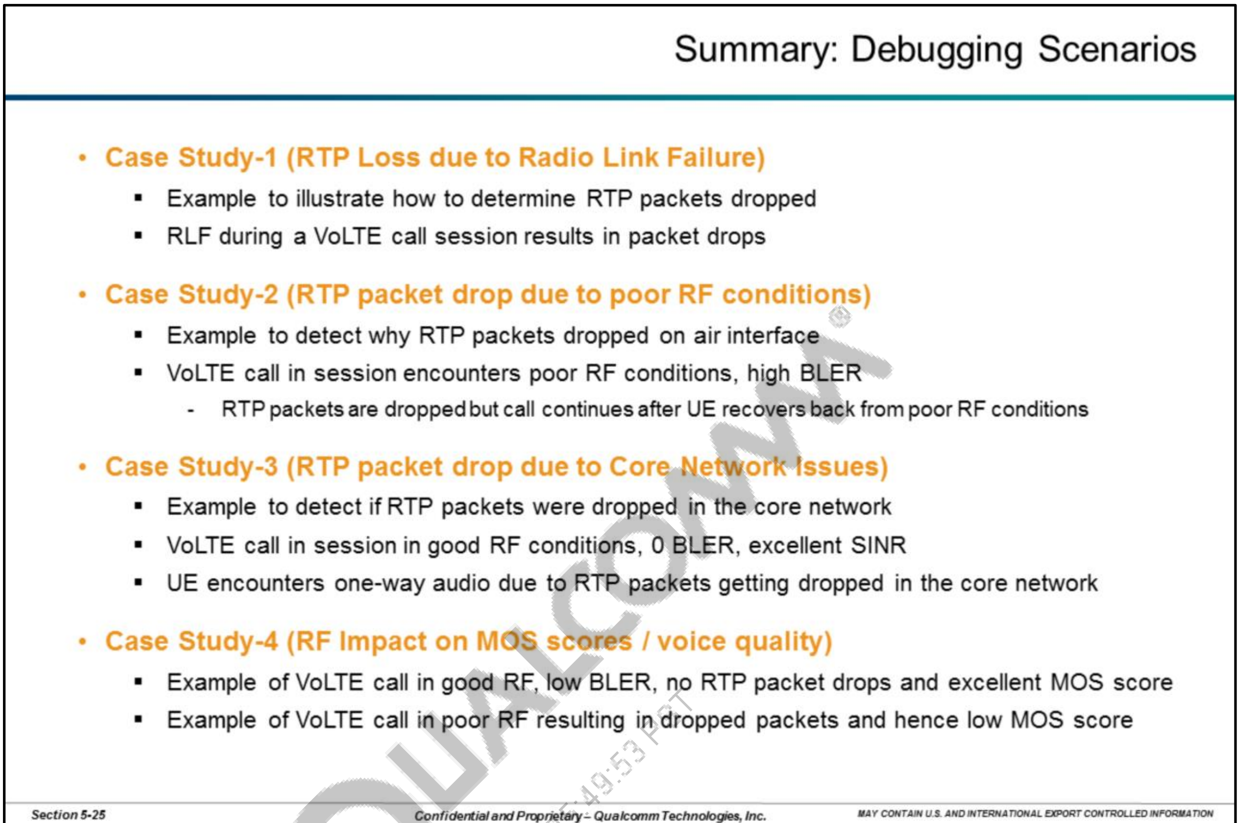
Notes


Summary: Debugging Scenarios
• Case Study-1 (RTP Loss due to Radio Link Failure)
▪ Example to illustrate how to determine RTP packets dropped
▪ RLF during a VoLTE call session results in packet drops
• Case Study-2 (RTP packet drop due to poor RF conditions)
▪ Example to detect why RTP packets dropped on air interface
▪ VoLTE call in session encounters poor RF conditions, high BLER
- RTP packets are dropped but call continues after UE recovers back from poor RF conditions
• Case Study-3 (RTP packet drop due to Core Network Issues)
▪ Example to detect if RTP packets were dropped in the core network
▪ VoLTE call in session in good RF conditions, 0 BLER, excellent SINR
▪ UE encounters one-way audio due to RTP packets getting dropped in the core network
• Case Study-4 (RF Impact on MOS scores / voice quality)
▪ Example of VoLTE call in good RF, low BLER, no RTP packet drops and excellent MOS score
▪ Example of VoLTE call in poor RF resulting in dropped packets and hence low MOS score
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Notes

Summary: Debugging Scenarios in This Section

Case Study-1 (RTP loss due to Radio Link Failure)

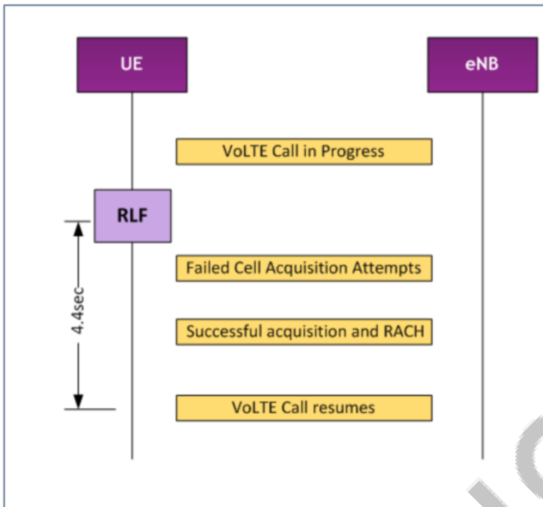
Case Study-2 (RTP packet drop due to poor RF conditions)

Case Study-3 (RTP packet drop due to Core Network Issues)

Case Study-4 (RF Impact on MOS scores / voice quality)

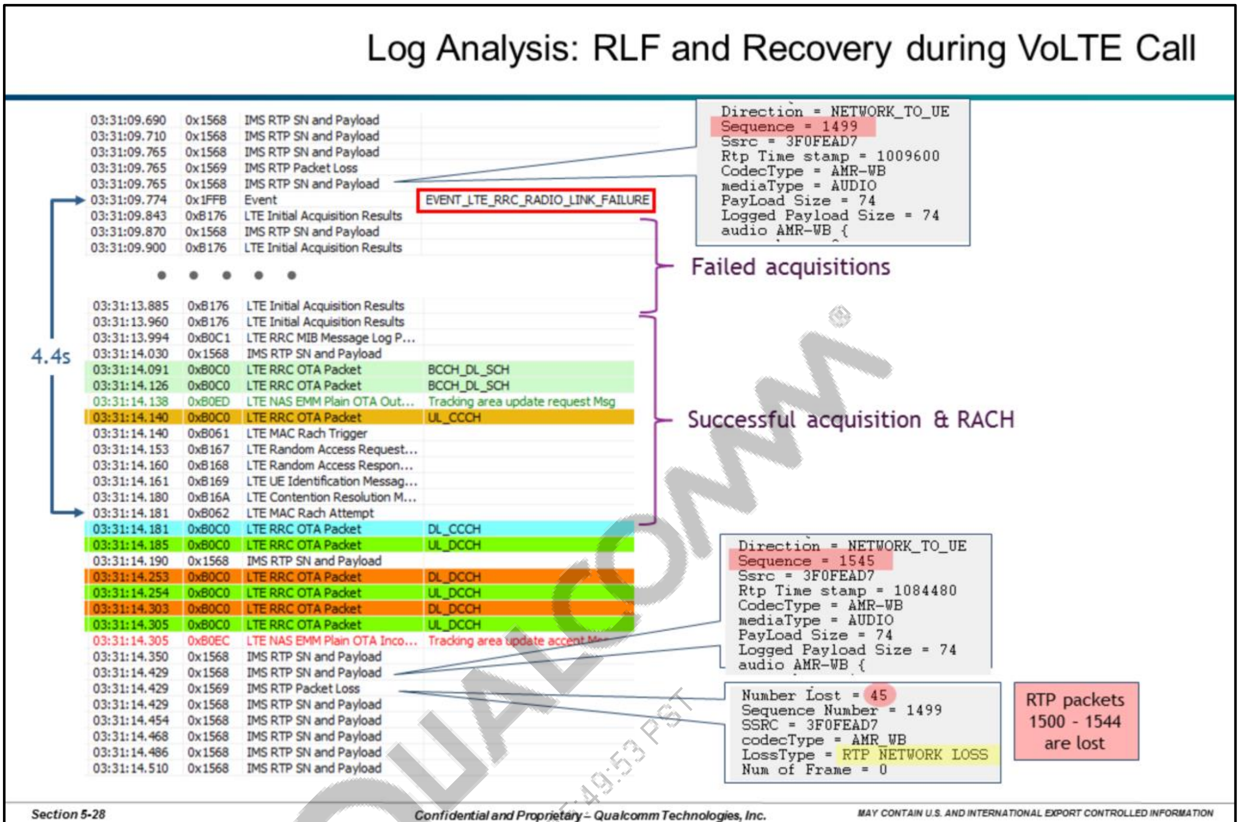
Notes

RLF and Recovery during VoLTE Call



- UE in an active VoLTE call declares RLF
- Cell acquisition initially fails and UE scans multiple frequencies
- Acquisition eventually passes and UE performs successful RACH procedure
- RTP traffic resumes
- RTP packet loss is observed

Notes



RLF and Recovery during VoLTE Call

The call did not drop because 4.4s interruption was less than the 10s RTP timeout timer set in the network.

Analysis Example – RLF and Recovery during VoLTE Call

Log Analysis Procedure: RLF and recovery during VoLTE Call

Open File: 05-01-RTP_loss_RLF

Notes

RLF and Recovery during VoLTE Call: Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	IMS RTP SN and Payload	0x1568	03:31:09.328 Through 03:31:09.765	RTP stream from network to UE with occasional dropped packets (like 03:31:09.514)
2	IMS RTP SN and Payload	0x1568	03:31:09.765	Last DL RTP packet before declaring RLF. **`Sequence = 1499`**
3	EVENT_LTE_RRC_RADIO_LINK_FAILURE	0x1FFB	03:31:09.774	UE declares **Radio Link Failure**
4	LTE Initial Acquisition Results	0xB176	03:31:09.843 through 03:31:13.885	Multiple acquisition failures over different bands for 4.4sec
5	LTE Initial Acquisition Results	0xB176	03:31:13.960	Successful acquisition
6	RACH Procedure	0xB062	03:31:14.181	`Rach result = Success`
7	LTE RRC OTA Packet	0xB0C0	03:31:14.140 03:31:14.305	RRC connection established
8	IMS RTP SN and Payload	0x1568	03:31:14.429	First DL RTP packet following RLF and acquisition. **`Sequence = 1545`**
9	IMS RTP Packet Loss	0x1569	03:31:14.429	**`Number Lost = 45`** (packets 1500 through 1544)

RLF and Recovery During VoLTE Call: Log Walk-Through

The log shows multiple UL comfort noise packets being generated (at 160ms periodicity) after RLF event. These packets are generated by the vocoder and are buffered, to be sent after connection is established.

In the Tracking area update request (03:31:14.138):

- voice_domain_pref
- length = 1 (0x1)
- UE_usage_setting = 1 (0x1) (Data centric)
- voice_domain_pref_for_EUTRAN = 3 (0x3) (IMS PS Voice preferred, CS Voice as secondary)

In the tracking area update accept (03:31:14.305):

- IMSVoPS = 1 (0x1) (IMS Vo PS Session in S1 Mode supported)

Summary: Debugging Scenarios in This Section

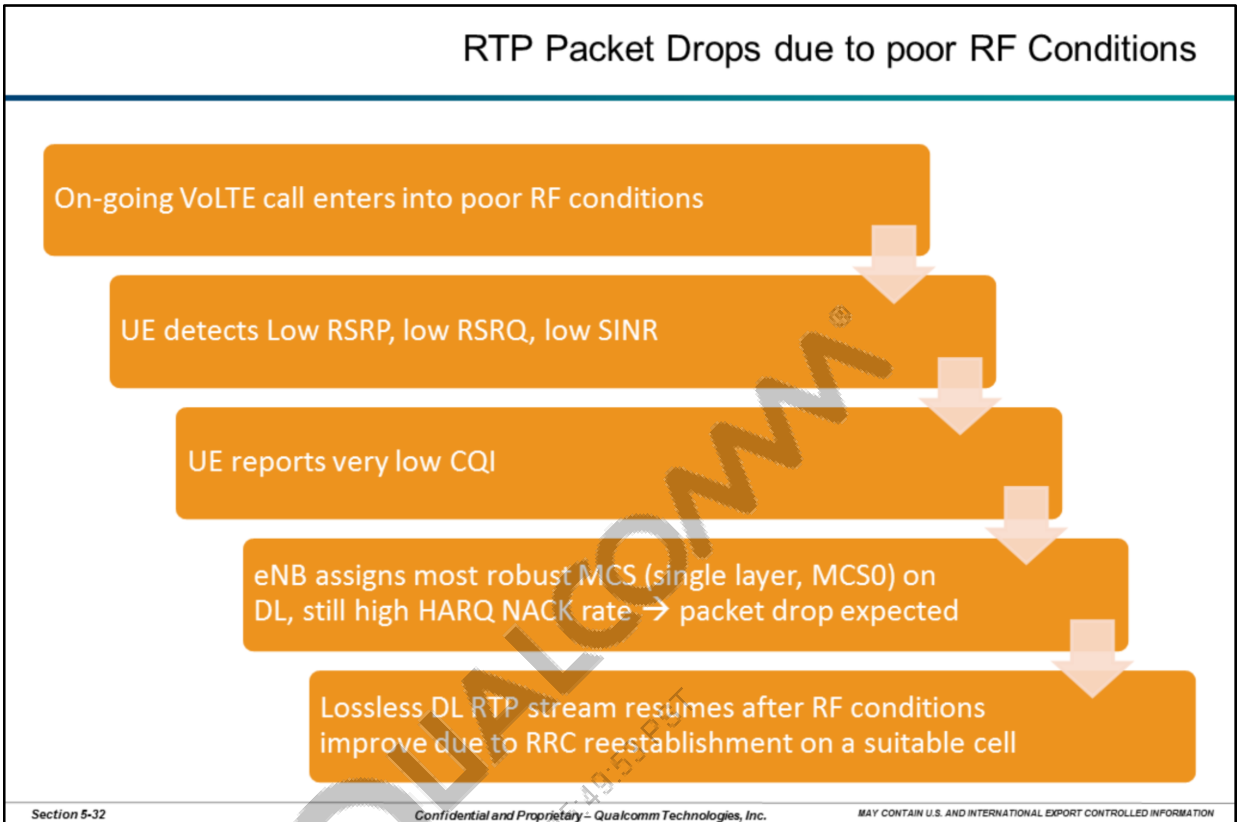
Case Study-1 (RTP Loss due to Radio Link Failure)

Case Study-2 (RTP packet drop due to poor RF conditions)

Case Study-3 (RTP packet drop due to Core Network Issues)

Case Study-4 (RF Impact on MOS scores / voice quality)

Notes


RTP Packet Drops due to poor RF Conditions
On-going VoLTE call enters into poor RF conditions
UE detects Low RSRP, low RSRQ, low SINR
UE reports very low CQI
eNB assigns most robust MCS (single layer, MCS0) on DL, still high HARQ NACK rate → packet drop expected
Lossless DL RTP stream resumes after RF conditions improve due to RRC reestablishment on a suitable cell
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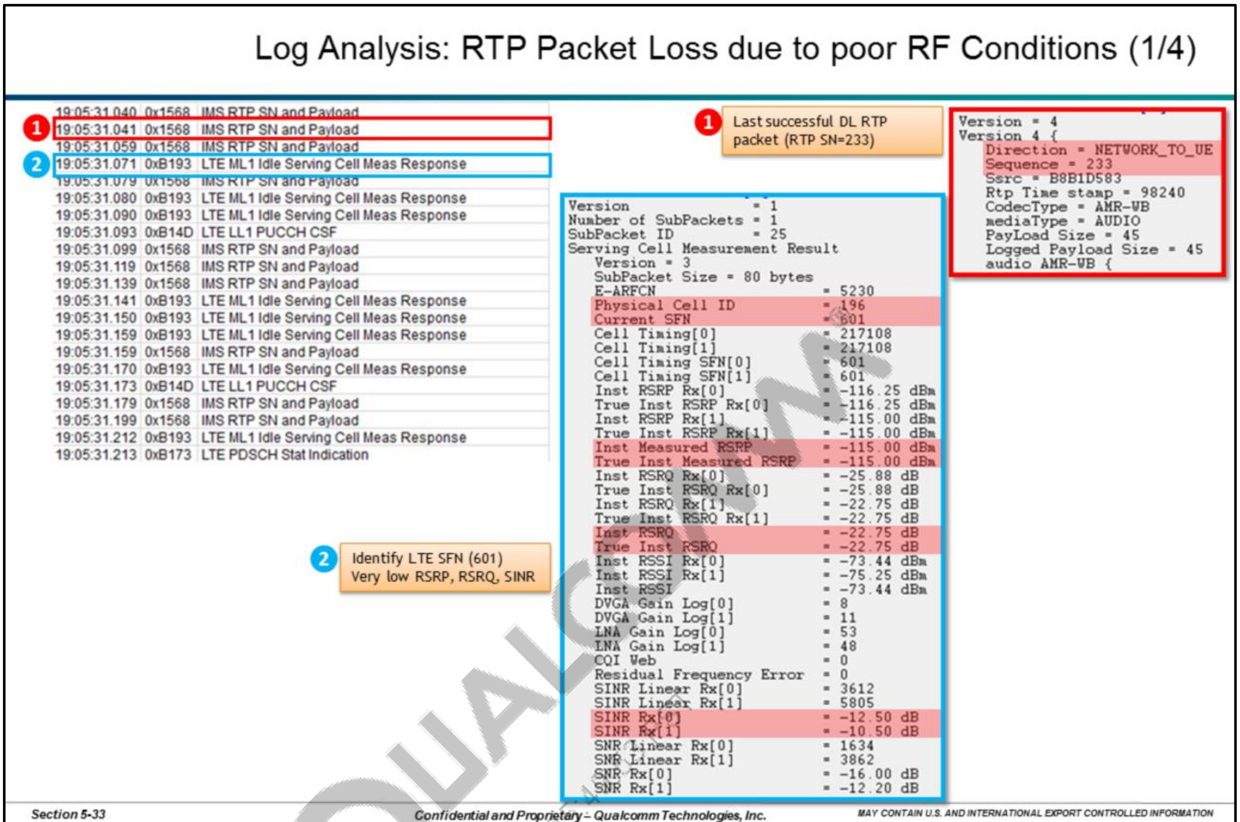
Notes

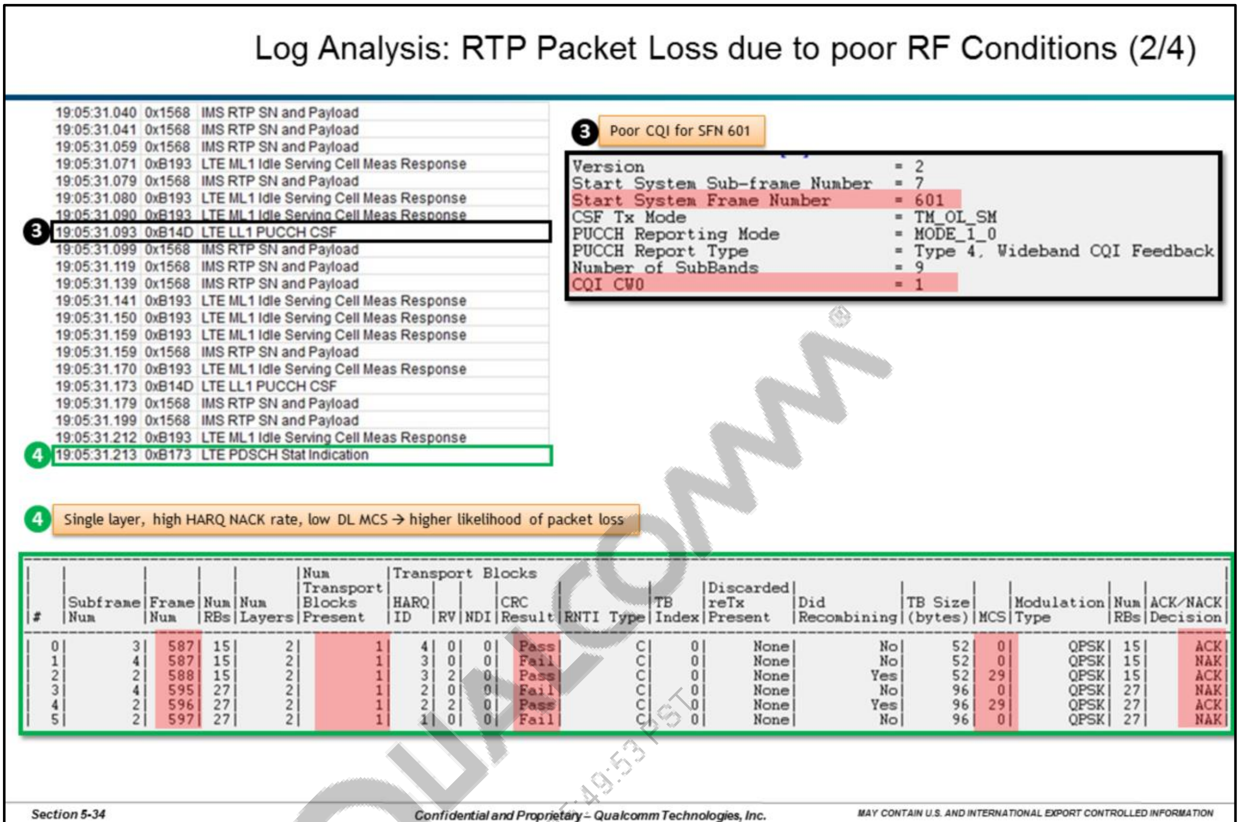


Step 1:

Identify the last successful DL RTP packet. RTP packet SN = 233 in this example in Network to UE direction. Use 0x1568 “IMS RTP SN and Payload” log packet for this information

Step 2:

Identify the LTE SFN and its RF conditions just after the last successful DL RTP packet transfer. Use 0xB193 “LTE ML1 Idle Serving Cell Meas Response” log packet for this information. Even though the log packet name suggests that is Idle, it is reported in connected mode also as seen in this example. LTE SFN = 601 for PCI = 196 in this log packet. Very poor RSRP, RSRQ and SINR for a VoLTE call.

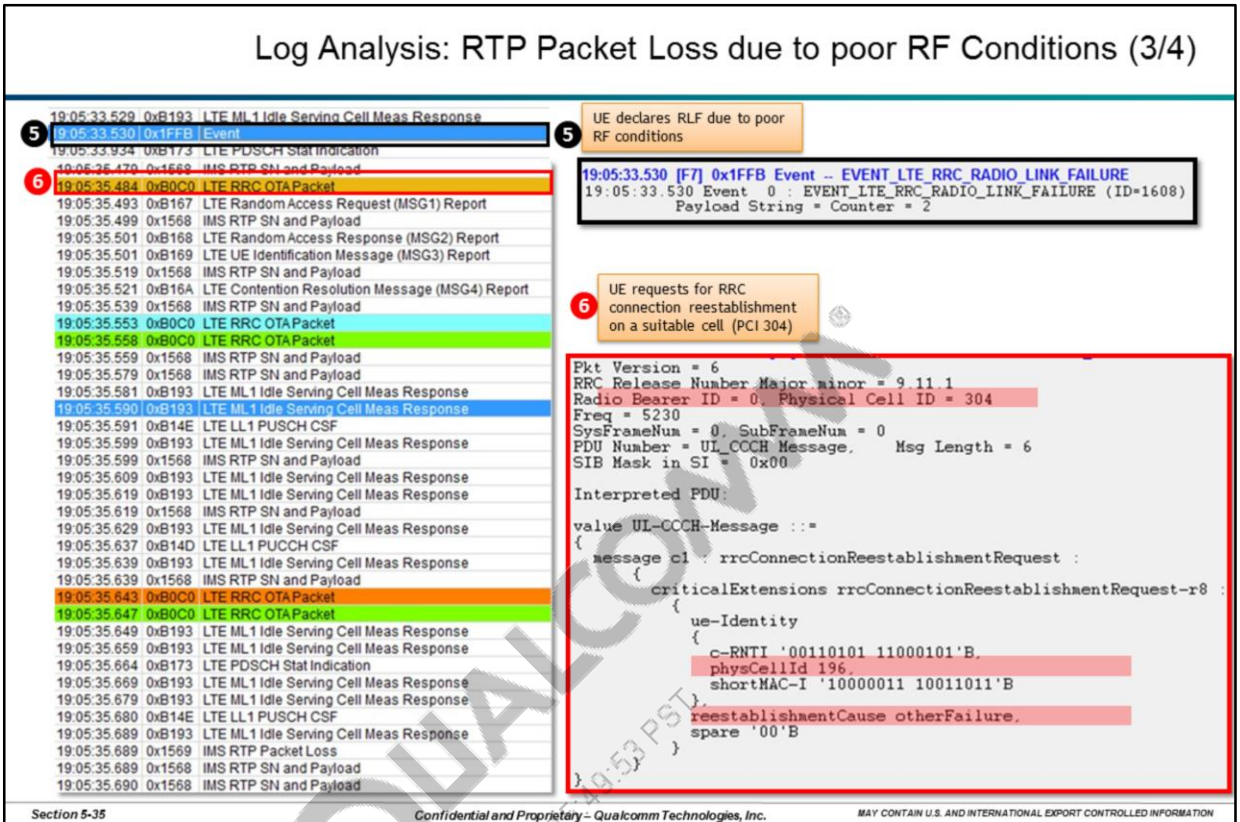


Step 3:

Identify CQI reported by UE just after the last successful DL RTP packet transfer. Use 0xB14D “LTE LL1 PUCCH CSF” log packet for this information. Wideband CQI for CW0 = 1 in this example for LTE SFN = 601, which is representative of poor DL RF conditions as seen in Step 2.

Step 4:

Determine BLER from HARQ NACK rate. Use 0xB173 “LTE PDSCH Stat Indication” log packet for this information. For the SFN’s around 601, we see single layer transmission and MCS=0. This shows the eNB is using the most robust MCS possible for this UE. Still we see high HARQ NACK rate which is expected in poor RF conditions as seen in step 2. It is expected that we will encounter RTP packet loss due to high BLER / HARQ NACK rate.

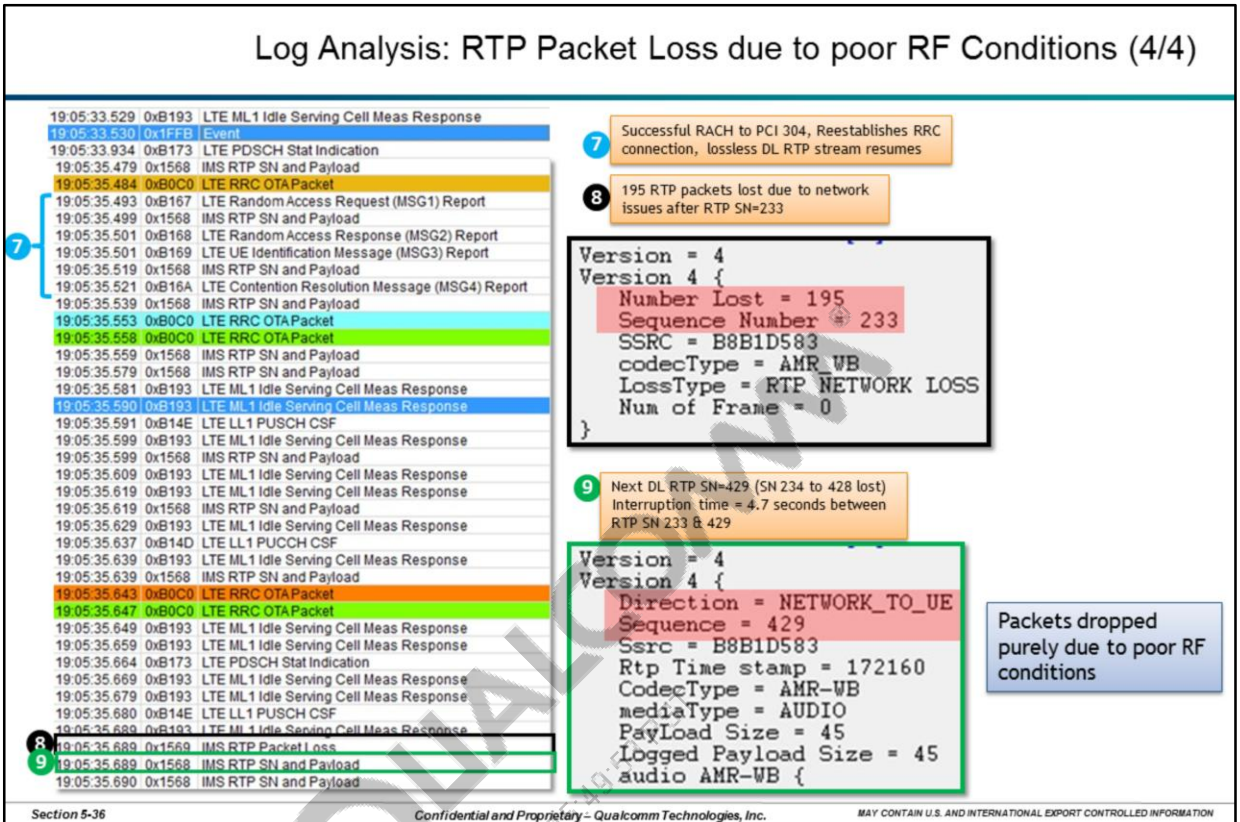


Step 5:

UE declares Radio Link Failure due to poor RF conditions. Use 0x1FFB "Event" event for this information.

Step 6:

UE requests for RRC connection reestablishment on a suitable cell following RLF (PCI 304 in this example). Use 0xB0C0 "LTE RRC OTA Packet" log packet for this request message



Step 7:

UE successfully RACHes to PCI 304 and reestablishes RRC connection.

Step 8:

Lossless DL RTP packet stream resumes. Use 0x1569 “IMS RTP Packet Loss” log packet to determine number of RTP packets lost and the last successfully received RTP packet. 195 packets lost in this example since SN 233

Step 9:

Use 0x1568 “IMS RTP SN and Payload” log packet to read the 196th RTP packet after SN 233 (SN 429) is successfully received

Analysis Example – RTP Packet Loss due to poor RF Conditions

Log Analysis Procedure: RTP Packet Loss due to poor RF conditions

Open File: 05-02_RTP_Loss_Poor_RF

Notes

RTP Packet Loss due to poor RF: Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	IMS RTP SN and Payload	0x1568	19:05:30.990 Through 19:05:31.040	RTP stream from network to UE
2	IMS RTP SN and Payload	0x1568	19:05:31.01	Last DL RTP packet before packet drops. `Sequence = 233`
3	LTE ML1 Idle LTE Serving Cell Meas Response	0xB193	19:05:31.071	Find closest log packet to determine LTE SFN and its RF conditions **SFN = 601, PCI=196, RSRP=-115dBm, RSRQ=-23dB, SINR=-11dB**
4	LTE ML1 Connected Mode LTE Intra-Freq Meas Results	0xB14D	19:05:31.093	Find closest log packet to determine CQI reported by UE for SFN closest to 601 **CQI = 1**
5	LTE PDSCH Stat Indication	0xB173	19:05:31.213	Find closest LTE PDSCH Stat summary to determine HARQ ACK/NACK rate for SFN's around 601
6	IMS RTP Packet Loss	0x1569	19:05:35.689	`Number Lost = 195` Due to Network issues since RTP SN = 233
7	IMS RTP SN and Payload	0x1568	19:05:35.689	First DL RTP packet received after 4.7 seconds. `Sequence = 429`

Notes

Summary: Debugging Scenarios in This Section

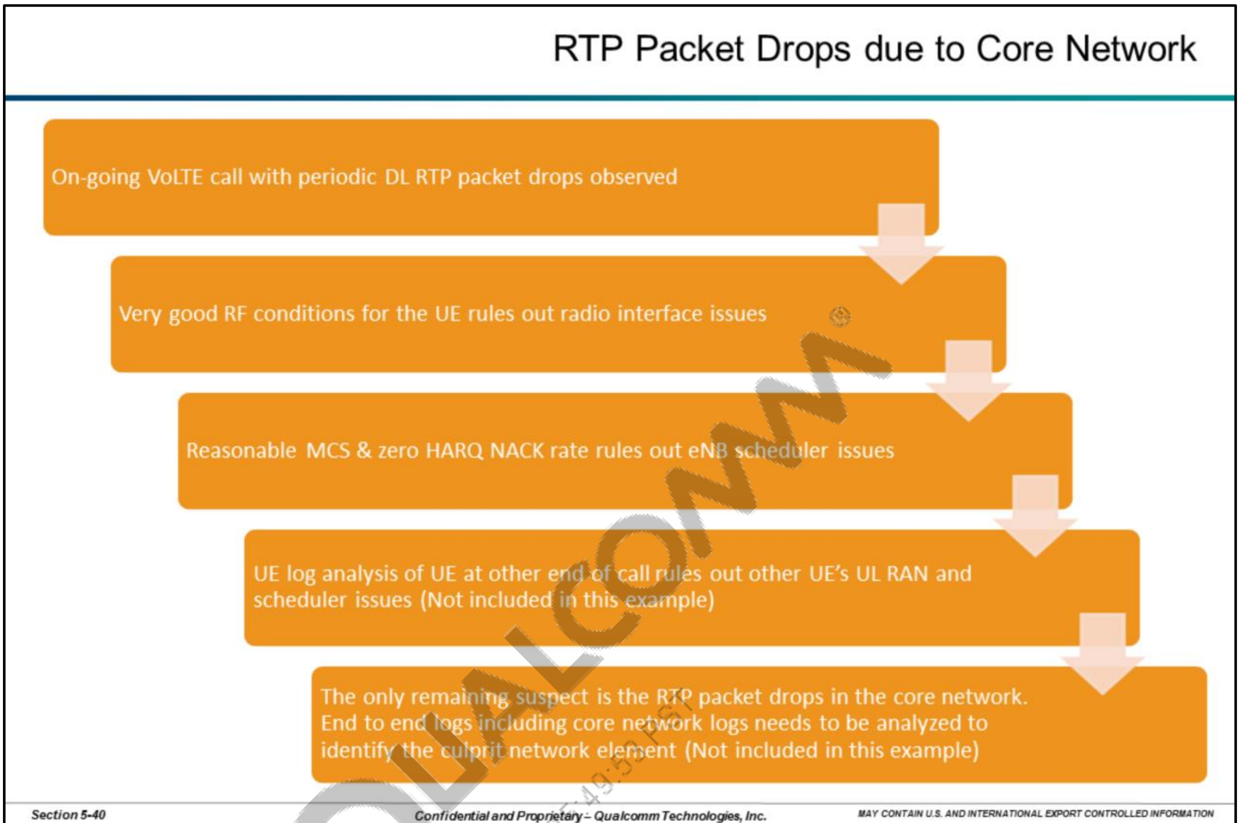
Case Study-1 (RTP Loss due to Radio Link Failure)

Case Study-2 (RTP packet drop due to poor RF conditions)

Case Study-3 (RTP packet drop due to Core Network Issues)

Case Study-4 (RF Impact on MOS scores / voice quality)

Notes


RTP Packet Drops due to Core Network
On-going VoLTE call with periodic DL RTP packet drops observed
Very good RF conditions for the UE rules out radio interface issues
Reasonable MCS & zero HARQ NACK rate rules out eNB scheduler issues
UE log analysis of UE at other end of call rules out other UE's UL RAN and scheduler issues (Not included in this example)
The only remaining suspect is the RTP packet drops in the core network. End to end logs including core network logs needs to be analyzed to identify the culprit network element (Not included in this example)
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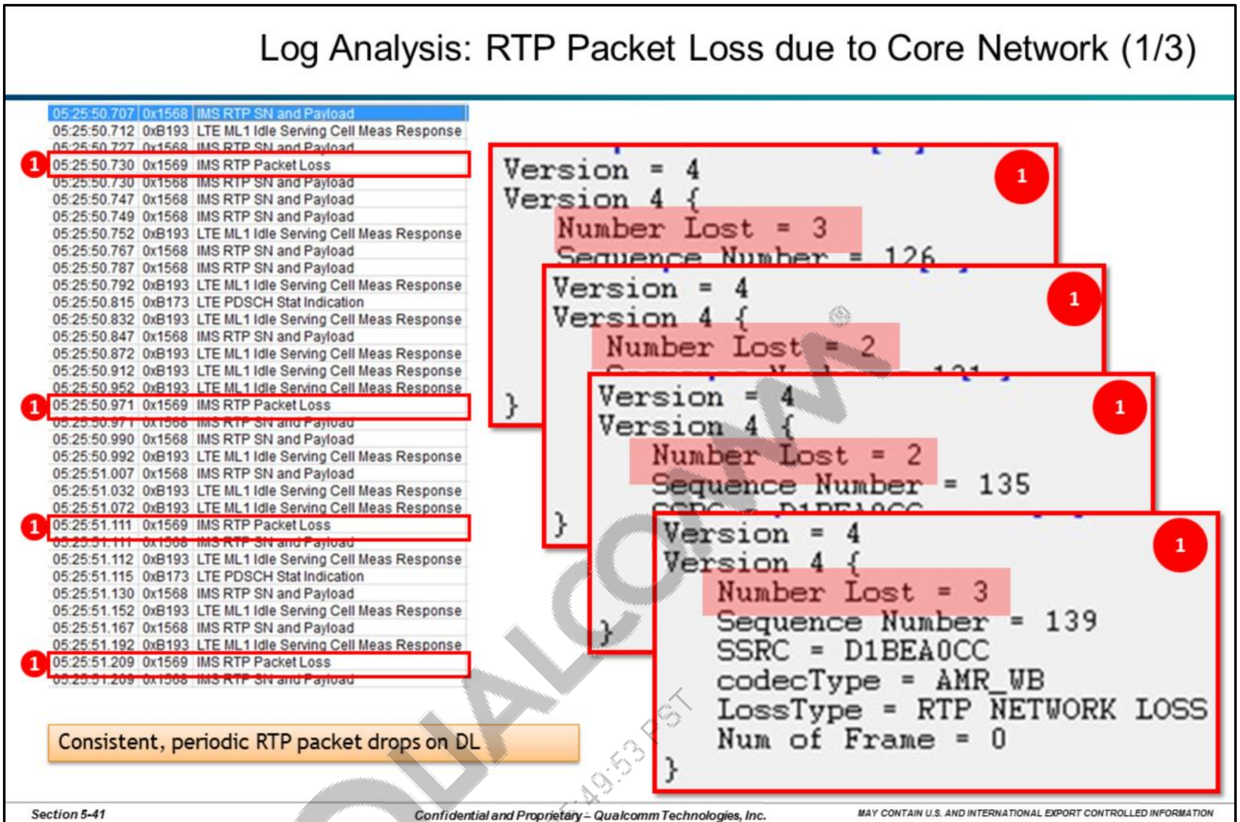
Notes



Step 1:

Identify consistent, periodic RTP packet drops. The absolute number of packet drops may not be high, but they occur frequently. May impact call quality. Use 0x1568 “IMS RTP SN and Payload” log packet for this information

Step 2:

First suspect is RF conditions. Identify RF conditions around dropped packets. Use 0xB193 “LTE ML1 Idle Serving Cell Meas Response” log packet for this information. Even though the log packet name suggests that is Idle, it is reported in connected mode also as seen in this example. Very good RSRP, RSRQ and SINR detected everywhere. So RF conditions can be ruled out.

Step 3:

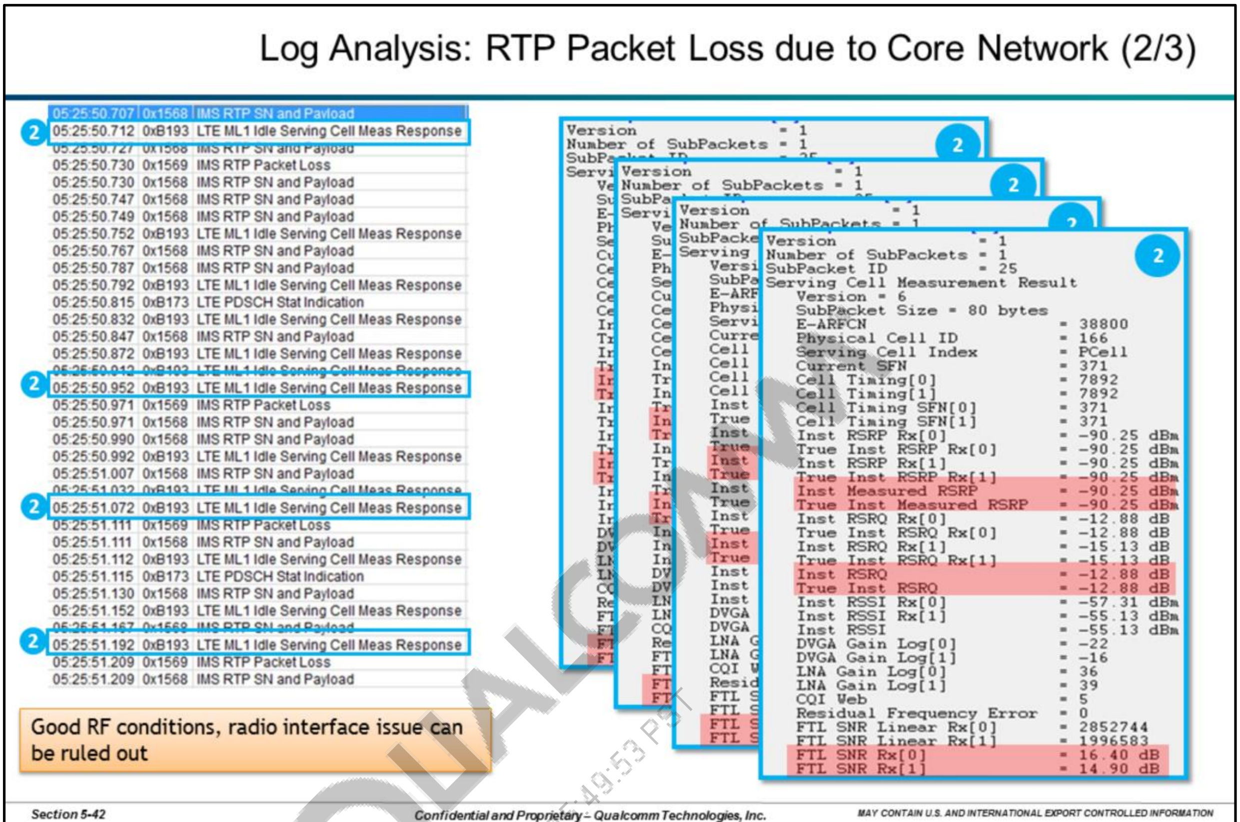
Next suspect is unusual behavior of eNB scheduler resulting in high BLER or HARQ NACK rate. Use 0xB173 “LTE PDSCH Stat Indication” log packet for this information. In this example, we see high MCS and practically 0 HARQ NACK rate which is expected from good RF conditions.

Step 4:

Next suspect is poor UL RF conditions of UE at the other end of the call resulting in RTP packets getting dropped at the other UE’s UL air interface. The other UE’s log is not shown in this example, but this case has been ruled out for this example.

Step 5:

The next step is to investigate core network packet drops using end to end logs.



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First suspect is RF conditions. Identify RF conditions around dropped packets. Use 0xB193 “LTE ML1 Idle Serving Cell Meas Response” log packet for this information. Even though the log packet name suggests that is Idle, it is reported in connected mode also as seen in this example. Very good RSRP, RSRQ and SINR detected everywhere. So RF conditions can be ruled out.

Step 3:

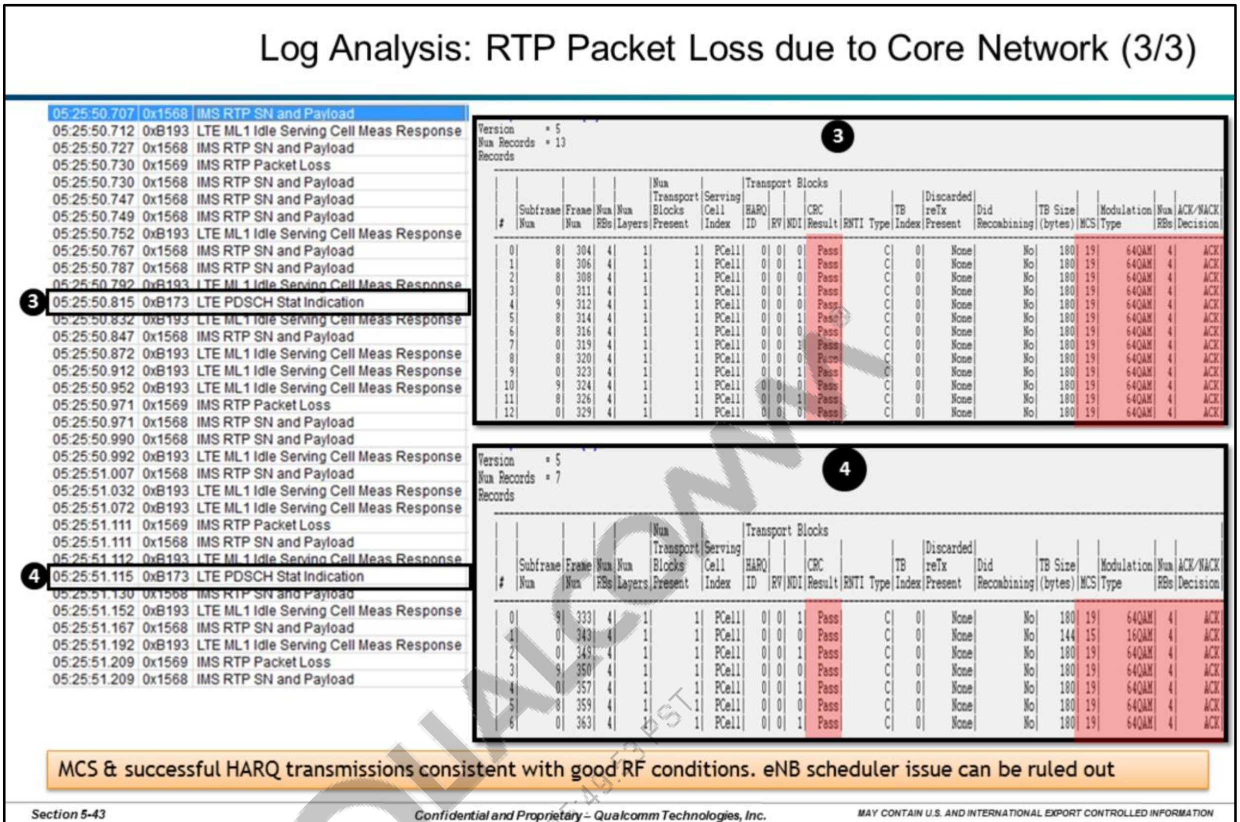
Next suspect is unusual behavior of eNB scheduler resulting in high BLER or HARQ NACK rate. Use 0xB173 “LTE PDSCH Stat Indication” log packet for this information. In this example, we see high MCS and practically 0 HARQ NACK rate which is expected from good RF conditions.

Step 4:

Next suspect is poor UL RF conditions of UE at the other end of the call resulting in RTP packets getting dropped at the other UE’s UL air interface. The other UE’s log is not shown in this example, but this case has been ruled out for this example.

Step 5:

The next step is to investigate core network packet drops using end to end logs.



Step 1:

Identify consistent, periodic RTP packet drops. The absolute number of packet drops may not be high, but they occur frequently. May impact call quality. Use 0x1568 "IMS RTP SN and Payload" log packet for this information

Step 2:

First suspect is RF conditions. Identify RF conditions around dropped packets. Use 0xB193 "LTE ML1 Idle Serving Cell Meas Response" log packet for this information. Even though the log packet name suggests that is Idle, it is reported in connected mode also as seen in this example. Very good RSRP, RSRQ and SINR detected everywhere. So RF conditions can be ruled out.

Step 3:

Next suspect is unusual behavior of eNB scheduler resulting in high BLER or HARQ NACK rate. Use 0xB173 "LTE PDSCH Stat Indication" log packet for this information. In this example, we see high MCS and practically 0 HARQ NACK rate which is expected from good RF conditions.

Step 4:

Next suspect is poor UL RF conditions of UE at the other end of the call resulting in RTP packets getting dropped at the other UE's UL air interface. The other UE's log is not shown in this example, but this case has been ruled out for this example.

Step 5:

The next step is to investigate core network packet drops using end to end logs.

Analysis Example – RTP Packet Loss due to Core Network

Log Analysis Procedure: RTP Packet Loss due to Core Network

Open File: 05-03_RTP_Loss_Core_Network

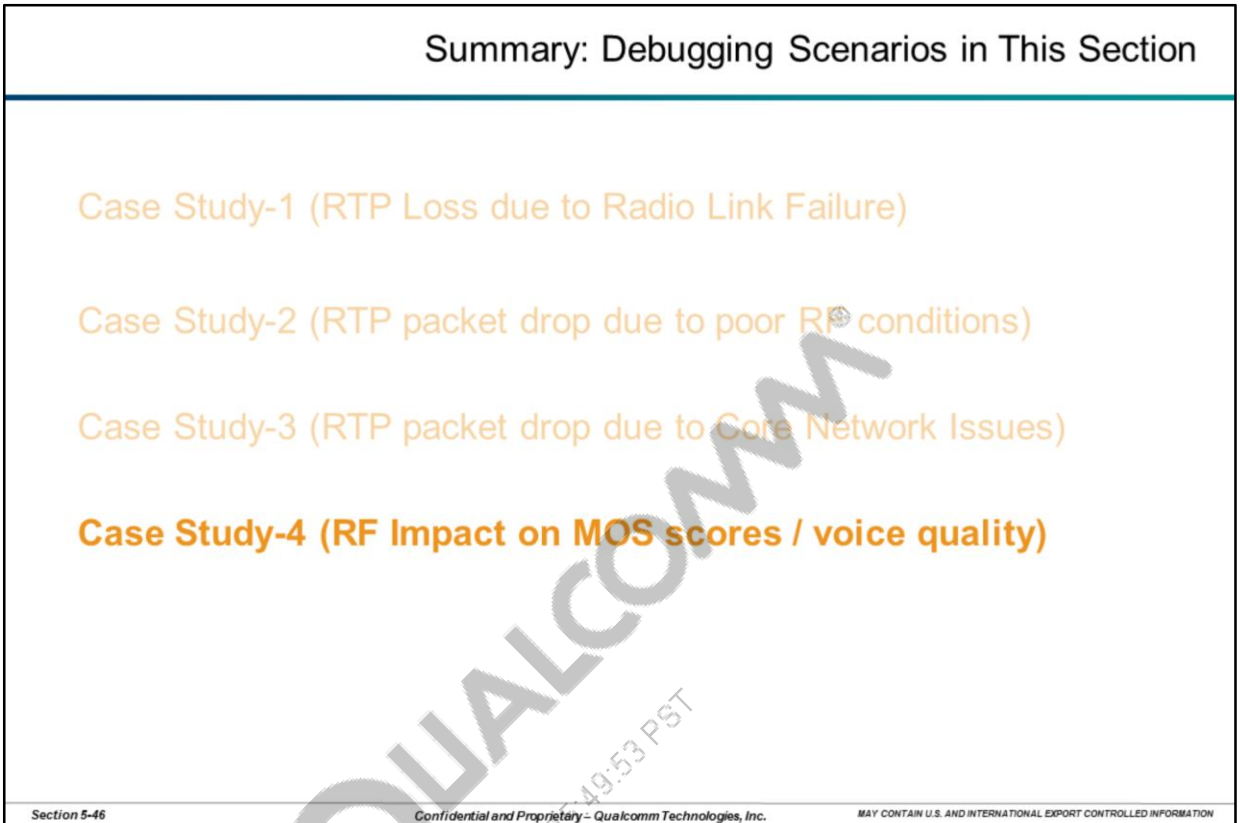
Notes

RTP Packet Loss due to Core Network: Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	IMS RTP Packet Loss	0x1569	05:25:48.010 Through 05:25:52.489	Periodic RTP packet drops from network to UE
2	LTE ML1 Idle LTE Serving Cell Meas Response	0xB193	05:25:50.712 through 05:25:52.472	Find closest log packet to determine RF conditions. **Very good RSRP, RSRQ & SINR. RAN issue ruled out**
3	LTE PDSCH Stat Indication	0xB173	05:25:50.815 through 05:25:52.315	Find closest LTE PDSCH Stat summary to determine HARQ ACK/NACK rate. **Practically zero HARQ NACK rate. Scheduler issue ruled out**
4	Analyze logs for UE at other end of the call to rule out the other UE's UL RF challenges. RTP packets can be dropped at the other UE's air interface also.			
5	Investigate core network issues. Analyze end to end logs and traces, including all involved core network elements.			

Steps 4 & 5 are not included in this example, but are important to identify the culprit network element

Notes


Summary: Debugging Scenarios in This Section
Case Study-1 (RTP Loss due to Radio Link Failure)
Case Study-2 (RTP packet drop due to poor RF conditions)
Case Study-3 (RTP packet drop due to Core Network Issues)
Case Study-4 (RF Impact on MOS scores / voice quality)
Section 5-46
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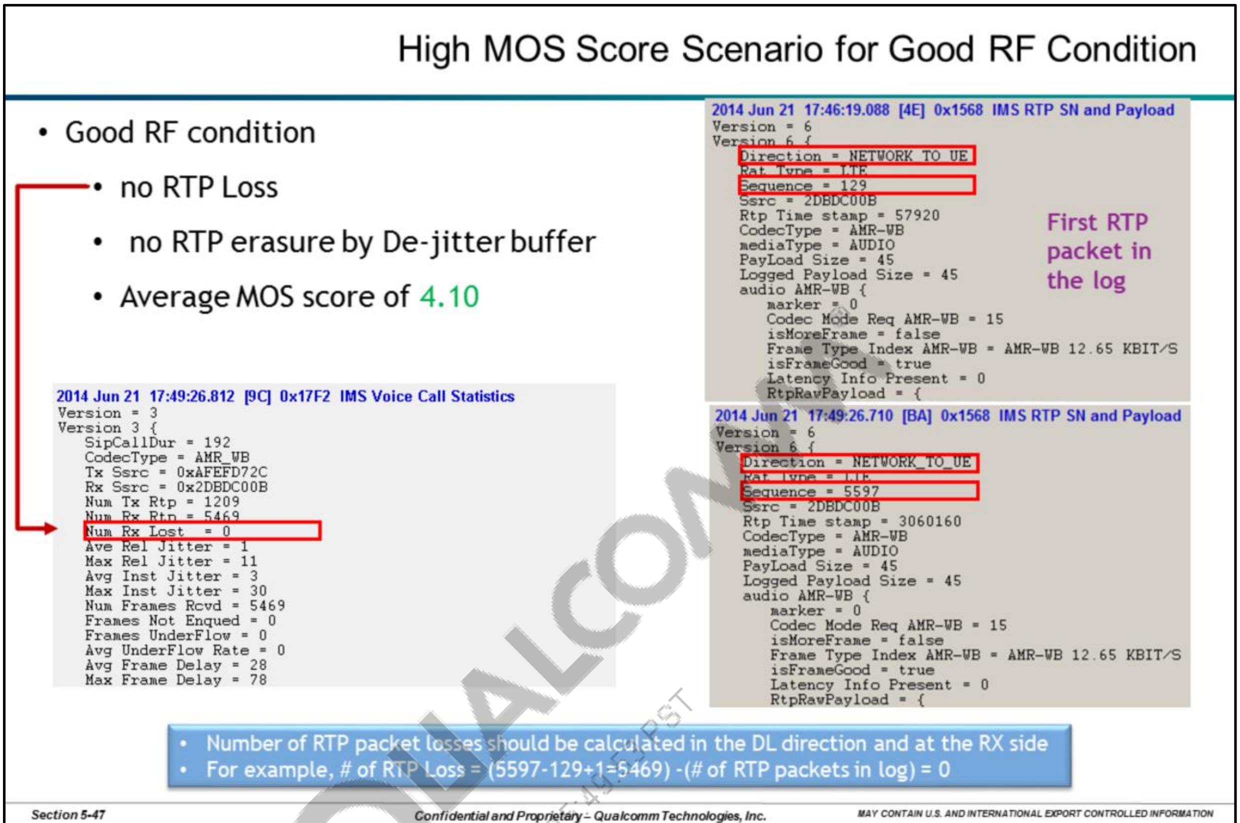
Notes


High MOS Score Scenario for Good RF Condition
• Good RF condition
• no RTP Loss
• no RTP erasure by De-jitter buffer
• Average MOS score of 4.10
2014 Jun 21 17:46:19.088 [4E] 0x1568 IMS RTP SN and Payload
Version = 6
Version 6 {
Direction = NETWORK_TO_UE
Rat Type = LTE
Sequence = 129
Ssrc = 2DBDC00B
Rtp Time stamp = 57920
CodecType = AMR-WB
mediaType = AUDIO
PayLoad Size = 45
Logged Payload Size = 45
audio AMR-WB {
marker = 0
Codec Mode Req AMR-WB = 15
isMoreFrame = false
Frame Type Index AMR-WB = AMR-WB 12.65 KBIT/S
isFrameGood = true
Latency Info Present = 0
RtpRawPayload = {
First RTP packet in the log
2014 Jun 21 17:49:26.812 [9C] 0x17F2 IMS Voice Call Statistics
Version = 3
Version 3 {
SipCallDur = 192
CodecType = AMR_WB
Tx Ssrc = 0xAFEFD72C
Rx Ssrc = 0x2DBDC00B
Num Tx Rtp = 1209
Num Rx Rtp = 5469
Num Rx Lost = 0
Ave Rel Jitter = 1
Max Rel Jitter = 11
Avg Inst Jitter = 3
Max Inst Jitter = 30
Num Frames Rcvd = 5469
Frames Not Enqued = 0
Frames UnderFlow = 0
Avg UnderFlow Rate = 0
Avg Frame Delay = 28
Max Frame Delay = 78
2014 Jun 21 17:49:26.710 [BA] 0x1568 IMS RTP SN and Payload
Version = 6
Version 6 {
Direction = NETWORK_TO_UE
Rat Type = LTE
Sequence = 5597
Ssrc = 2DBDC00B
Rtp Time stamp = 3060160
CodecType = AMR-WB
mediaType = AUDIO
PayLoad Size = 45
Logged Payload Size = 45
audio AMR-WB {
marker = 0
Codec Mode Req AMR-WB = 15
isMoreFrame = false
Frame Type Index AMR-WB = AMR-WB 12.65 KBIT/S
isFrameGood = true
Latency Info Present = 0
RtpRawPayload = {
• Number of RTP packet losses should be calculated in the DL direction and at the RX side
• For example, # of RTP Loss = (5597-129+1=5469) -(# of RTP packets in log) = 0
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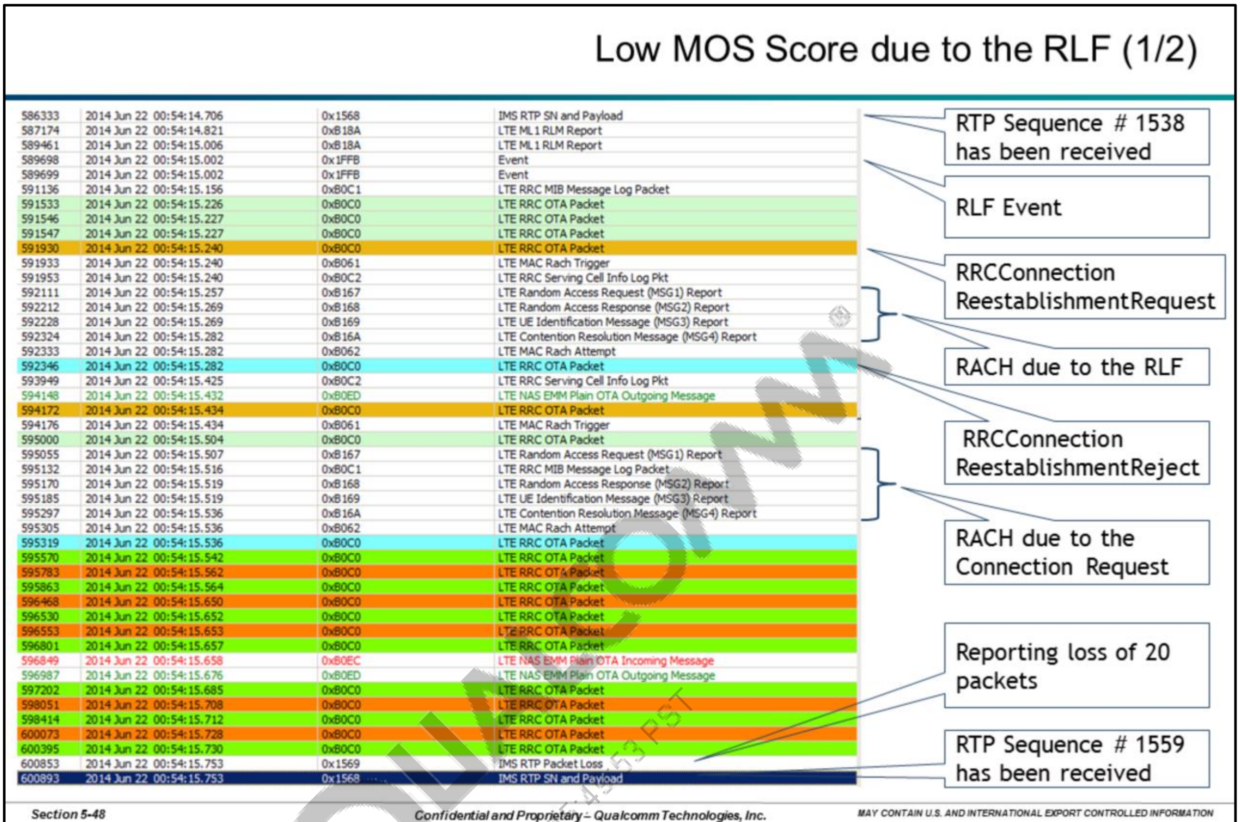
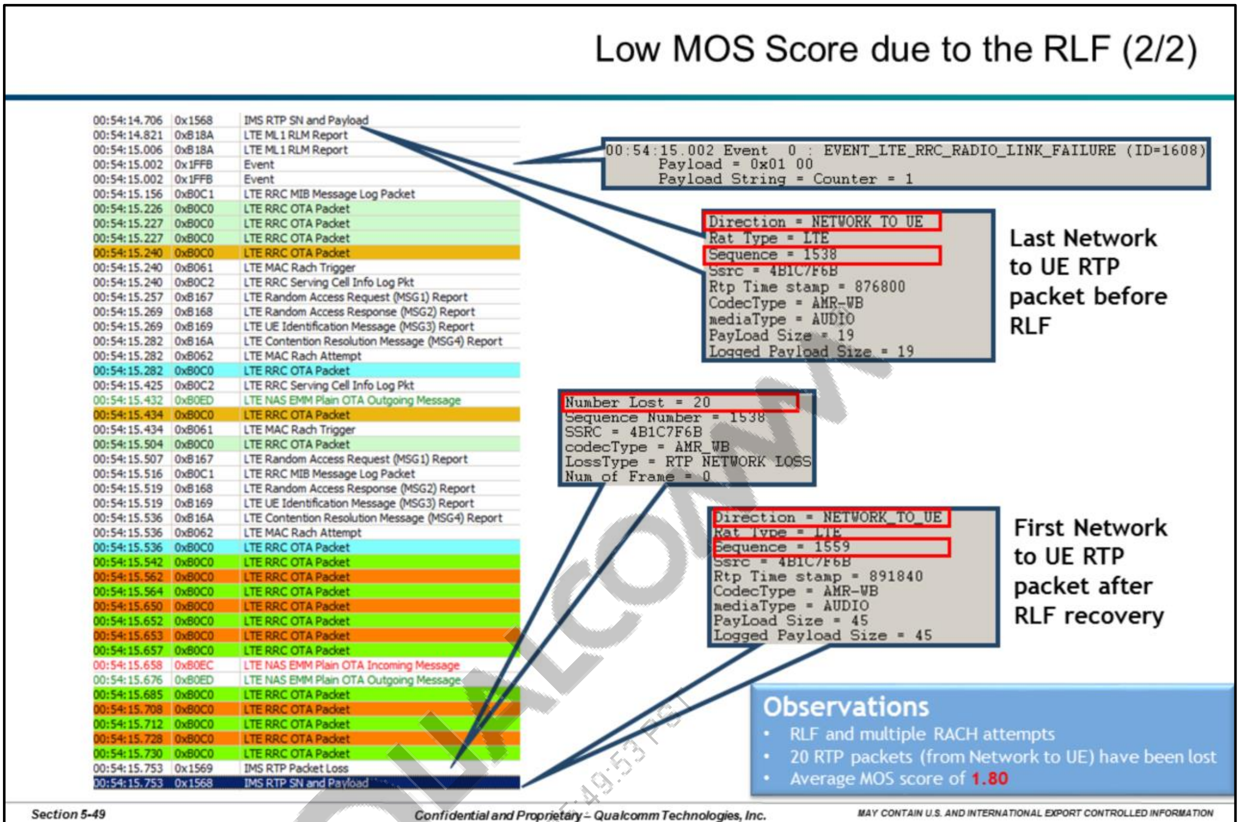
Notes



Low MOS Score due to the RLF (1/2)

586333	2014 Jun 22 00:54:14.706	0x1568	IMS RTP SN and Payload
587174	2014 Jun 22 00:54:14.821	0xB18A	LTE ML1 RLM Report
589461	2014 Jun 22 00:54:15.006	0xB18A	LTE ML1 RLM Report
589698	2014 Jun 22 00:54:15.002	0x1FFB	Event
589699	2014 Jun 22 00:54:15.002	0x1FFB	Event
591136	2014 Jun 22 00:54:15.156	0xB0C1	LTE RRC MIB Message Log Packet
591533	2014 Jun 22 00:54:15.226	0xB0C0	LTE RRC OTA Packet
591546	2014 Jun 22 00:54:15.227	0xB0C0	LTE RRC OTA Packet
591547	2014 Jun 22 00:54:15.227	0xB0C0	LTE RRC OTA Packet
591930	2014 Jun 22 00:54:15.240	0xB0C0	LTE RRC OTA Packet
591933	2014 Jun 22 00:54:15.240	0xB061	LTE MAC Rach Trigger
591953	2014 Jun 22 00:54:15.240	0xB0C2	LTE RRC Serving Cell Info Log Pkt
592111	2014 Jun 22 00:54:15.257	0xB167	LTE Random Access Request (MSG1) Report
592212	2014 Jun 22 00:54:15.269	0xB168	LTE Random Access Response (MSG2) Report
592228	2014 Jun 22 00:54:15.269	0xB169	LTE UE Identification Message (MSG3) Report
592324	2014 Jun 22 00:54:15.282	0xB16A	LTE Contention Resolution Message (MSG4) Report
592333	2014 Jun 22 00:54:15.282	0xB062	LTE MAC Rach Attempt
592346	2014 Jun 22 00:54:15.282	0xB0C0	LTE RRC OTA Packet
593949	2014 Jun 22 00:54:15.425	0xB0C2	LTE RRC Serving Cell Info Log Pkt
594148	2014 Jun 22 00:54:15.432	0xB0ED	LTE NAS EMM Plain OTA Outgoing Message
594172	2014 Jun 22 00:54:15.434	0xB0C0	LTE RRC OTA Packet
594176	2014 Jun 22 00:54:15.434	0xB061	LTE MAC Rach Trigger
595000	2014 Jun 22 00:54:15.504	0xB0C0	LTE RRC OTA Packet
595055	2014 Jun 22 00:54:15.507	0xB167	LTE Random Access Request (MSG1) Report
595132	2014 Jun 22 00:54:15.516	0xB0C1	LTE RRC MIB Message Log Packet
595170	2014 Jun 22 00:54:15.519	0xB168	LTE Random Access Response (MSG2) Report
595185	2014 Jun 22 00:54:15.519	0xB169	LTE UE Identification Message (MSG3) Report
595297	2014 Jun 22 00:54:15.536	0xB16A	LTE Contention Resolution Message (MSG4) Report
595305	2014 Jun 22 00:54:15.536	0xB062	LTE MAC Rach Attempt
595319	2014 Jun 22 00:54:15.536	0xB0C0	LTE RRC OTA Packet
595570	2014 Jun 22 00:54:15.542	0xB0C0	LTE RRC OTA Packet
595783	2014 Jun 22 00:54:15.562	0xB0C0	LTE RRC OTA Packet
595863	2014 Jun 22 00:54:15.564	0xB0C0	LTE RRC OTA Packet
596468	2014 Jun 22 00:54:15.650	0xB0C0	LTE RRC OTA Packet
596530	2014 Jun 22 00:54:15.652	0xB0C0	LTE RRC OTA Packet
596553	2014 Jun 22 00:54:15.653	0xB0C0	LTE RRC OTA Packet
596801	2014 Jun 22 00:54:15.657	0xB0C0	LTE RRC OTA Packet
596849	2014 Jun 22 00:54:15.658	0xB0EC	LTE NAS EMM Plain OTA Incoming Message
596987	2014 Jun 22 00:54:15.676	0xB0ED	LTE NAS EMM Plain OTA Outgoing Message
597202	2014 Jun 22 00:54:15.685	0xB0C0	LTE RRC OTA Packet
598051	2014 Jun 22 00:54:15.708	0xB0C0	LTE RRC OTA Packet
598414	2014 Jun 22 00:54:15.712	0xB0C0	LTE RRC OTA Packet
600073	2014 Jun 22 00:54:15.728	0xB0C0	LTE RRC OTA Packet
600395	2014 Jun 22 00:54:15.730	0xB0C0	LTE RRC OTA Packet
600853	2014 Jun 22 00:54:15.753	0x1569	IMS RTP Packet Loss
600893	2014 Jun 22 00:54:15.753	0x1568	IMS RTP SN and Payload

Notes


Low MOS Score due to the RLF (2/2)
00:54:14.706 0x1568 IMS RTP SN and Payload
00:54:14.821 0xB18A LTE ML1 RLM Report
00:54:15.006 0xB18A LTE ML1 RLM Report
00:54:15.002 0x1FFB Event
00:54:15.002 0x1FFB Event
00:54:15.156 0xB0C1 LTE RRC MIB Message Log Packet
00:54:15.226 0xB0C0 LTE RRC OTA Packet
00:54:15.227 0xB0C0 LTE RRC OTA Packet
00:54:15.227 0xB0C0 LTE RRC OTA Packet
00:54:15.240 0xB0C0 LTE RRC OTA Packet
00:54:15.240 0xB061 LTE MAC Rach Trigger
00:54:15.240 0xB0C2 LTE RRC Serving Cell Info Log Pkt
00:54:15.257 0xB167 LTE Random Access Request (MSG1) Report
00:54:15.269 0xB168 LTE Random Access Response (MSG2) Report
00:54:15.269 0xB169 LTE UE Identification Message (MSG3) Report
00:54:15.282 0xB16A LTE Contention Resolution Message (MSG4) Report
00:54:15.282 0xB062 LTE MAC Rach Attempt
00:54:15.282 0xB0C0 LTE RRC OTA Packet
00:54:15.425 0xB0C2 LTE RRC Serving Cell Info Log Pkt
00:54:15.432 0xB0ED LTE NAS EMM Plain OTA Outgoing Message
00:54:15.434 0xB0C0 LTE RRC OTA Packet
00:54:15.434 0xB061 LTE MAC Rach Trigger
00:54:15.504 0xB0C0 LTE RRC OTA Packet
00:54:15.507 0xB167 LTE Random Access Request (MSG1) Report
00:54:15.516 0xB0C1 LTE RRC MIB Message Log Packet
00:54:15.519 0xB168 LTE Random Access Response (MSG2) Report
00:54:15.519 0xB169 LTE UE Identification Message (MSG3) Report
00:54:15.536 0xB16A LTE Contention Resolution Message (MSG4) Report
00:54:15.536 0xB062 LTE MAC Rach Attempt
00:54:15.536 0xB0C0 LTE RRC OTA Packet
00:54:15.542 0xB0C0 LTE RRC OTA Packet
00:54:15.562 0xB0C0 LTE RRC OTA Packet
00:54:15.564 0xB0C0 LTE RRC OTA Packet
00:54:15.650 0xB0C0 LTE RRC OTA Packet
00:54:15.652 0xB0C0 LTE RRC OTA Packet
00:54:15.653 0xB0C0 LTE RRC OTA Packet
00:54:15.657 0xB0C0 LTE RRC OTA Packet
00:54:15.658 0xB0EC LTE NAS EMM Plain OTA Incoming Message
00:54:15.676 0xB0ED LTE NAS EMM Plain OTA Outgoing Message
00:54:15.685 0xB0C0 LTE RRC OTA Packet
00:54:15.708 0xB0C0 LTE RRC OTA Packet
00:54:15.712 0xB0C0 LTE RRC OTA Packet
00:54:15.728 0xB0C0 LTE RRC OTA Packet
00:54:15.730 0xB0C0 LTE RRC OTA Packet
00:54:15.753 0x1569 IMS RTP Packet Loss
00:54:15.753 0x1568 IMS RTP SN and Payload
00:54:15.002 Event 0 : EVENT_LTE_RRC_RADIO_LINK_FAILURE (ID=1608)
Payload = 0x01 00
Payload String = Counter = 1
Direction = NETWORK TO UE
Rat Type = LTE
Sequence = 1538
Ssrc = 4B1C7F6B
Rtp Time stamp = 876800
CodecType = AMR-WB
mediaType = AUDIO
PayLoad Size = 19
Logged Payload Size = 19
Last Network to UE RTP packet before RLF
Number Lost = 20
Sequence Number = 1538
SSRC = 4B1C7F6B
codecType = AMR_WB
LossType = RTP NETWORK LOSS
Num of Frame = 0
Direction = NETWORK_TO_UE
Rat Type = LTE
Sequence = 1559
Ssrc = 4B1C7F6B
Rtp Time stamp = 891840
CodecType = AMR-WB
mediaType = AUDIO
PayLoad Size = 45
Logged Payload Size = 45
First Network to UE RTP packet after RLF recovery
Observations
RLF and multiple RACH attempts
20 RTP packets (from Network to UE) have been lost
Average MOS score of 1.80
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Notes

Log Analysis: Low POLQA MOS Score due to the RLF

Log Analysis Procedure: Low POLQA MOS Score due to the RLF

Open File: 05-04-Low_MOS_Score_Scenario

Notes

Low POLQA MOS Score due to the RLF: Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	IMS RTP SN and Payload	0x1568	00:54:14:706	RTP message from Network to UE with Sequence Number of 1538
2	RRC Radio Link Failure	0x1FFB	00:54:15.002	RLF due to the SIB read failure is reported
5	RRC Connection Reestablishment Request	0xB0C0	00:54:15.240	Reestablishment Cause: otherFailure
6	RACH Trigger	0xB061	00:54:15.240	RACH Reason = RLF
7	RACH Procedure	0xB167 0xB168 0xB169 0xB16A	00:54:15.257 through 00:54:15.282	MSG1 through MSG4
8	RACH Attempt	0xB062	00:54:15.282	RACH result = Success
9	RRC Connection Reestablishment Reject	0xB0C0	00:54:15.282	The UE request for RRC Connection Reestablishment gets rejected by the Network.
10	RRC Connection Establishment Request	0xB0C0	00:54:15.434	The UE performs initial acquisition. establishmentCause mo-Signalling

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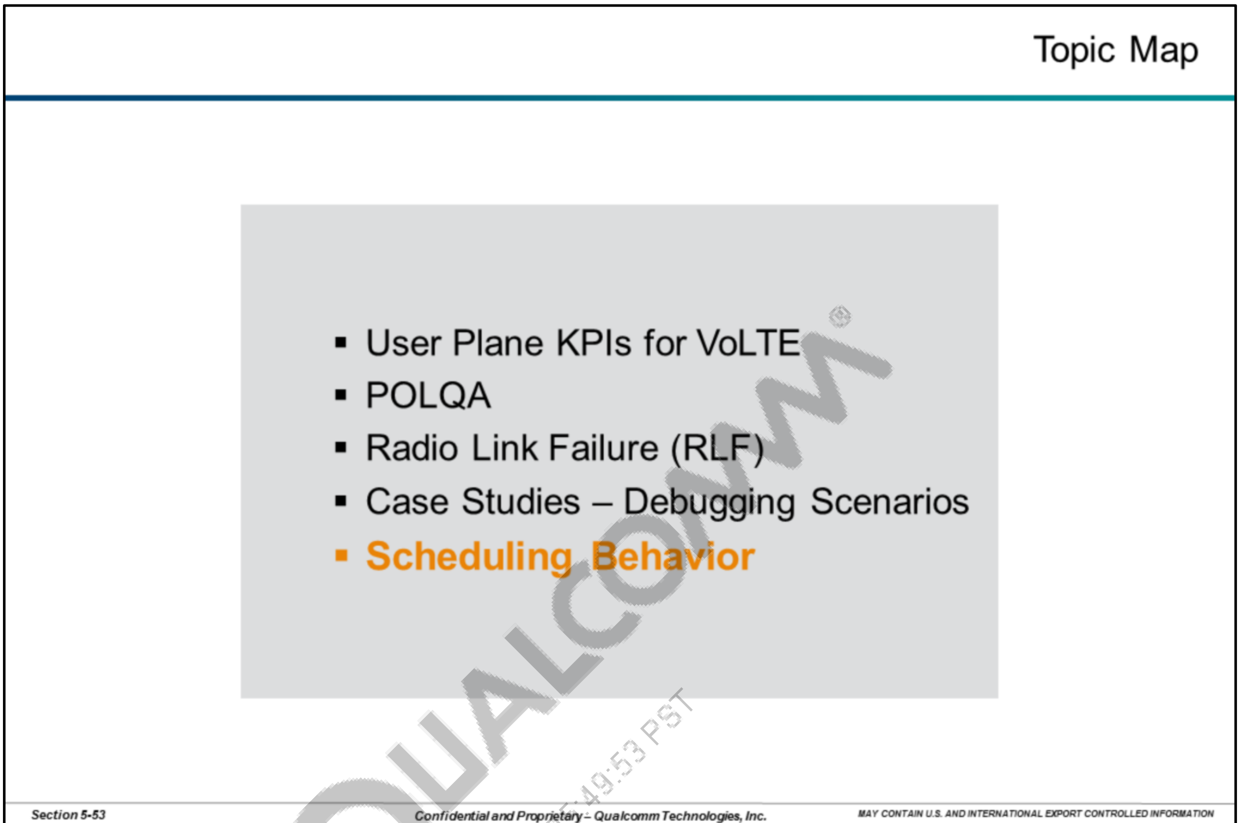
Notes

Low POLQA MOS Score due to the RLF: Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
11	RACH Trigger	0xB061	00:54:15.434	RACH reason = CONNECTION_REQ
12	RACH Procedure	0xB167 0xB168 0xB169 0xB16A	00:54:15.507 through 00:54:15.536	MSG1 through MSG4
13	RACH Attempt	0xB062	00:54:15.536	RACH result = Success
14	RRC Connection Setup	0xB0C0	00:54:15.536	The eNodeB acknowledges UE RRC Connection Request.
15	RRC Connection Setup Complete	0xB0C0	00:54:15.542	The UE sends the RRC connection Complete to eNodeB.
16	IMS RTP SN and Payload	0x1568	00:54:15.753	RTP message from Network to UE with Sequence Number of 1559

Notes


Topic Map
User Plane KPIs for VoLTE
POLQA
Radio Link Failure (RLF)
Case Studies – Debugging Scenarios
Scheduling Behavior
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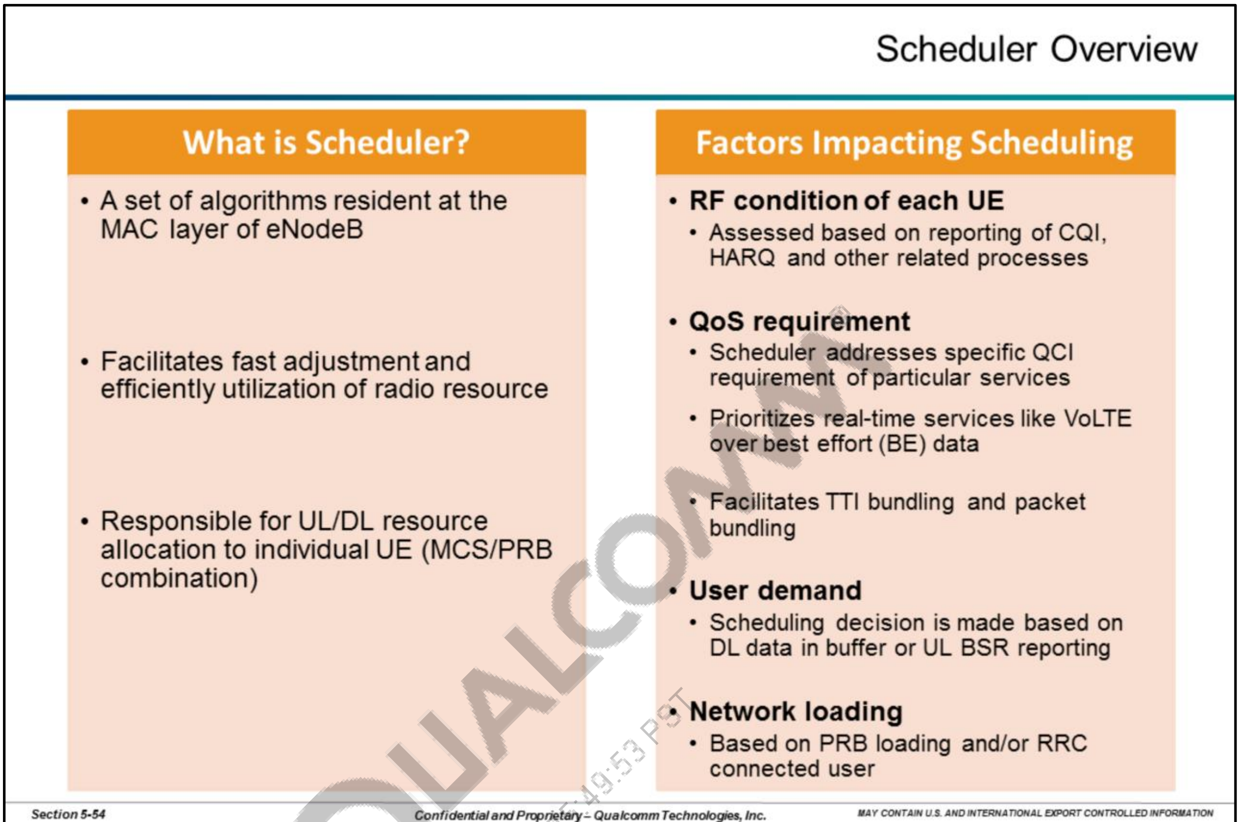
Notes



During each TTI the eNB scheduler shall:

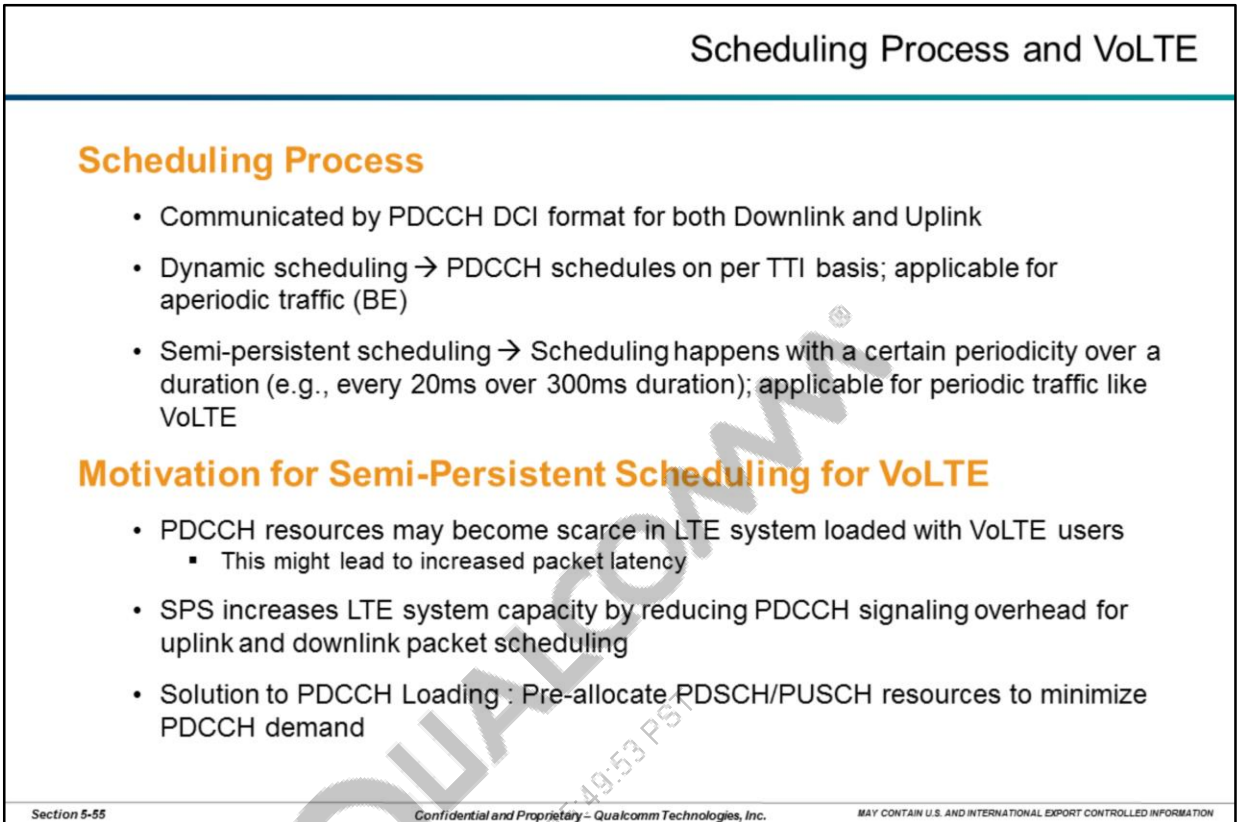
Consider the physical radio environment per UE. The UEs report their perceived radio quality, as an input to the scheduler to decide which Modulation and Coding scheme to use. The solution relies on rapid adaptation to channel variations, employing HARQ (Hybrid Automatic Repeat Request) with soft-combining and rate adaptation.

Prioritize the QoS service requirements amongst the UEs. LTE supports both delay sensitive real-time services as well as datacom services requiring high data peak rates.

Inform the UEs of allocated radio resources. The eNB schedules the UEs both on the downlink and on the uplink. For each UE scheduled in a TTI the user data will be carried in a Transport Block (TB). DL there can be a maximum of two TBs generated per TTI per UE – if spatial multiplexing is used. The TB is delivered on a transport channel. In LTE the number of channels is decreased compare to UMTS. For the user plane there is only one shared transport channel in each direction. The TB sent on the channel, can therefore contain bits from a number of services, multiplexed together.

Type of Scheduler

- **Round Robin** : UE scheduled in sequence with equal periodicity
- **Best CQI** : More resources assigned to UEs reporting higher CQI
- **Max Throughput** : Goal is to maximize cell throughput by assigning more resources to users in better RF
- **Proportional Fair** : Tries to achieves best spectral by treating UEs of same priority equally; this is the most commonly deployed scheduling algorithm
- **Resource Fair** : Maximizes sum rate of all UE while ensuring fairness and service priority



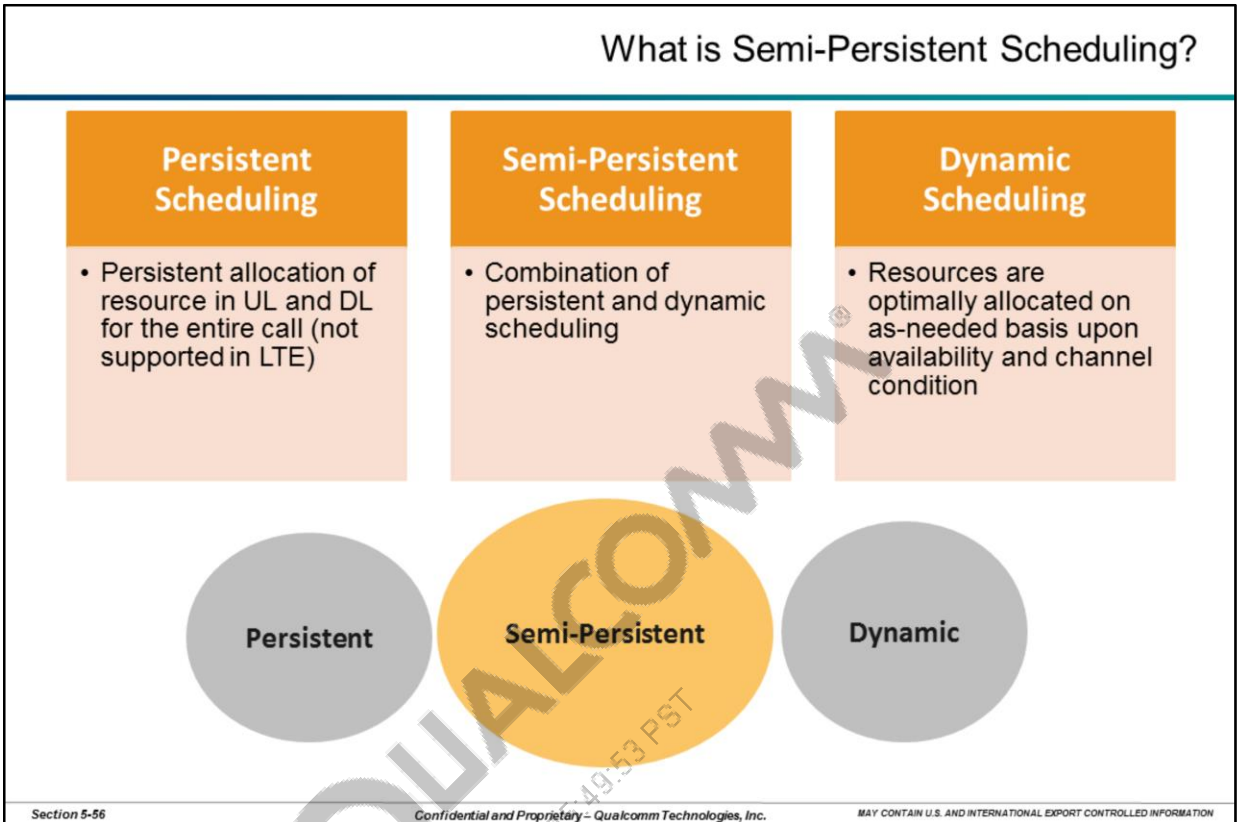
Round Robin Scheduler (RR): UEs are assigned with shared resources in sequence (one after another). Thus every UE is scheduled with equal periodicity without taking CQI into account. RR is a fair scheduling, since every UE is scheduled equally frequently. The scheduling only based on the RBs available and the RB may be grouped into several RBs for each UE packet during scheduling based on first come first serve basis.

Best CQI Scheduler (BCQI): Assigns RBs to the UE with the best radio link conditions. In order to perform scheduling, the channel quality indicator (CQI) reports are generated by the UE, but with a certain delay. These reports contain the value of the signal-to noise and interference ratio (SINR) measured by the user. A higher CQI value means better channel condition. Based on the CQI received, the best CQI is selected for scheduling.

Max. Throughput Scheduler : Scheduler performs the assignment of resources in two stages. In the first stage, each PRB group is assigned to the user who can support the highest bit rate (best CQI). In the second stage, the best MCS for each user is determined.

Proportional Fair Scheduler: A compromise between Maximum Rate and Round Robin. It pursues the maximum rate, and meanwhile ensures that none of UE is starving. The UEs are scheduled according to their service priority. Then scheduler assigns resources to the UE with highest priority.

Resource Fair Scheduler: Maximizes the sum rate of all UEs while guaranteeing fairness with respect to the number of RBs a UE gets (an equal amount of resources for all users).



Semi-Persistent Scheduling

Efficient VoIP support is a fundamental requirement for Evolved UTRA. Because there is no circuit switched domain, voice service will be supported in the packet switched domain only. Therefore, it is necessary for E-UTRA to support a large portion of voice capacity that is currently being handled by traditional circuit switched networks. To achieve this goal, packet scheduling algorithms and related resource allocation methods are destined to play a pivotal role among all the elements of system.

One of the challenges for efficient VOIP support is control signaling overhead for VoIP transmissions. The traditional full dynamic scheduling scheme could become a bottleneck and limit the system capacity. Hence the need for a different type of scheduling that requires less control signaling overhead without losing some of the flexibility of resource allocation in time and frequency domain of the dynamic scheduling.

Summary: Scheduler Behavior Debugging Scenarios

- **Case Study-1 (Excessive DL PRB allocation due to Resource Allocation Type 0 (RAT0))**
  - Example of RAT 0 inefficiency for VoLTE
  - Min 4 RB's mandatory for 20MHz BW, very inefficient for small VoLTE payload especially in good RF conditions with high MCS
- **Case Study-2 (Inefficient DL resource usage by scheduler)**
  - Example showing scheduler adding unnecessary padding bits and increasing DL PRB allocation
- **Case Study-3 (Efficient UL scheduler: no UL padding - Good Case)**
  - Example showing a desirable case on UL scheduling and how to detect it
  - No padding bits, optimum UL PRB's allocated
- **Case Study-4 (Excessive UL padding)**
  - Example showing a case where scheduler adds unnecessary UL padding bits and results in using more PRBs
  - This inefficiency can be critical on UL for cell-edge UEs that are power limited

Notes

Summary: Scheduler Behavior Case Studies

Case Study-1 (Excessive DL PRB allocation due to Resource Allocation Type 0 (RAT 0))

Case Study-2 (Inefficient DL resource usage by scheduler)

Case Study-3 (Efficient UL scheduler: no UL padding - Good Case)

Case Study-4 (Excessive UL padding)

Notes

Log Analysis: Excessive DL PRB Allocation due to Resource Allocation Type 0 (RAT0)

#	Time	Type	Description
4264	2014 Aug 13 12:58:03.644	0xB...	LTE MAC DL Transport Block
4362	2014 Aug 13 12:58:03.650	0x15...	IMS RTP SN and Payload
4377	2014 Aug 13 12:58:03.654	0xB...	LTE PDSCH Stat Indication
4508	2014 Aug 13 12:58:03.670	0x15...	IMS RTP SN and Payload
4590	2014 Aug 13 12:58:03.686	0x15...	IMS RTP SN and Payload
4675	2014 Aug 13 12:58:03.690	0x15...	IMS RTP SN and Payload
4748	2014 Aug 13 12:58:03.694	0xB...	LTE MAC DL Transport Block
4871	2014 Aug 13 12:58:03.710	0x15...	IMS RTP SN and Payload
5007	2014 Aug 13 12:58:03.730	0x15...	IMS RTP SN and Payload
5054	2014 Aug 13 12:58:03.744	0xB...	LTE MAC DL Transport Block
5151	2014 Aug 13 12:58:03.750	0x15...	IMS RTP SN and Payload
5282	2014 Aug 13 12:58:03.770	0x15...	IMS RTP SN and Payload
5409	2014 Aug 13 12:58:03.790	0x15...	IMS RTP SN and Payload
5425	2014 Aug 13 12:58:03.794	0xB...	LTE MAC DL Transport Block
5541	2014 Aug 13 12:58:03.810	0x15...	IMS RTP SN and Payload
5682	2014 Aug 13 12:58:03.830	0x15...	IMS RTP SN and Payload
5713	2014 Aug 13 12:58:03.844	0xB...	LTE MAC DL Transport Block
5764	2014 Aug 13 12:58:03.846	0x15...	IMS RTP SN and Payload
5847	2014 Aug 13 12:58:03.850	0x15...	IMS RTP SN and Payload
5981	2014 Aug 13 12:58:03.870	0x15...	IMS RTP SN and Payload
6111	2014 Aug 13 12:58:03.890	0x15...	IMS RTP SN and Payload
6125	2014 Aug 13 12:58:03.894	0xB...	LTE MAC DL Transport Block
6240	2014 Aug 13 12:58:03.910	0x15...	IMS RTP SN and Payload
6373	2014 Aug 13 12:58:03.930	0x15...	IMS RTP SN and Payload
6405	2014 Aug 13 12:58:03.944	0xB...	LTE MAC DL Transport Block
6503	2014 Aug 13 12:58:03.950	0x15...	IMS RTP SN and Payload
6519	2014 Aug 13 12:58:03.954	0xB...	LTE PDSCH Stat Indication
6634	2014 Aug 13 12:58:03.970	0x15...	IMS RTP SN and Payload
6774	2014 Aug 13 12:58:03.990	0x15...	IMS RTP SN and Payload
6788	2014 Aug 13 12:58:03.994	0xB...	LTE MAC DL Transport Block
6859	2014 Aug 13 12:58:04.006	0x15...	IMS RTP SN and Payload
6941	2014 Aug 13 12:58:04.010	0x15...	IMS RTP SN and Payload
7081	2014 Aug 13 12:58:04.030	0x15...	IMS RTP SN and Payload
7115	2014 Aug 13 12:58:04.044	0xB...	LTE MAC DL Transport Block
7211	2014 Aug 13 12:58:04.050	0x15...	IMS RTP SN and Payload
7339	2014 Aug 13 12:58:04.070	0x15...	IMS RTP SN and Payload
7467	2014 Aug 13 12:58:04.090	0x15...	IMS RTP SN and Payload
7481	2014 Aug 13 12:58:04.094	0xB...	LTE MAC DL Transport Block
7598	2014 Aug 13 12:58:04.110	0x15...	IMS RTP SN and Payload
7740	2014 Aug 13 12:58:04.130	0x15...	IMS RTP SN and Payload

SFN	Sub-FN	RNTI Type	HARQ ID	Area ID	PMCH ID	DL TBS (bytes)	RLC PDUs	EMBMS PDUs	Padding
613	8	C-RNTI	0			317	1		271
613	8	C-RNTI	0			317	1		273
615	8	C-RNTI	0			373	1		327
615	8	C-RNTI	0			373	1		329
617	8	C-RNTI	0			373	1		327
617	8	C-RNTI	0			373	1		329

Subframe Num	Frame Num	Num RBs	Num Layers	Num Transport Blocks Present	TB Size (bytes)	MCS	Modulation Type	Num RBs	ACK/NACK Decision
8	605	4	2	2	320	27	64QAM	4	ACK
					320	27	64QAM	4	ACK
8	607	4	2	2	320	27	64QAM	4	ACK
					320	27	64QAM	4	ACK
8	609	4	2	2	320	27	64QAM	4	ACK
					320	27	64QAM	4	ACK
8	611	4	2	2	320	27	64QAM	4	ACK
					320	27	64QAM	4	ACK
8	613	4	2	2	320	27	64QAM	4	ACK
					320	27	64QAM	4	ACK
8	615	4	2	2	376	28	64QAM	4	ACK
					376	28	64QAM	4	ACK
8	617	4	2	2	376	28	64QAM	4	ACK
					376	28	64QAM	4	ACK
8	619	4	2	2	376	28	64QAM	4	ACK
					376	28	64QAM	4	ACK

Observations

- Downlink scheduling happened every 20ms (14.25kbps WB codec with NO RoHC → 85Bytes / 20ms)
- Unnecessarily large PRBs allocation was due to RAT0, which assigns minimum 4 PRBs for 20MHz channel → impacts capacity

Notes

Log Analysis: Capacity Impact due to Resource Allocation Type 0 (RAT0)

SFN	Sub-FN	Actual Payload (Byte)	Padding (Byte)	Total MAC Payload (Byte)	MCS	Actual PRB Used	PRB without Padding
613	8	46 (layer-1)	271	317	27	4	1
613	8	44 (layer-2)	273	317	27	4	1
615	8	46 (layer-1)	327	373	28	4	1
615	8	44 (layer-2)	329	373	28	4	1
617	8	46 (layer-1)	327	373	28	4	1
617	8	44 (layer-2)	329	373	28	4	1
Duration : ~40ms		270 (13%)	1856 (87%)	2126 (100%)		24 (100%)	6 (25%)

Conclusion
- RAT0 required a minimum of 4 PRB allocation in the Downlink for 20MHz channel
- With very high MCS (64-QAM), this resulted in TBS size requirement of 5160 bits (MCS27) and 5992 bits (MCS28)
- Addition of 87% padding bits was to match with TBS requirement, which resulted in 75% higher occupancy of DL PRB → may significantly impact DL cell capacity under load

Recommendation
- Implement RAT1/RAT2 to eliminate minimum 4 PRB allocation restriction in the Downlink for 20MHz channel

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Capacity Impact due to RAT0

The RF condition was excellent and 2 TBs were used by the eNB.

Analysis – Excessive DL PRB Allocation due to Resource Allocation Type 0 (RAT0)

Log Analysis Procedure: Excessive DL PRB Allocation due to RAT0

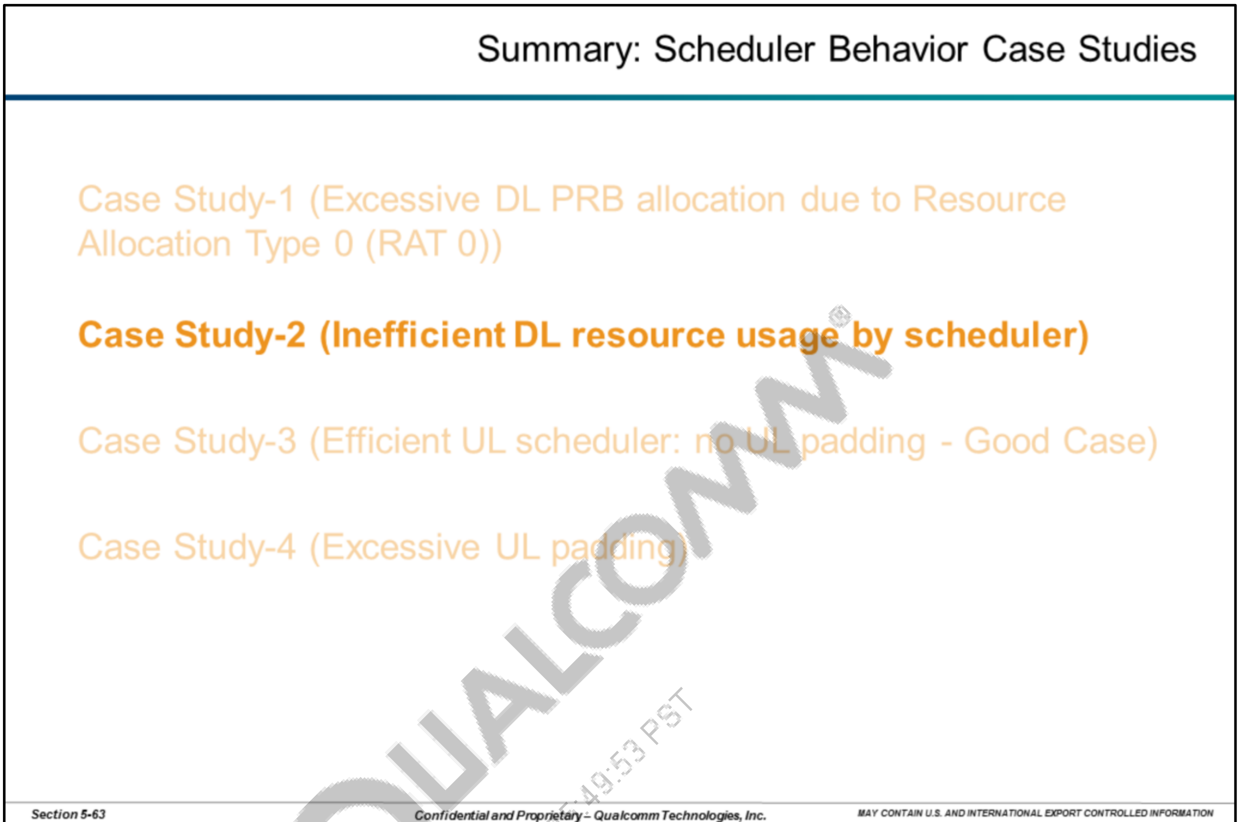
Open File: 05-05-Excessive_DL_Alloc_RAT0

Notes

Excessive DL PRB Allocation due to Resource Allocation Type 0 (RAT0): Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	IMS RTP SN & Payload	0x1568	12:58:03.790	AMR WB Codec Type 14.25kbps
2	LTE MAC DL Transport Block	0xB063	12:58:03.794	DL MAC Payload & Padding Byte
3	LTE PDSCH Stat Indication	0xB173	12:58:03.954	DL PRB and MCS allocation

Notes


Summary: Scheduler Behavior Case Studies
Case Study-1 (Excessive DL PRB allocation due to Resource Allocation Type 0 (RAT 0))
Case Study-2 (Inefficient DL resource usage by scheduler)
Case Study-3 (Efficient UL scheduler: no UL padding - Good Case)
Case Study-4 (Excessive UL padding)
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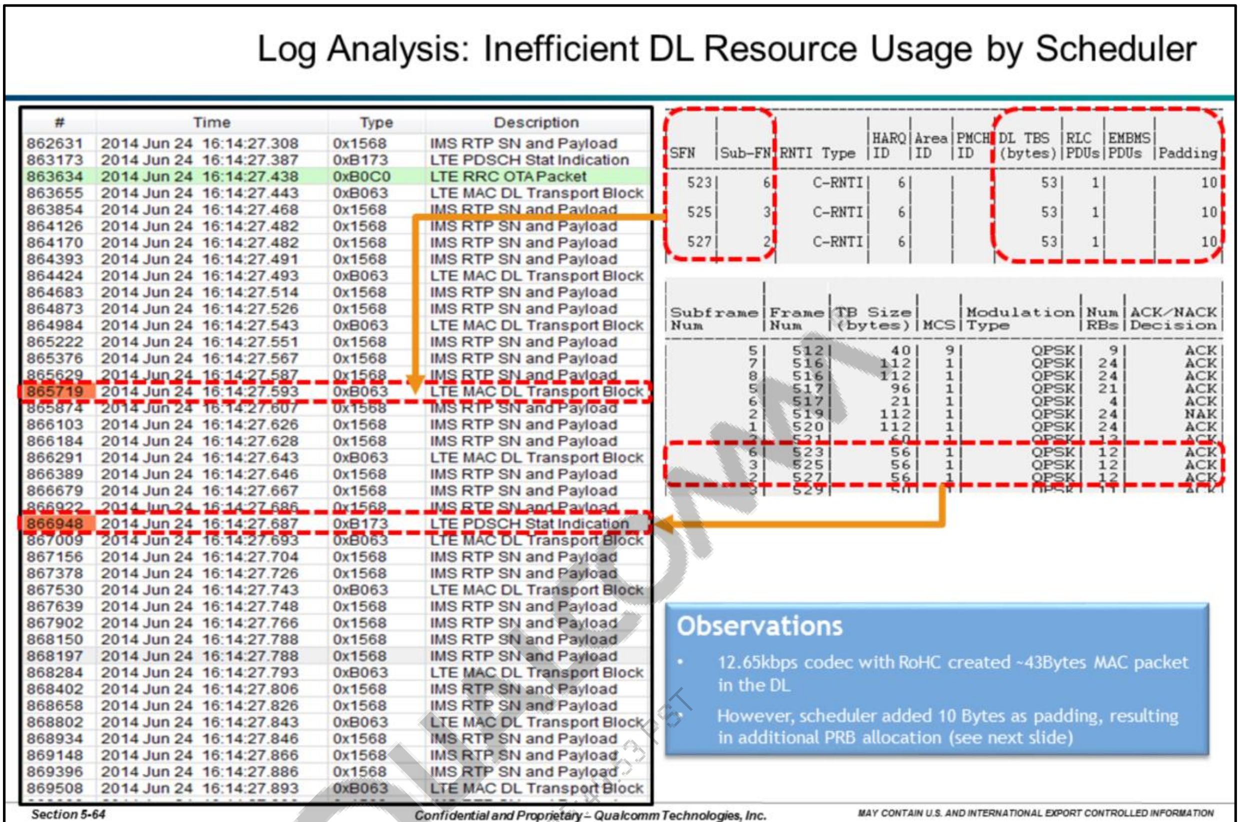
Notes



Log Analysis: Inefficient DL Resource Usage by Scheduler

#	Time	Type	Description
862631	2014 Jun 24 16:14:27.308	0x1568	IMS RTP SN and Payload
863173	2014 Jun 24 16:14:27.387	0xB173	LTE PDSCH Stat Indication
863634	2014 Jun 24 16:14:27.438	0xB0C0	LTE RRC OTA Packet
863655	2014 Jun 24 16:14:27.443	0xB063	LTE MAC DL Transport Block
863854	2014 Jun 24 16:14:27.468	0x1568	IMS RTP SN and Payload
864126	2014 Jun 24 16:14:27.482	0x1568	IMS RTP SN and Payload
864170	2014 Jun 24 16:14:27.482	0x1568	IMS RTP SN and Payload
864393	2014 Jun 24 16:14:27.491	0x1568	IMS RTP SN and Payload
864424	2014 Jun 24 16:14:27.493	0xB063	LTE MAC DL Transport Block
864683	2014 Jun 24 16:14:27.514	0x1568	IMS RTP SN and Payload
864873	2014 Jun 24 16:14:27.526	0x1568	IMS RTP SN and Payload
864984	2014 Jun 24 16:14:27.543	0xB063	LTE MAC DL Transport Block
865222	2014 Jun 24 16:14:27.551	0x1568	IMS RTP SN and Payload
865376	2014 Jun 24 16:14:27.567	0x1568	IMS RTP SN and Payload
865629	2014 Jun 24 16:14:27.587	0x1568	IMS RTP SN and Payload
865719	2014 Jun 24 16:14:27.593	0xB063	LTE MAC DL Transport Block
865874	2014 Jun 24 16:14:27.607	0x1568	IMS RTP SN and Payload
866103	2014 Jun 24 16:14:27.626	0x1568	IMS RTP SN and Payload
866184	2014 Jun 24 16:14:27.628	0x1568	IMS RTP SN and Payload
866291	2014 Jun 24 16:14:27.643	0xB063	LTE MAC DL Transport Block
866389	2014 Jun 24 16:14:27.646	0x1568	IMS RTP SN and Payload
866679	2014 Jun 24 16:14:27.667	0x1568	IMS RTP SN and Payload
866922	2014 Jun 24 16:14:27.686	0x1568	IMS RTP SN and Payload
866948	2014 Jun 24 16:14:27.687	0xB173	LTE PDSCH Stat Indication
867009	2014 Jun 24 16:14:27.693	0xB063	LTE MAC DL Transport Block
867156	2014 Jun 24 16:14:27.704	0x1568	IMS RTP SN and Payload
867378	2014 Jun 24 16:14:27.726	0x1568	IMS RTP SN and Payload
867530	2014 Jun 24 16:14:27.743	0xB063	LTE MAC DL Transport Block
867639	2014 Jun 24 16:14:27.748	0x1568	IMS RTP SN and Payload
867902	2014 Jun 24 16:14:27.766	0x1568	IMS RTP SN and Payload
868150	2014 Jun 24 16:14:27.788	0x1568	IMS RTP SN and Payload
868197	2014 Jun 24 16:14:27.788	0x1568	IMS RTP SN and Payload
868284	2014 Jun 24 16:14:27.793	0xB063	LTE MAC DL Transport Block
868402	2014 Jun 24 16:14:27.806	0x1568	IMS RTP SN and Payload
868658	2014 Jun 24 16:14:27.826	0x1568	IMS RTP SN and Payload
868802	2014 Jun 24 16:14:27.843	0xB063	LTE MAC DL Transport Block
868934	2014 Jun 24 16:14:27.846	0x1568	IMS RTP SN and Payload
869148	2014 Jun 24 16:14:27.866	0x1568	IMS RTP SN and Payload
869396	2014 Jun 24 16:14:27.886	0x1568	IMS RTP SN and Payload
869508	2014 Jun 24 16:14:27.893	0xB063	LTE MAC DL Transport Block

SFN	Sub-FN	RNTI Type	HARQ ID	Area ID	PMCH ID	DL TBS (bytes)	RLC PDUs	EMBMS PDUs	Padding
523	6	C-RNTI	6			53	1		10
525	3	C-RNTI	6			53	1		10
527	2	C-RNTI	6			53	1		10

Subframe Num	Frame Num	TB Size (bytes)	MCS	Modulation Type	Num RBs	ACK/NACK Decision
5	512	40	9	QPSK	9	ACK
7	516	112	1	QPSK	24	ACK
8	516	112	1	QPSK	24	ACK
5	517	96	1	QPSK	21	ACK
6	517	21	1	QPSK	4	ACK
2	519	112	1	QPSK	24	NAK
1	520	112	1	QPSK	24	ACK
2	521	60	1	QPSK	12	ACK
6	523	56	1	QPSK	12	ACK
3	525	56	1	QPSK	12	ACK
2	527	56	1	QPSK	12	ACK
3	529	[illegible]	1	QPSK	[illegible]	ACK

Observations

- 12.65kbps codec with RoHC created ~43Bytes MAC packet in the DL
- However, scheduler added 10 Bytes as padding, resulting in additional PRB allocation (see next slide)

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Notes

Log Analysis: Capacity Impact due to Inefficient DL Scheduling

SFN	Sub-FN	Actual Payload (Byte)	Padding (Byte)	Total MAC Payload (Byte)	MCS	Actual PRB Used	PRB without Padding
523	6	43	10	53	1	12	10
525	3	43	10	53	1	12	10
527	2	43	10	53	1	12	10
Duration : ~36ms		43 (81%)	10 (19%)	53 (100%)	1	12 (100%)	10 (83%)

Conclusion

- Per Table 7.1.7.2.1-1 of 3GPP 36.213, 43 Bytes (344 bits) can be accommodated in 10 PRBs at MCS=1
- Addition of unnecessary padding resulted in over-consumption of DL PRB
  - May cause PDSCH bottleneck under loaded scenario
- Within a span of 36ms 3 DL scheduling happened, each of which required PDCCH assignment
  - With SPS, this could have been managed with only 1 PDCCH assignment → May impact PDCCH capacity under loaded scenario

Recommendation

- Review scheduler algorithm and avoid unnecessary consumption of DL PRB

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Notes

Analysis – Inefficient DL Resource Usage by Scheduler

Log Analysis Procedure: Inefficient DL Resource Allocation by Scheduler

Open File: 05-06-Inefficient_DL_Alloc

Notes

Inefficient DL Resource Usage : Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	LTE MAC DL Transport Block	0xB063	16:14:27.593	DL MAC Payload and Padding Byte
2	LTE PDSCH Stat Indication	0xB173	16:14:27.687	DL PRB and MCS allocation

Notes

Summary: Scheduler Behavior Case Studies

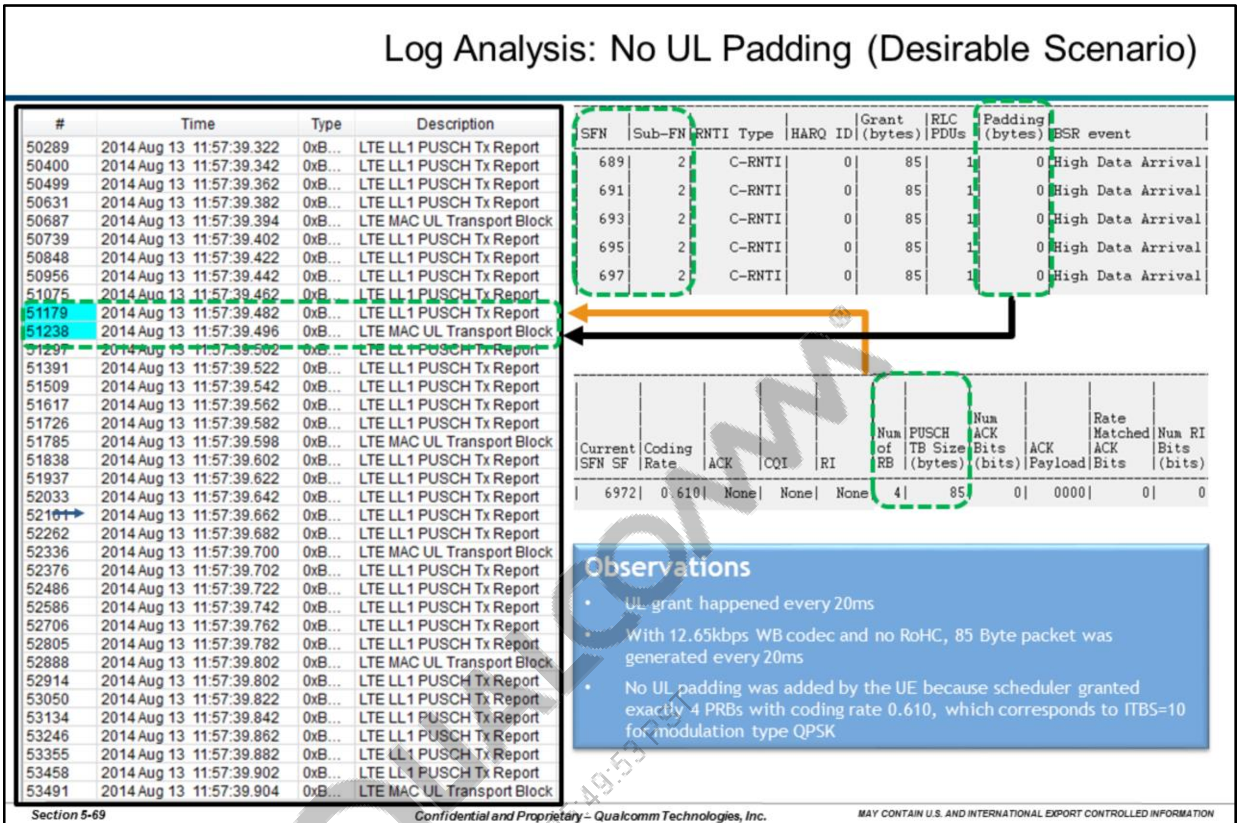
Case Study-1 (Excessive DL PRB allocation due to Resource Allocation Type 0 (RAT 0))

Case Study-2 (Inefficient DL resource usage by scheduler)

Case Study-3 (Efficient UL scheduler: no UL padding - Good Case)

Case Study-4 (Excessive UL padding)

Notes


Log Analysis: No UL Padding (Desirable Scenario)
Time Type Description
50289 2014 Aug 13 11:57:39.322 0xB... LTE LL1 PUSCH Tx Report
50400 2014 Aug 13 11:57:39.342 0xB... LTE LL1 PUSCH Tx Report
50499 2014 Aug 13 11:57:39.362 0xB... LTE LL1 PUSCH Tx Report
50631 2014 Aug 13 11:57:39.382 0xB... LTE LL1 PUSCH Tx Report
50687 2014 Aug 13 11:57:39.394 0xB... LTE MAC UL Transport Block
50739 2014 Aug 13 11:57:39.402 0xB... LTE LL1 PUSCH Tx Report
50848 2014 Aug 13 11:57:39.422 0xB... LTE LL1 PUSCH Tx Report
50956 2014 Aug 13 11:57:39.442 0xB... LTE LL1 PUSCH Tx Report
51075 2014 Aug 13 11:57:39.462 0xB... LTE LL1 PUSCH Tx Report
51179 2014 Aug 13 11:57:39.482 0xB... LTE LL1 PUSCH Tx Report
51238 2014 Aug 13 11:57:39.496 0xB... LTE MAC UL Transport Block
51297 2014 Aug 13 11:57:39.502 0xB... LTE LL1 PUSCH Tx Report
51391 2014 Aug 13 11:57:39.522 0xB... LTE LL1 PUSCH Tx Report
51509 2014 Aug 13 11:57:39.542 0xB... LTE LL1 PUSCH Tx Report
51617 2014 Aug 13 11:57:39.562 0xB... LTE LL1 PUSCH Tx Report
51726 2014 Aug 13 11:57:39.582 0xB... LTE LL1 PUSCH Tx Report
51785 2014 Aug 13 11:57:39.598 0xB... LTE MAC UL Transport Block
51838 2014 Aug 13 11:57:39.602 0xB... LTE LL1 PUSCH Tx Report
51937 2014 Aug 13 11:57:39.622 0xB... LTE LL1 PUSCH Tx Report
52033 2014 Aug 13 11:57:39.642 0xB... LTE LL1 PUSCH Tx Report
52161 2014 Aug 13 11:57:39.662 0xB... LTE LL1 PUSCH Tx Report
52262 2014 Aug 13 11:57:39.682 0xB... LTE LL1 PUSCH Tx Report
52336 2014 Aug 13 11:57:39.700 0xB... LTE MAC UL Transport Block
52376 2014 Aug 13 11:57:39.702 0xB... LTE LL1 PUSCH Tx Report
52486 2014 Aug 13 11:57:39.722 0xB... LTE LL1 PUSCH Tx Report
52586 2014 Aug 13 11:57:39.742 0xB... LTE LL1 PUSCH Tx Report
52706 2014 Aug 13 11:57:39.762 0xB... LTE LL1 PUSCH Tx Report
52805 2014 Aug 13 11:57:39.782 0xB... LTE LL1 PUSCH Tx Report
52888 2014 Aug 13 11:57:39.802 0xB... LTE MAC UL Transport Block
52914 2014 Aug 13 11:57:39.802 0xB... LTE LL1 PUSCH Tx Report
53050 2014 Aug 13 11:57:39.822 0xB... LTE LL1 PUSCH Tx Report
53134 2014 Aug 13 11:57:39.842 0xB... LTE LL1 PUSCH Tx Report
53246 2014 Aug 13 11:57:39.862 0xB... LTE LL1 PUSCH Tx Report
53355 2014 Aug 13 11:57:39.882 0xB... LTE LL1 PUSCH Tx Report
53458 2014 Aug 13 11:57:39.902 0xB... LTE LL1 PUSCH Tx Report
53491 2014 Aug 13 11:57:39.904 0xB... LTE MAC UL Transport Block
SFN | Sub-FN | RNTI Type | HARQ ID | Grant (bytes) | RLC PDUs | Padding (bytes) | BSR event
689 | 2 | C-RNTI | 0 | 85 | 1 | 0 | High Data Arrival
691 | 2 | C-RNTI | 0 | 85 | 1 | 0 | High Data Arrival
693 | 2 | C-RNTI | 0 | 85 | 1 | 0 | High Data Arrival
695 | 2 | C-RNTI | 0 | 85 | 1 | 0 | High Data Arrival
697 | 2 | C-RNTI | 0 | 85 | 1 | 0 | High Data Arrival
Current SFN SF | Coding Rate | ACK | CQI | RI | Num of RB | PUSCH TB Size (bytes) | Num ACK Bits (bits) | ACK Payload | Rate Matched ACK Bits | Num RI Bits (bits)
6972 | 0.610 | None | None | None | 4 | 85 | 0 | 0000 | 0 | 0
Observations
• UL grant happened every 20ms
• With 12.65kbps WB codec and no RoHC, 85 Byte packet was generated every 20ms
• No UL padding was added by the UE because scheduler granted exactly 4 PRBs with coding rate 0.610, which corresponds to ITBS=10 for modulation type QPSK
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Notes

Analysis – No UL Padding

Log Analysis Procedure: Efficient UL scheduler: no UL padding

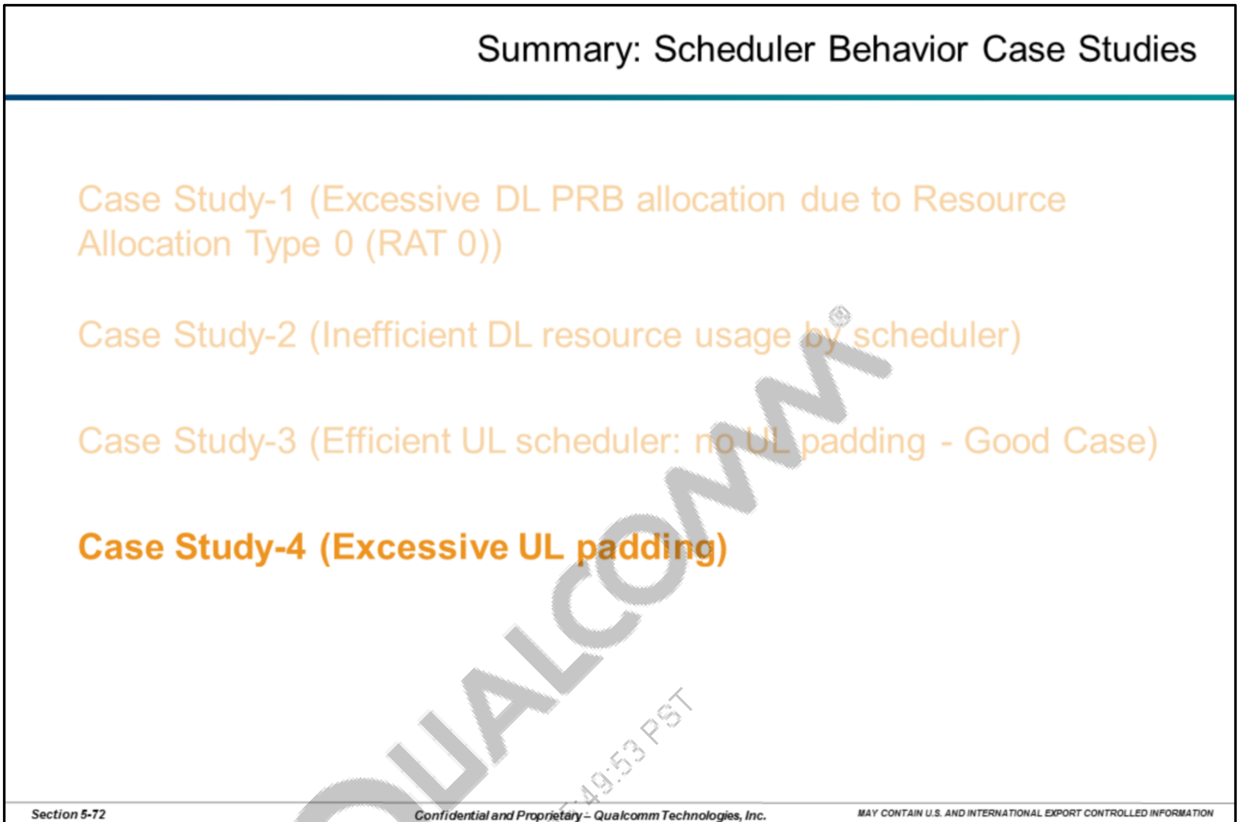
Open File: 05-07-No_UL_Padding

Notes

No UL Padding: Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	LTE MAC UL Transport Block	0xB064	11:57:39.496	UL MAC Payload and Padding Byte
2	LTE LL1 PUSCH Tx Report	0xB139	11:57:39.482	UL PRB and Coding rate

Notes


Summary: Scheduler Behavior Case Studies
Case Study-1 (Excessive DL PRB allocation due to Resource Allocation Type 0 (RAT 0))
Case Study-2 (Inefficient DL resource usage by scheduler)
Case Study-3 (Efficient UL scheduler: no UL padding - Good Case)
Case Study-4 (Excessive UL padding)
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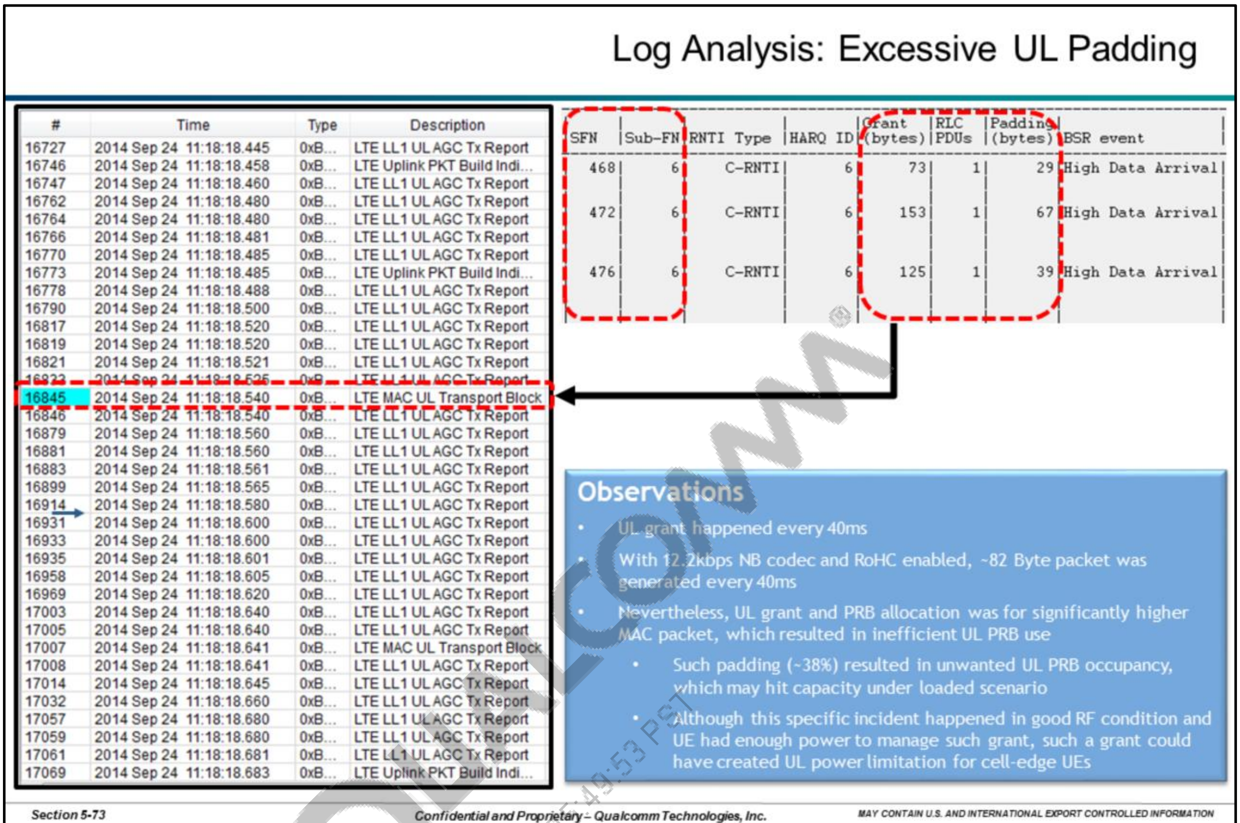
Notes



Excessive UL Padding

40ms UL Scheduling periodicity is a representation of UL packet bundling used by the scheduler.

While use of UL padding resulted in inefficiency of the UL PUSCH PRB usage, use of UL packet bundling resulted in efficient use of PDCCH resources.

Analysis – Excessive UL Padding

Log Analysis Procedure: Excessive UL Padding

Open File: 05-08-Excessive_UL_Padding

Notes

Excessive UL Padding: Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	LTE MAC UL Transport Block	0xB064	11:18:18.540	UL MAC Payload and Padding Byte

Notes


Appendix
Appendix
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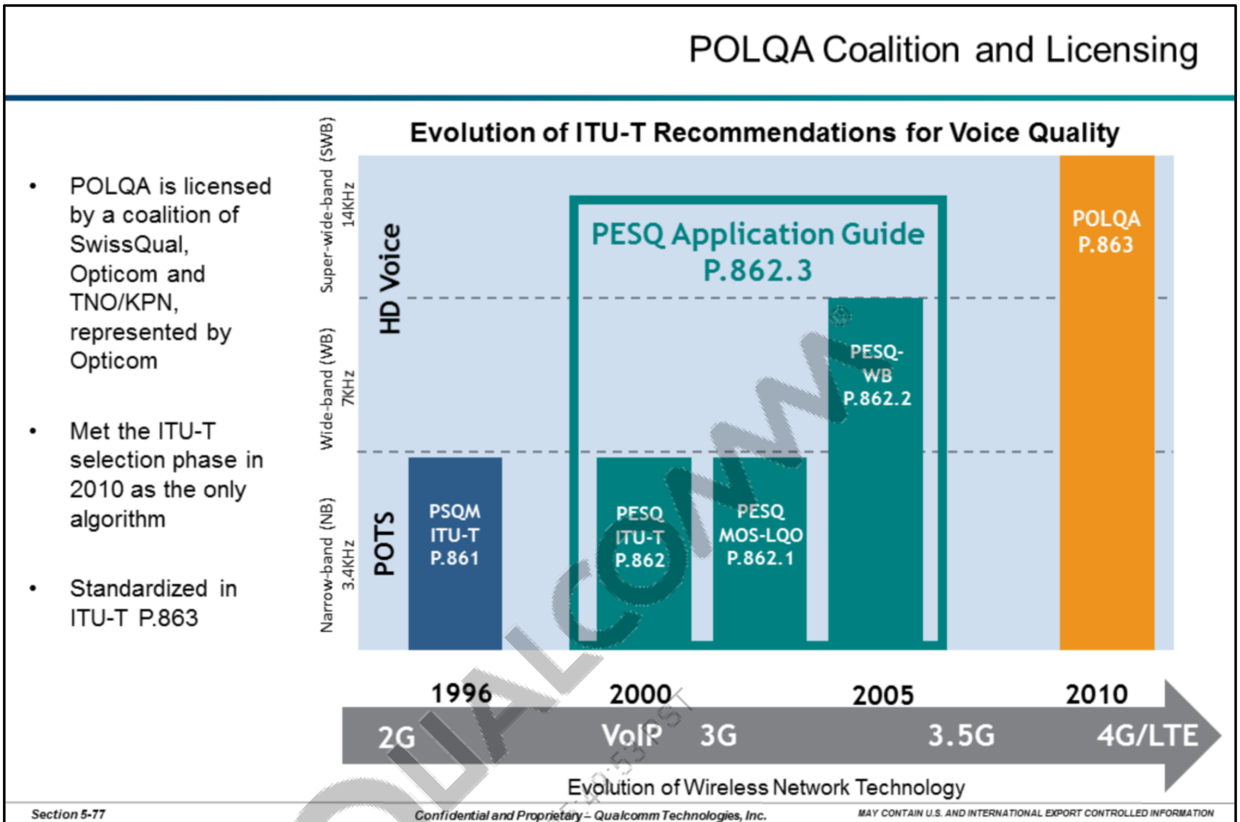
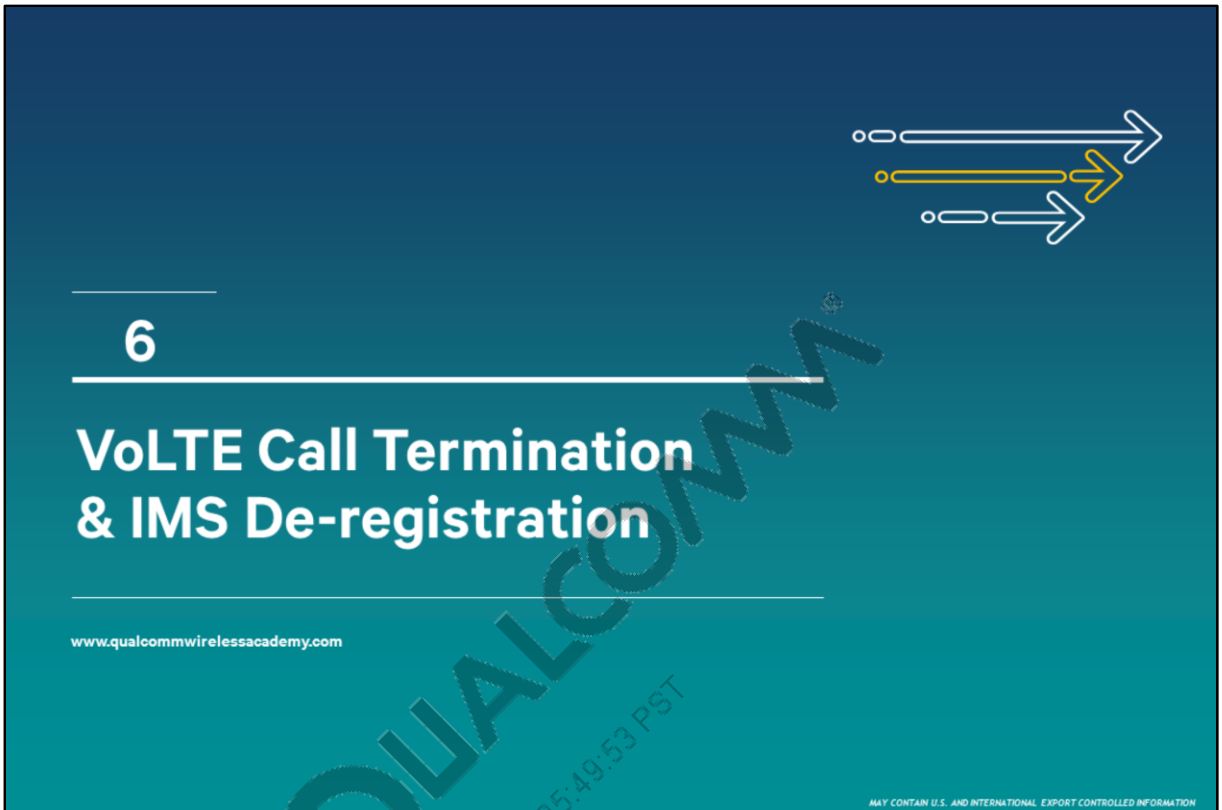
Notes



Perceptual Objective Listening Quality Assessment

- **Measurement Scope**
  - Predict speech quality by means of signal analysis
  - Close to subjective quality scores
  - Uses real speech samples
- **Technology Capabilities**
  - Successor of PESQ
  - Covers also higher bandwidth audio signals (wideband and ultra wideband 50-14000 Hz)
- **Standards and Website**
  - ITU-T P.863 (PESQ ITU-T P.862)
  - www.polqa.info
- **Description**
  - Full Reference (FR) algorithm rating degraded/processed speech in relation to original sample
  - Calculates perceptual differences between listener side and talker side (based on signal samples)
  - Perceptual psycho-acoustic modeling as used in MP3 or AAC
  - Analysis in the frequency domain with help of masking functions
  - Results in MOS scores with rating between 1 and 5

Comments/Notes


6
VoLTE Call Termination
& IMS De-registration
www.qualcommwirelessacademy.com
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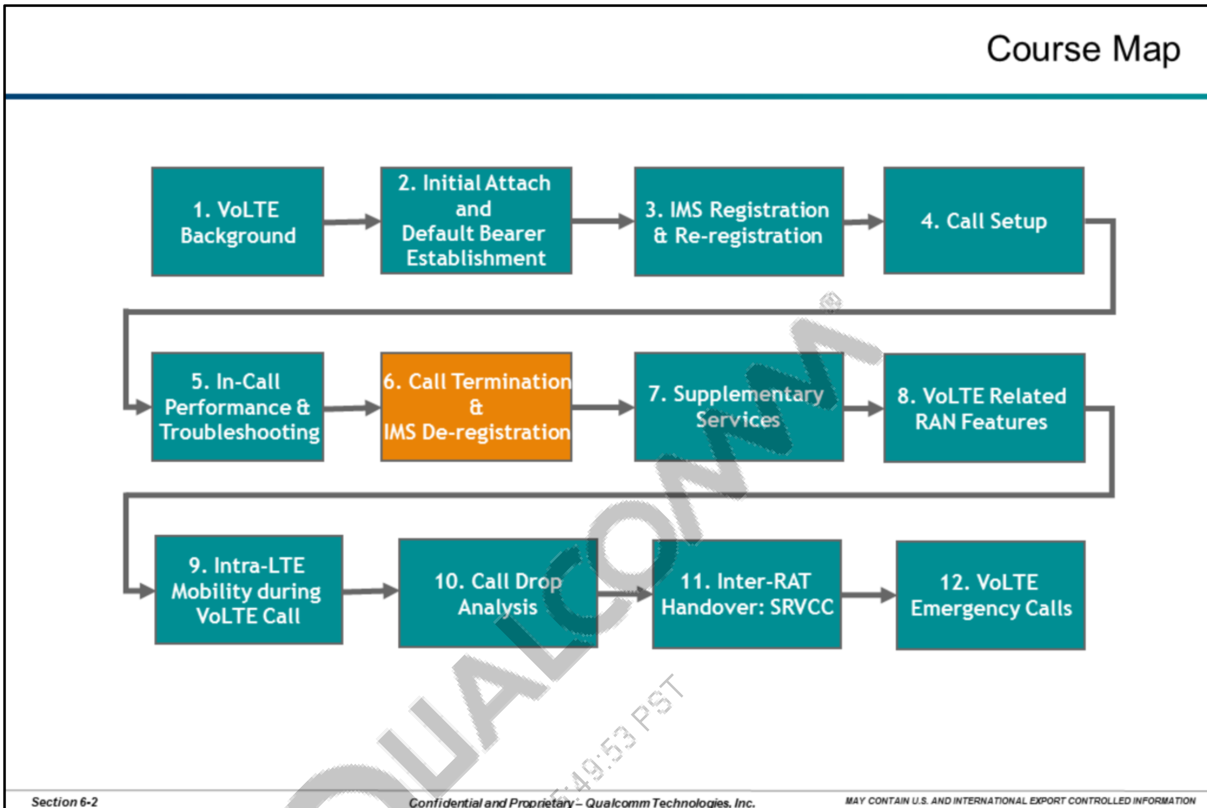
Course Map
1. VoLTE Background
2. Initial Attach and Default Bearer Establishment
3. IMS Registration & Re-registration
4. Call Setup
5. In-Call Performance & Troubleshooting
6. Call Termination & IMS De-registration
7. Supplementary Services
8. VoLTE Related RAN Features
9. Intra-LTE Mobility during VoLTE Call
10. Call Drop Analysis
11. Inter-RAT Handover: SRVCC
12. VoLTE Emergency Calls
Section 6-2
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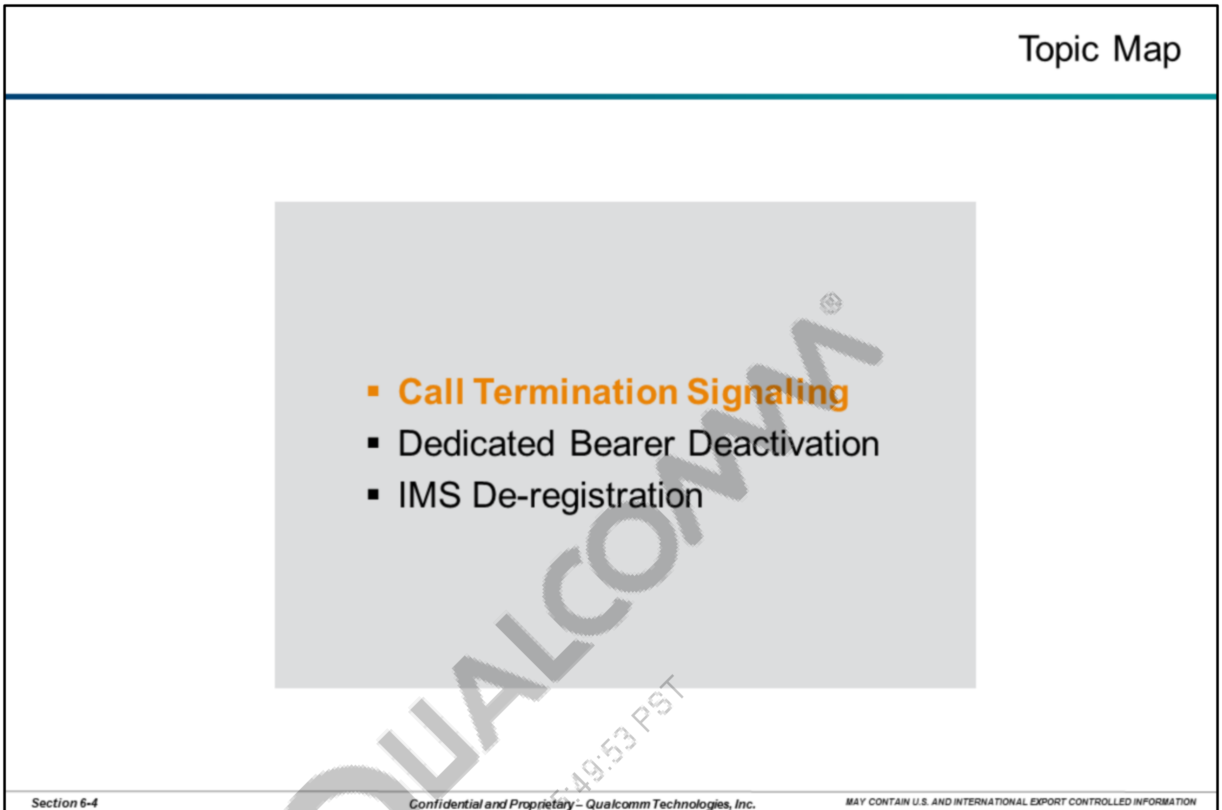
Notes

Objectives

- Describe the signaling procedures of:
  - VoLTE call termination
  - IMS de-registration
- Analyze the following logs:
  - Call termination
  - Dedicated bearer deactivation
  - IMS de-registration

Notes


Topic Map
Call Termination Signaling
Dedicated Bearer Deactivation
IMS De-registration
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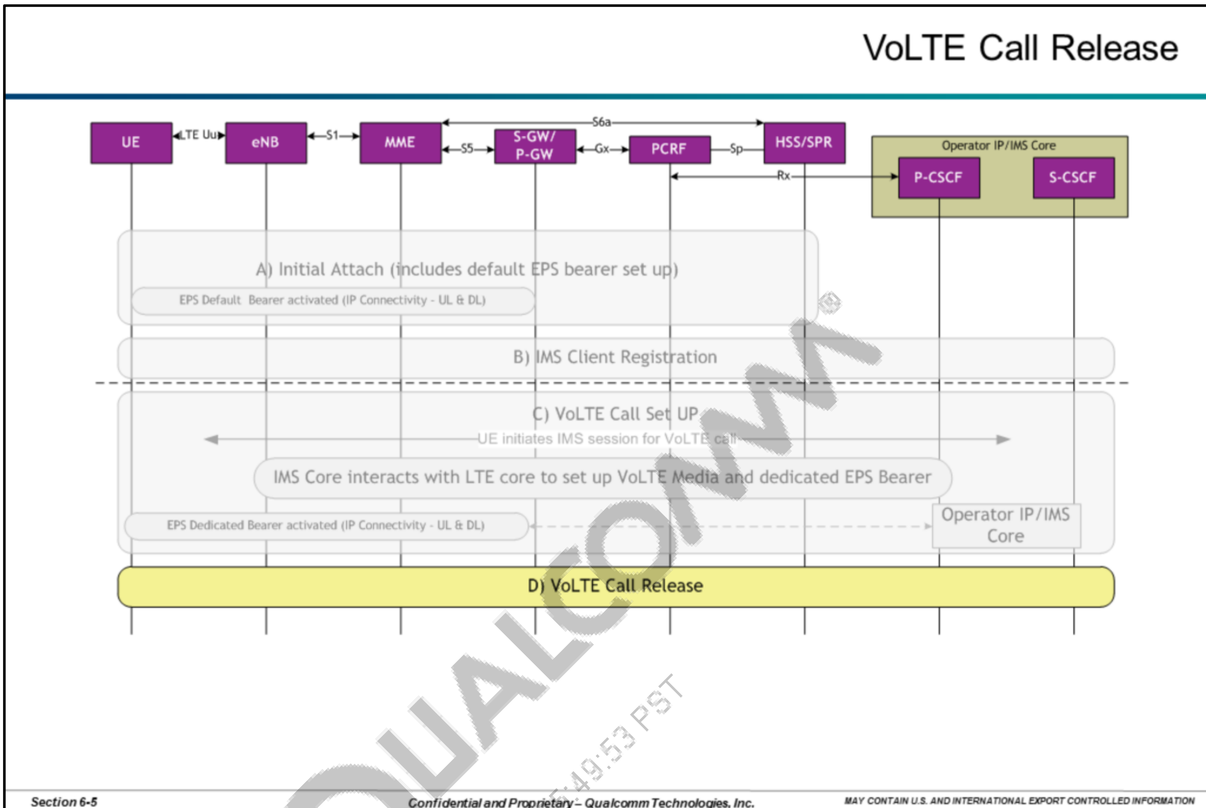
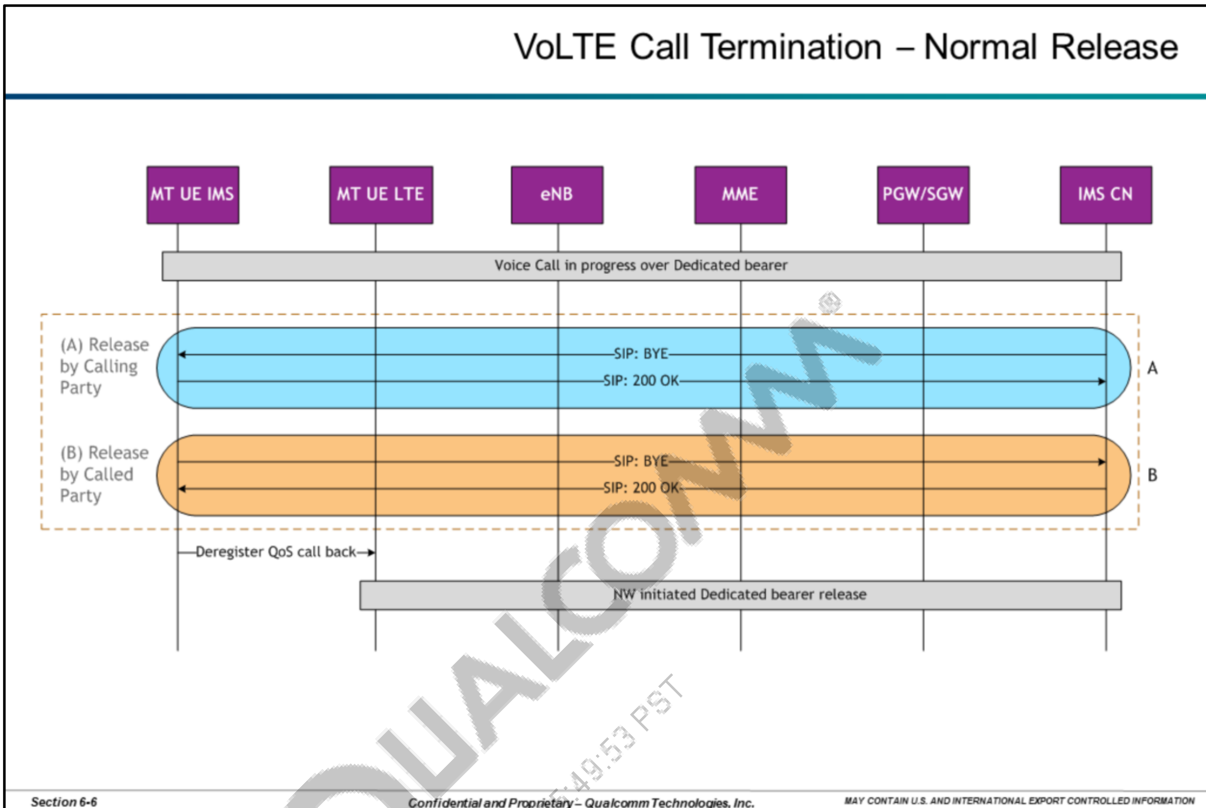
Notes



VoLTE Call Release

Only normal release is covered in this class.

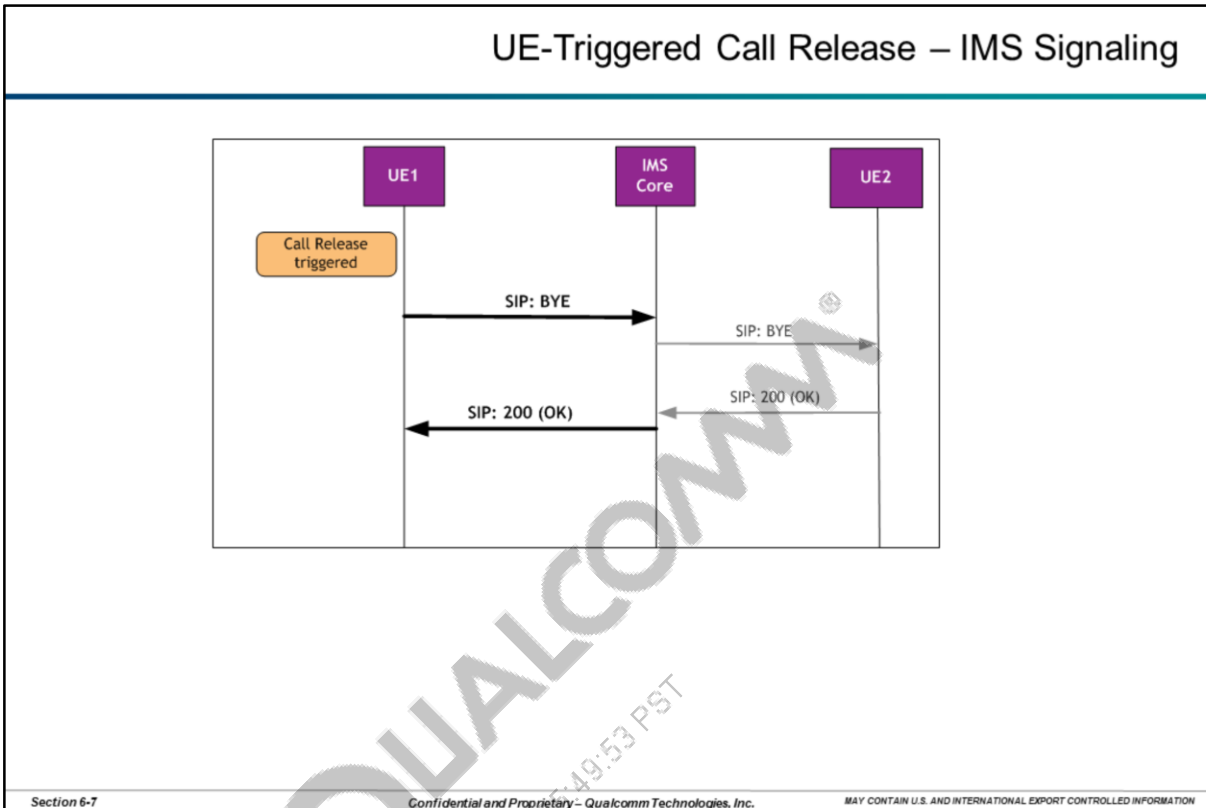
VoLTE call termination in out-of-coverage scenario is not covered.



VoLTE Call Termination – Normal Release

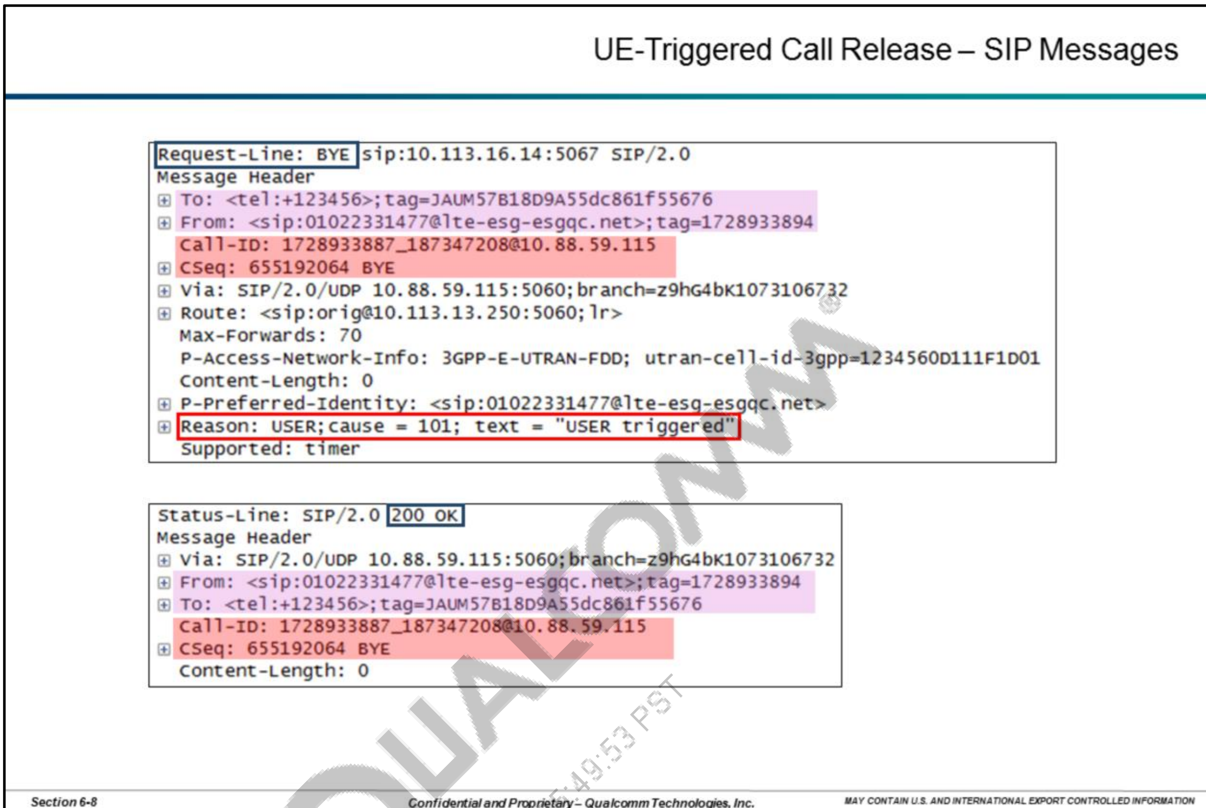
VoLTE call termination by remote or local user follows these steps:

1. The UE is involved in a VoLTE session. The media stream has been established and is carrying VoLTE frames.
2. The ongoing media session can be terminated by the remote user (Option A) or by the local user (Option B).
   - In option A, the remote user ends the session, hence the UE receives a SIP:BYE from the IMS CN and in response sends a SIP:200 OK.
   - In option B, the local user's IMS stack sends a SIP:BYE to the IMS CN, which responds with a SIP:200 OK.
   - In either option, the UE IMS stack deletes the QoS it had originally installed during call setup.
3. At the end of the call, the IMS core network triggers network-initiated deactivation of the Dedicated Radio Bearer to carry VoLTE voice traffic assigned to the source and target UEs.
4. Subsequently, the network may transition the UE to RRC Idle (using an inactivity timer) and release bearers for IMS signaling until the UE is paged and requests to set up RRC Connection again.



UE-Triggered Call Release – IMS Signaling

- UE1 sends a SIP:BYE request to the UE2
- IMS core delivers the SIP:BYE to the UE2
- UE2 responds with 200 (OK) and terminates the call
- IMS core delivers 200 (OK) to UE1



UE-Triggered Call Release – SIP Messages

- The Reason header field indicates the cause for the call termination is “user-triggered” indicating a normal termination of the call.
- The ‘To’ and ‘From’ fields are identical in both the BYE request and the 200 OK response as they refer to the originating party, regardless of the direction of the message.
- Both the BYE request and the 200 OK response have the same CSeq, as they belong to the same dialog.
- Both the BYE request and the 200 OK response share the same Call-ID, which does not change throughout the call.
- Both the BYE request and the 200 OK response are header only messages. Content-Length is set to ‘0’ in both messages.

BYE Request - Reason

- The BYE request may include a **Reason** header field with a **Reason code**
- The server must release the call upon receiving the BYE request, regardless of the Reason code
- The **Reason** header field can be used by the UE to update a UI message

Notes

Log Analysis: VoLTE Call Termination

Log Analysis Procedure: VoLTE Call Termination

Open File: 06-01-Call_Termination

Notes

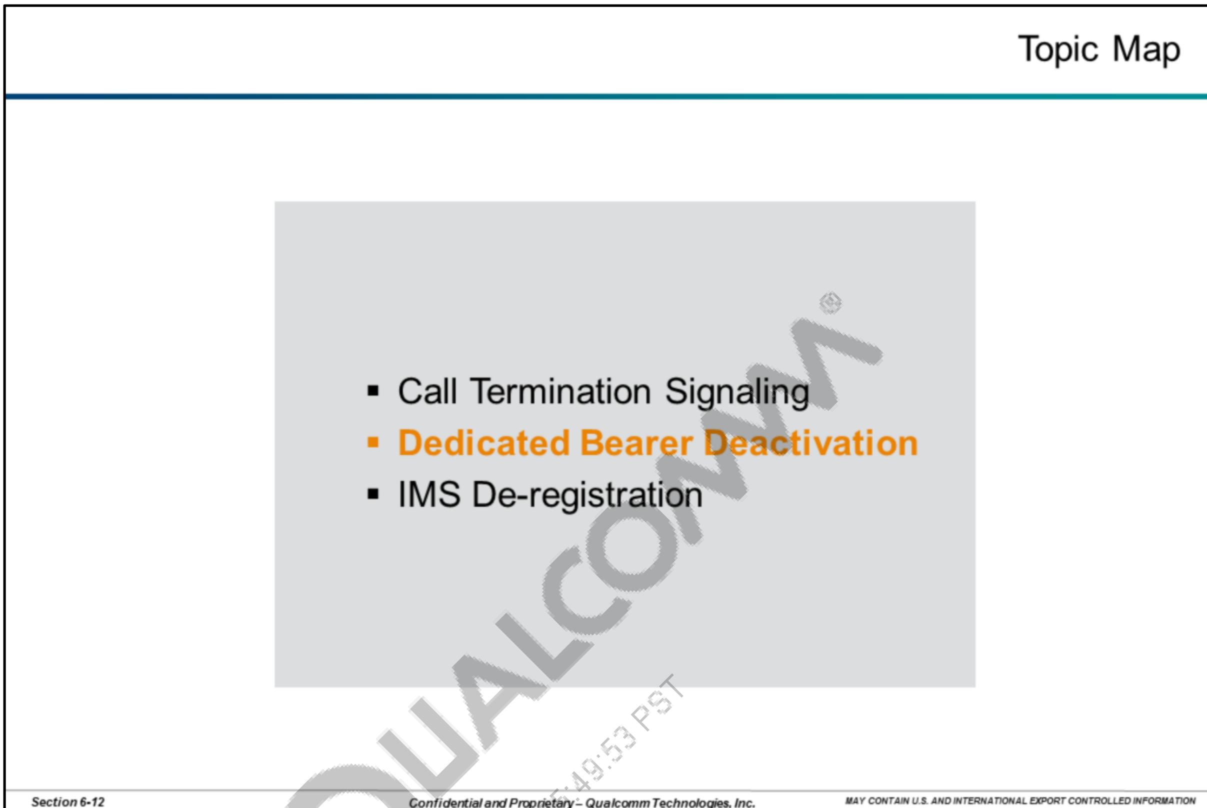
VoLTE Call Termination: Log Walk-Through

Step	Look for	Time Stamp	Verify
1	SIP: BYE	03:44:28.355	Reason: USER; cause = "USER triggered" (Graceful call termination)
2	SIP: 200 OK (BYE)	03:44:28.402	Same CSeq as the previous SIP BYE Same Call-ID as the previous SIP BYE

Analysis Summary

The arrival of messages during logging could impact the order in which time stamps are shown.

If needed while analyzing a log file in the browser, use the menu “Edit” + “Find on this Page” (Ctrl+F) to find a specific timestamp.


Topic Map
▪ Call Termination Signaling
▪ Dedicated Bearer Deactivation
▪ IMS De-registration
Section 6-12
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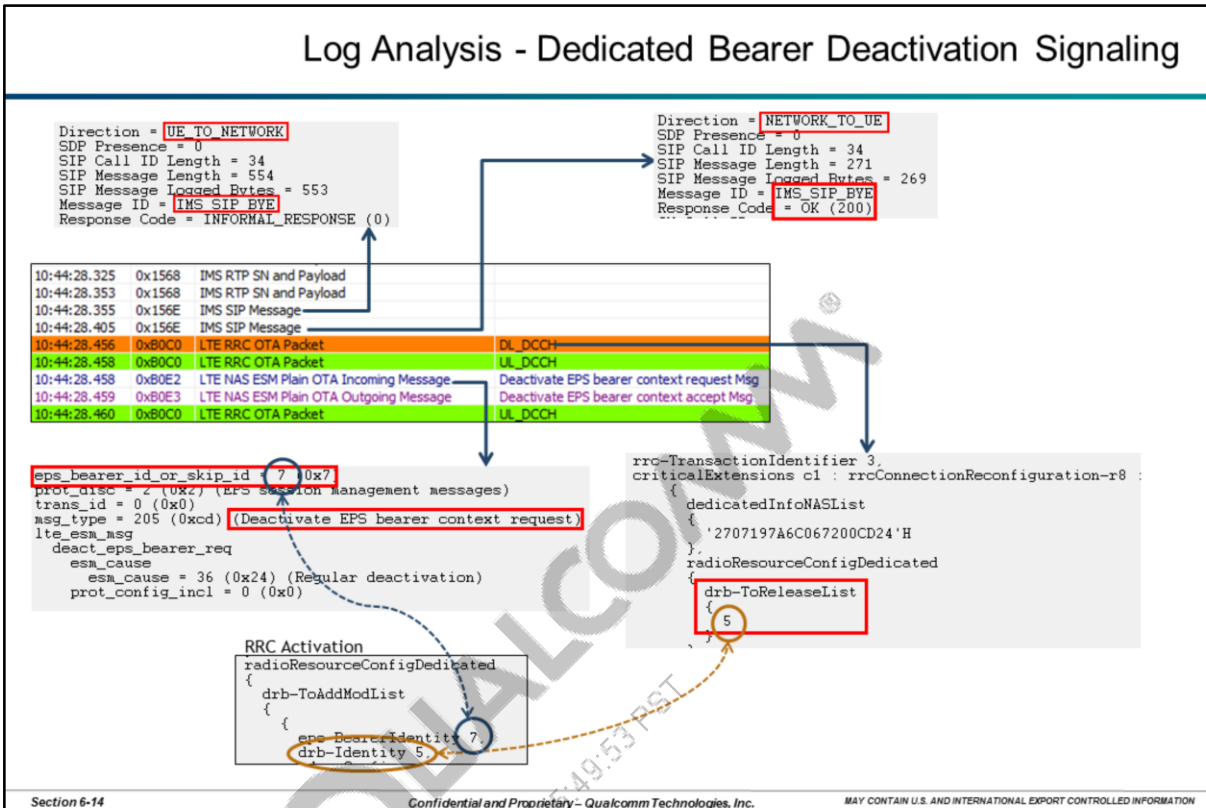
Notes

Dedicated Bearer Deactivation at Call Termination

- RTP traffic is carried over a dedicated bearer that is activated during call setup
- The dedicated bearer is configured with QoS settings suitable for real-time traffic
- At call termination, the network deactivates the dedicated bearer

Notes



Log Analysis - Dedicated Bearer Deactivation Signaling

UE initiates call termination by sending SIP BYE.

Network releases the dedicated bearer after call termination.


Log Analysis: Dedicated Bearer Deactivation
Log Analysis Procedure: Dedicated Bearer Release
Open File: 06-01-Call_Termination
Section 6-15
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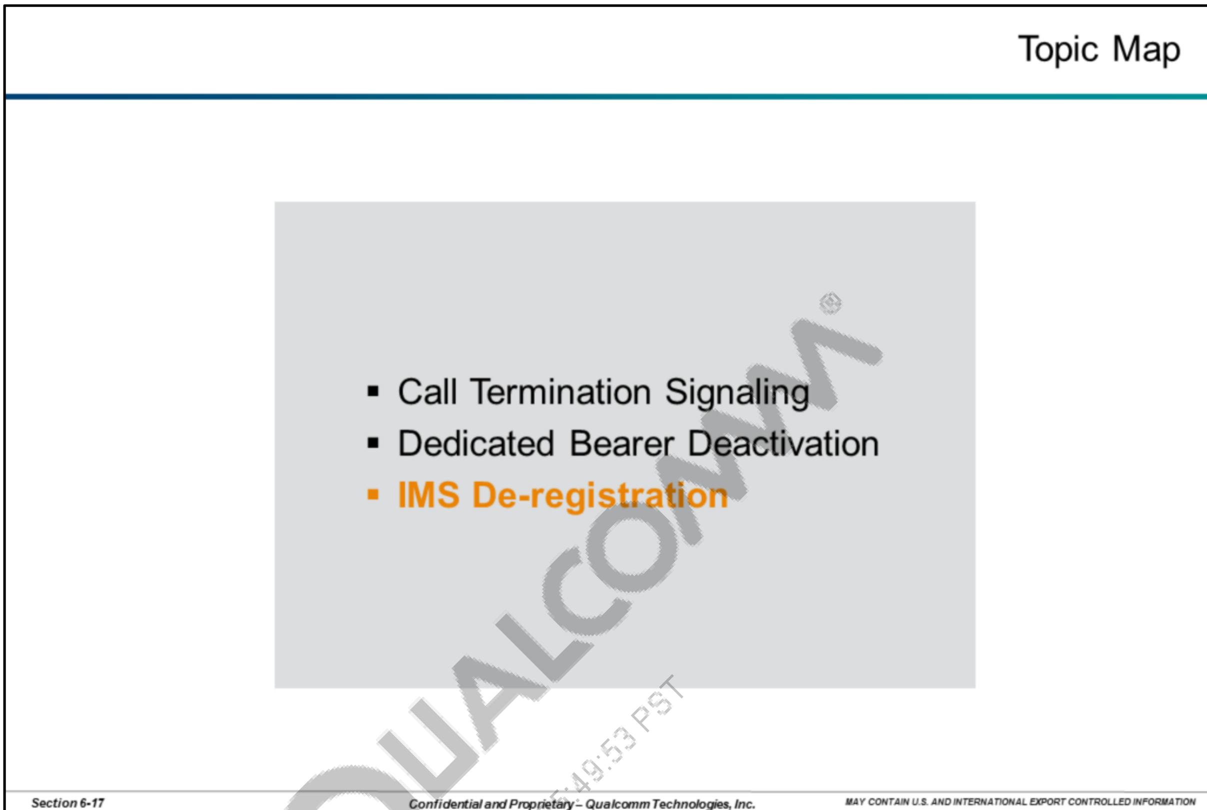
Notes

Dedicated Bearer Deactivation: Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	IMS SIP Message	0x156E	10:44:28.355	UE sends IMS_SIP_BYE
2	IMS SIP Message	0x156E	10:44:28.405	Network sends 200OK in response to the SIP: BYE message from UE
3	RRC Connection Reconfiguration	0xB0C0	10:44:28.456	DRB with bearer ID 5 is listed in the drb-ToReleaseList
4	NAS ESM Plain OTA Incoming Message	0xB0E2	10:44:28.458	Deactivate EPS bearer context request Msg
5	NAS ESM Plain OTA Outgoing Message	0xB0E3	10:44:28.459	Deactivate EPS bearer context accept Msg

Notes


Topic Map
Call Termination Signaling
Dedicated Bearer Deactivation
IMS De-registration
Section 6-17
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Notes

Typical IMS De-registration Triggers

UE-Triggered

- Power off
- Airplane mode

Network-Triggered

- Network-initiated detach from EPC

Service-Triggered

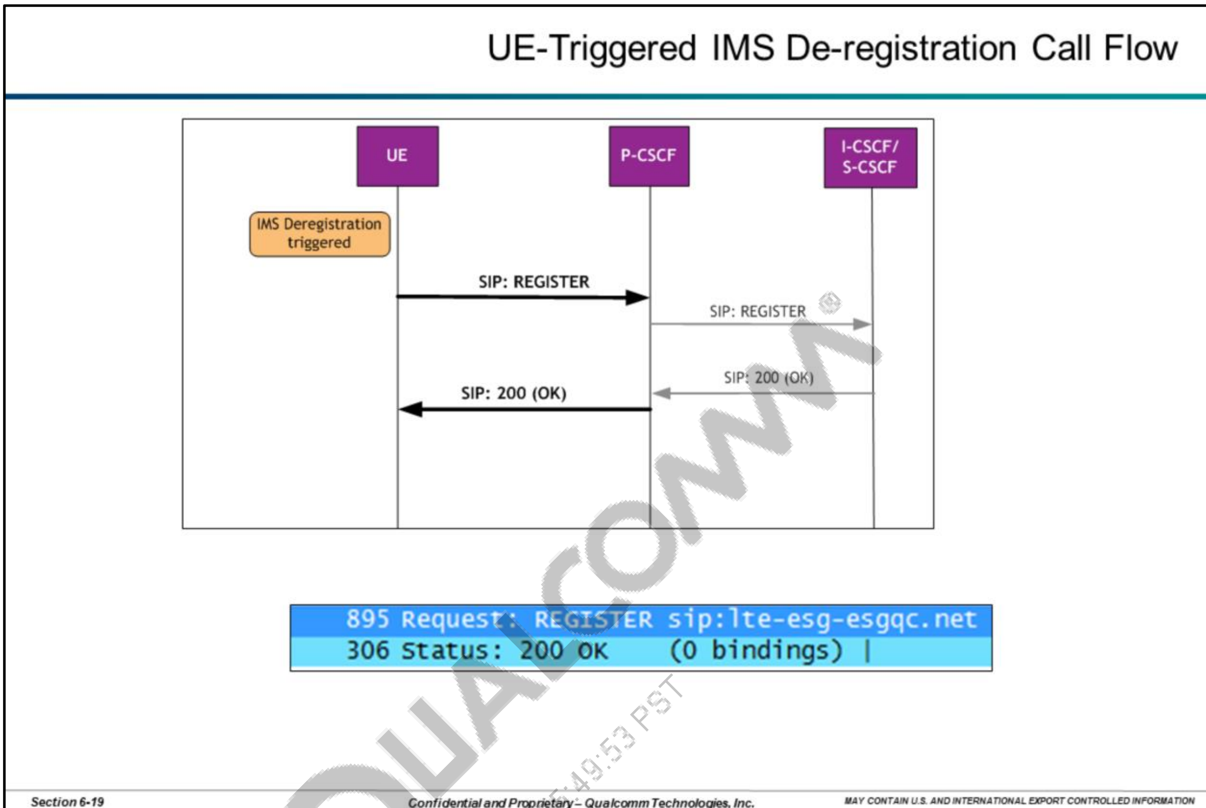
- LTE/IMS registration expiration

IMS Deregistration Triggers

The UE will explicitly deregister only for some of the cases (for example, when the UE is powered off).

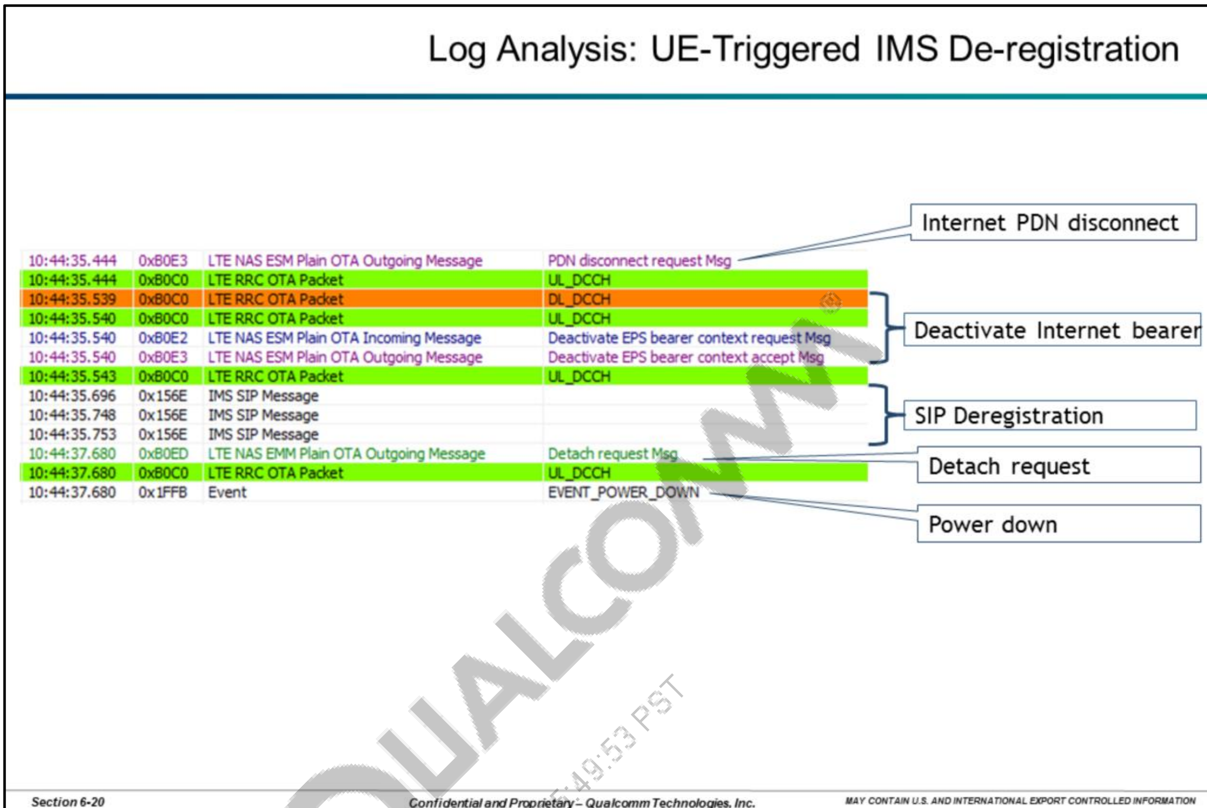
In other cases, the UE is implicitly detached (for example, the network detaches UE from EPC).

For details, refer to 3GPP TS 24.229, sections 5.1.1.6, 5.1.1.7, and 5.2.5.



IMS deregistration steps are detailed below.

1. The UE constructs a REGISTER request as follows:
   a) The UE includes the headers specified in Section 5.1.1.6 of 3GPP 24.229. The Expires header set to zero indicates the UE wishes to deregister.
   b) The UE also inserts a Require and Proxy-Require header field with the option tag “sec-agree” (which permits negotiation of common security mechanism between the UE and P-CSCF).
   c) If a URI belongs to an implicit registration set, all URIs in that set shall be deregistered along with this URI. The temporary public URI may be used in deregistration.
   d) The REGISTER is sent to P-CSCF protected by the UEs outbound SA (Security Association – between the client port at the UE and the server port at the P-CSCF).
2. The P-CSCF processes the REGISTER request and forwards the REGISTER to the S-CSCF indicating that it is integrity protected.
3. The S-CSCF notices that the P-CSCF had marked the REGISTER as being integrity protected. Hence, the S-CSCF performs deregistration procedures, including removing the bindings of the UE’s contact addresses of the public user identities being deregistered. The S-CSCF sends a 200 OK response to the P-CSCF via the I-CSCF.
4. The P-CSCF updates its state information about the UE’s registration and state of SA accordingly on receiving the 200 OK response and forwards it to the UE on the UE’s inbound SA. The UE performs the steps listed in Section 5.1.1.6 of 3GPP 24.229. These include:
   a) Clearing all registration states associated with deregistered public user identities.
   b) If no more public user identities are registered, the UE shall delete the security associations and related keys it may have towards the IM CN subsystem.
   c) If all public user identities are deregistered and the security associations are removed, then the UE shall consider subscription to the registration event package cancelled. The UE shall no longer be able to receive signaling from the P-CSCF.


Log Analysis: UE-Triggered IMS De-registration
10:44:35.444 0xB0E3 LTE NAS ESM Plain OTA Outgoing Message PDN disconnect request Msg
10:44:35.444 0xB0C0 LTE RRC OTA Packet UL_DCCH
10:44:35.539 0xB0C0 LTE RRC OTA Packet DL_DCCH
10:44:35.540 0xB0C0 LTE RRC OTA Packet UL_DCCH
10:44:35.540 0xB0E2 LTE NAS ESM Plain OTA Incoming Message Deactivate EPS bearer context request Msg
10:44:35.540 0xB0E3 LTE NAS ESM Plain OTA Outgoing Message Deactivate EPS bearer context accept Msg
10:44:35.543 0xB0C0 LTE RRC OTA Packet UL_DCCH
10:44:35.696 0x156E IMS SIP Message
10:44:35.748 0x156E IMS SIP Message
10:44:35.753 0x156E IMS SIP Message
10:44:37.680 0xB0ED LTE NAS EMM Plain OTA Outgoing Message Detach request Msg
10:44:37.680 0xB0C0 LTE RRC OTA Packet UL_DCCH
10:44:37.680 0x1FFB Event EVENT_POWER_DOWN
Internet PDN disconnect
Deactivate Internet bearer
SIP Deregistration
Detach request
Power down
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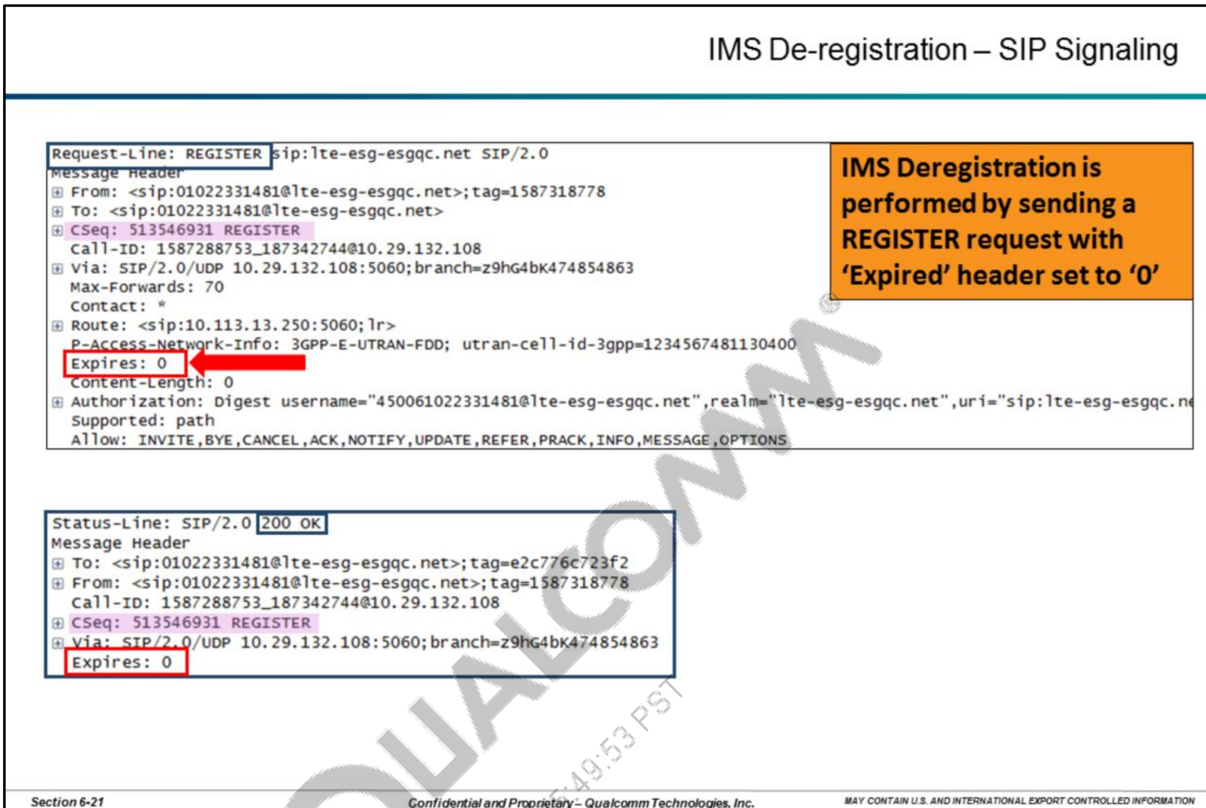
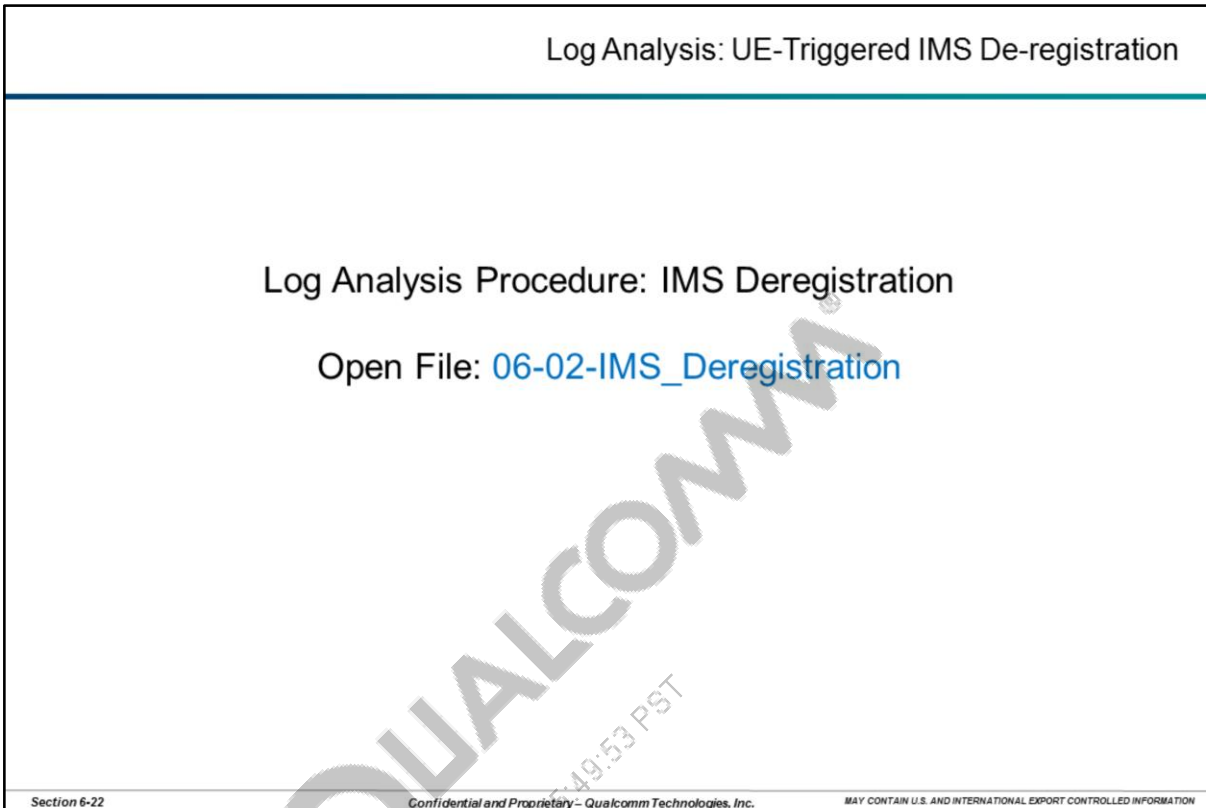
Notes



IMS De-registration – SIP Signaling

UE initiates IMS de-registration by sending a Register request with Expires header field set to zero. The network acknowledges the UE de-registration and sends 200 OK response with Expires set to zero.


Log Analysis: UE-Triggered IMS De-registration
Log Analysis Procedure: IMS Deregistration
Open File: 06-02-IMS_Deregistration
Section 6-22
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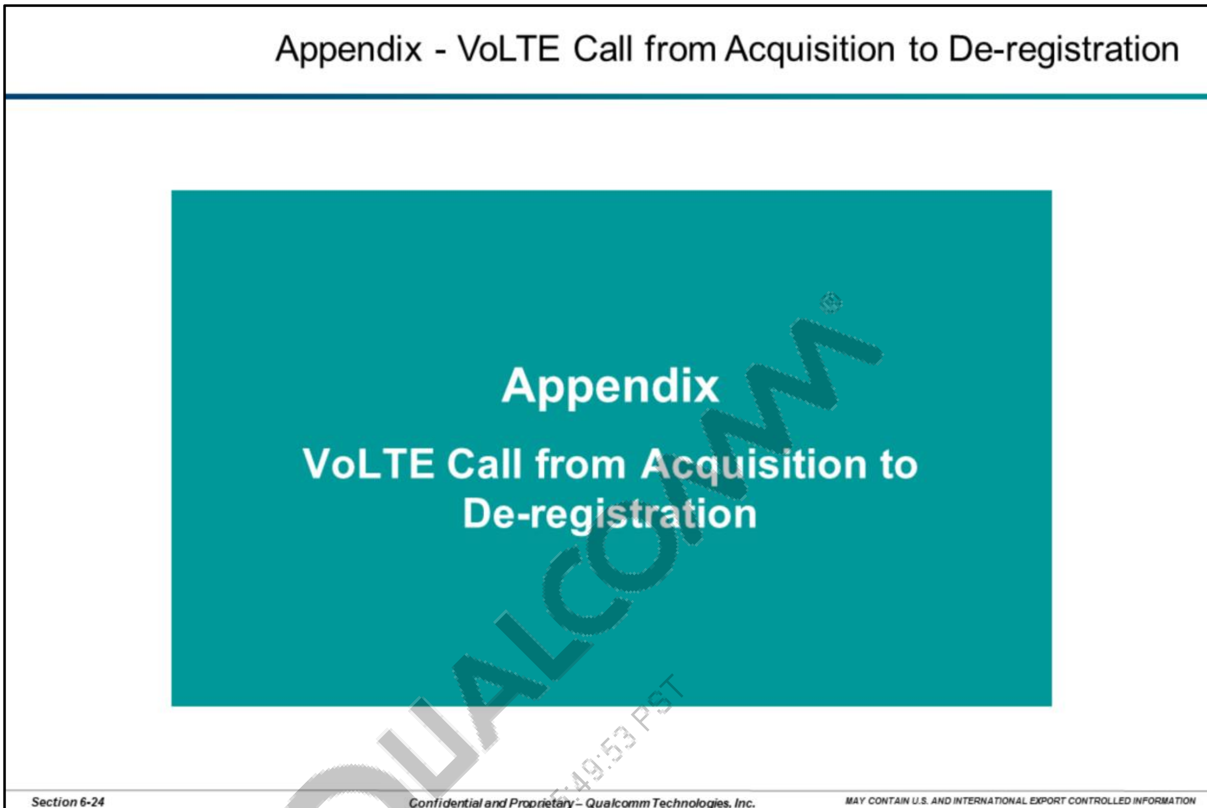
Notes

UE-Triggered IMS De-registration: Log Walk-Through

Step	Look for	Time Stamp	Verify
1	SIP: REGISTER	12:24:00.893	Method set to REGISTER in Request-Line Expires = 0
2	SIP: 200 OK (REGISTER)	12:24:00.935	Same CSeq as the previous SIP REGISTER Same Call-ID as the previous SIP REGISTER

Notes


Appendix - VoLTE Call from Acquisition to De-registration
Appendix
VoLTE Call from Acquisition to De-registration
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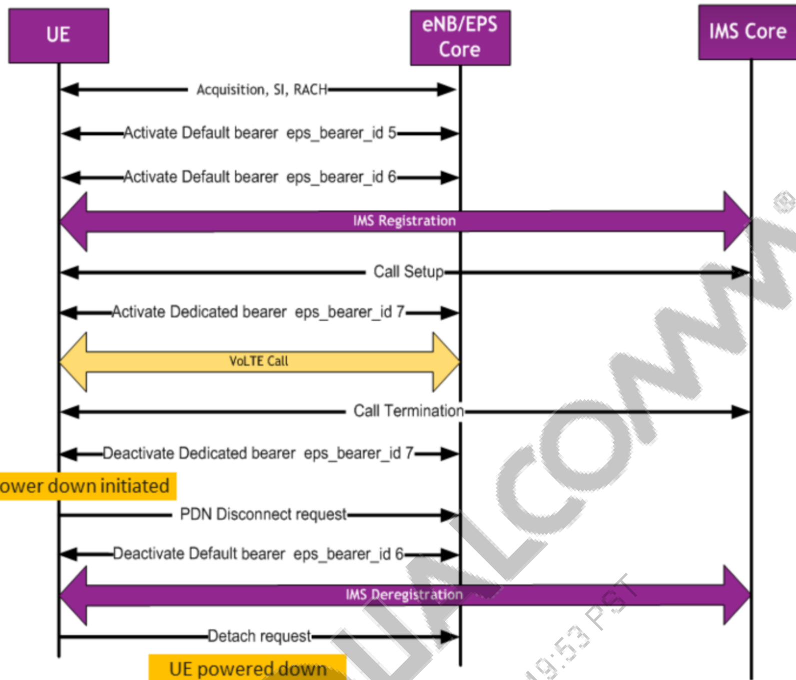
Notes

Call Flow



- eps_bearer_id 5
  Default bearer
  QCI = 5
  IMS PDN
  RLC AM mode
- eps_bearer_id 6
  Default bearer
  QCI = 6
  Internet PDN
  RLC AM mode
- eps_bearer_id 7
  Dedicated bearer
  QCI = 1
  IMS PDN
  RLC UM mode

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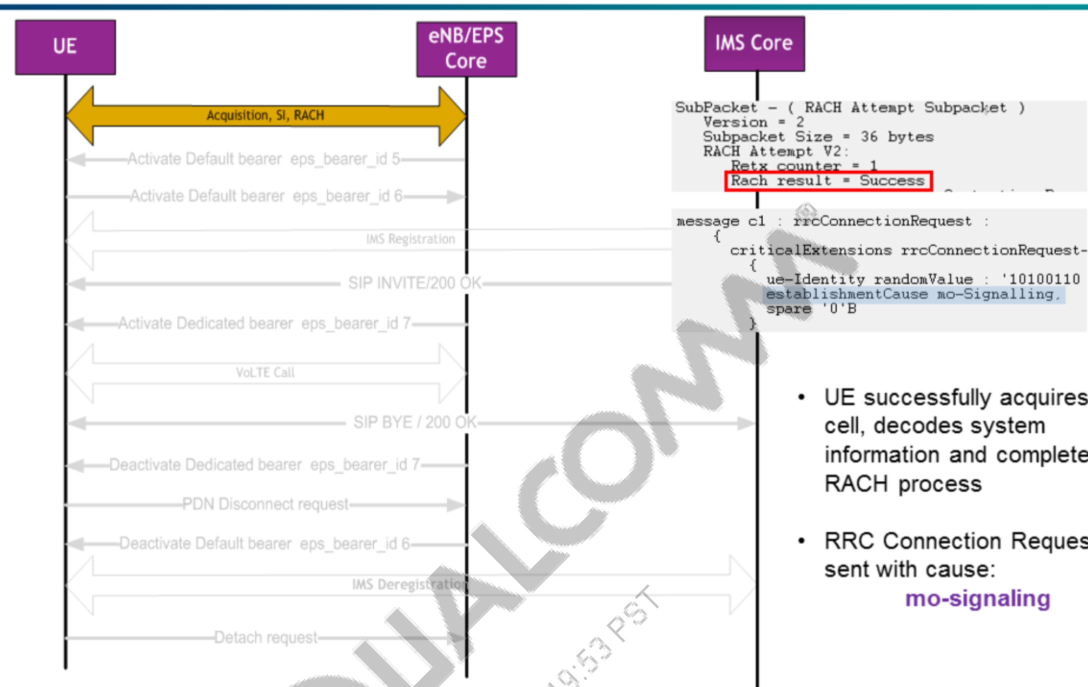
Notes

Log Analysis: Acquisition, SI, RACH



- UE successfully acquires cell, decodes system information and completes RACH process
- RRC Connection Request is sent with cause: **mo-signaling**

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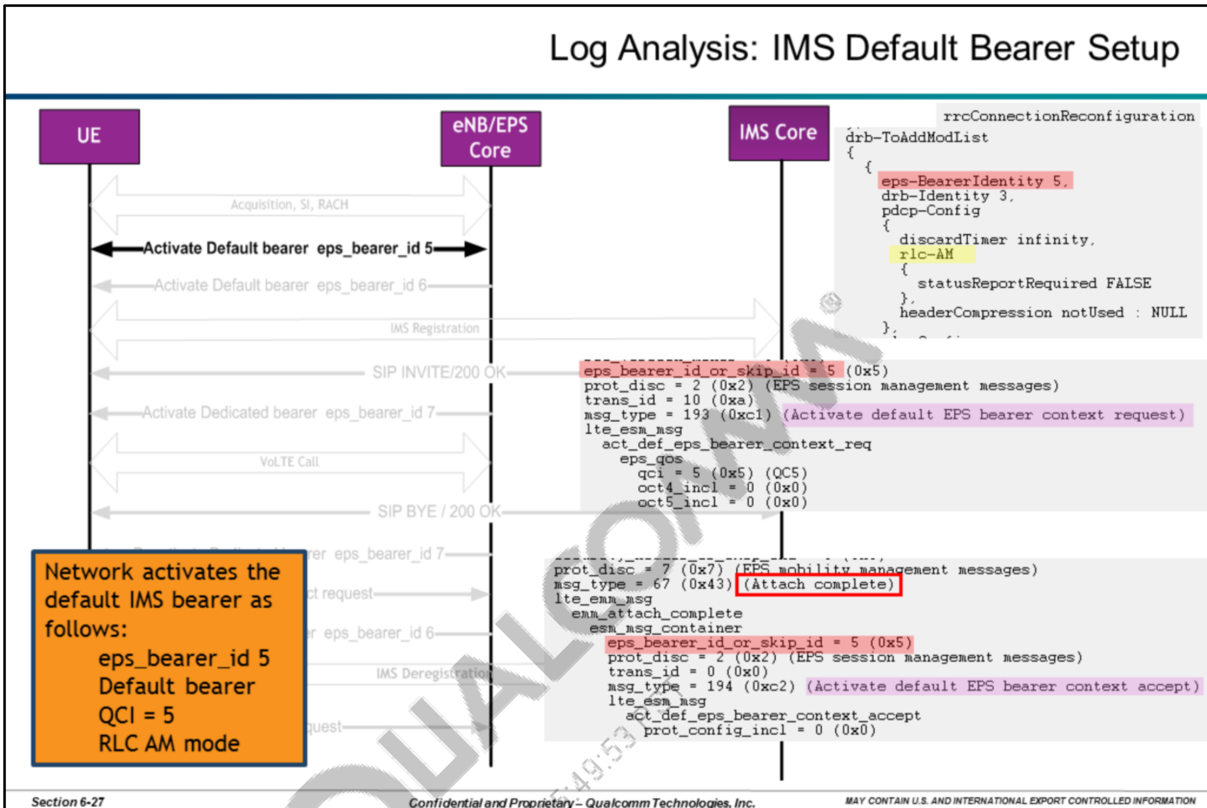
Notes


Log Analysis: IMS Default Bearer Setup
UE
eNB/EPS Core
IMS Core
Acquisition, SI, RACH
Activate Default bearer eps_bearer_id 5
Activate Default bearer eps_bearer_id 6
IMS Registration
SIP INVITE/200 OK
Activate Dedicated bearer eps_bearer_id 7
VoLTE Call
SIP BYE / 200 OK
rrcConnectionReconfiguration
drb-ToAddModList
eps-BearerIdentity 5,
drb-Identity 3,
pdcp-Config
discardTimer infinity,
rlc-AM
statusReportRequired FALSE
headerCompression notUsed : NULL
eps_bearer_id_or_skip_id = 5 (0x5)
prot_disc = 2 (0x2) (EPS session management messages)
trans_id = 10 (0xa)
msg_type = 193 (0xc1) (Activate default EPS bearer context request)
lte_esm_msg
act_def_eps_bearer_context_req
eps_qos
qci = 5 (0x5) (QC5)
oct4_incl = 0 (0x0)
oct5_incl = 0 (0x0)
prot_disc = 7 (0x7) (EPS mobility management messages)
msg_type = 67 (0x43) (Attach complete)
lte_emm_msg
emm_attach_complete
esm_msg_container
eps_bearer_id_or_skip_id = 5 (0x5)
prot_disc = 2 (0x2) (EPS session management messages)
trans_id = 0 (0x0)
msg_type = 194 (0xc2) (Activate default EPS bearer context accept)
lte_esm_msg
act_def_eps_bearer_context_accept
prot_config_incl = 0 (0x0)
Network activates the default IMS bearer as follows:
eps_bearer_id 5
Default bearer
QCI = 5
RLC AM mode
IMS Deregistration
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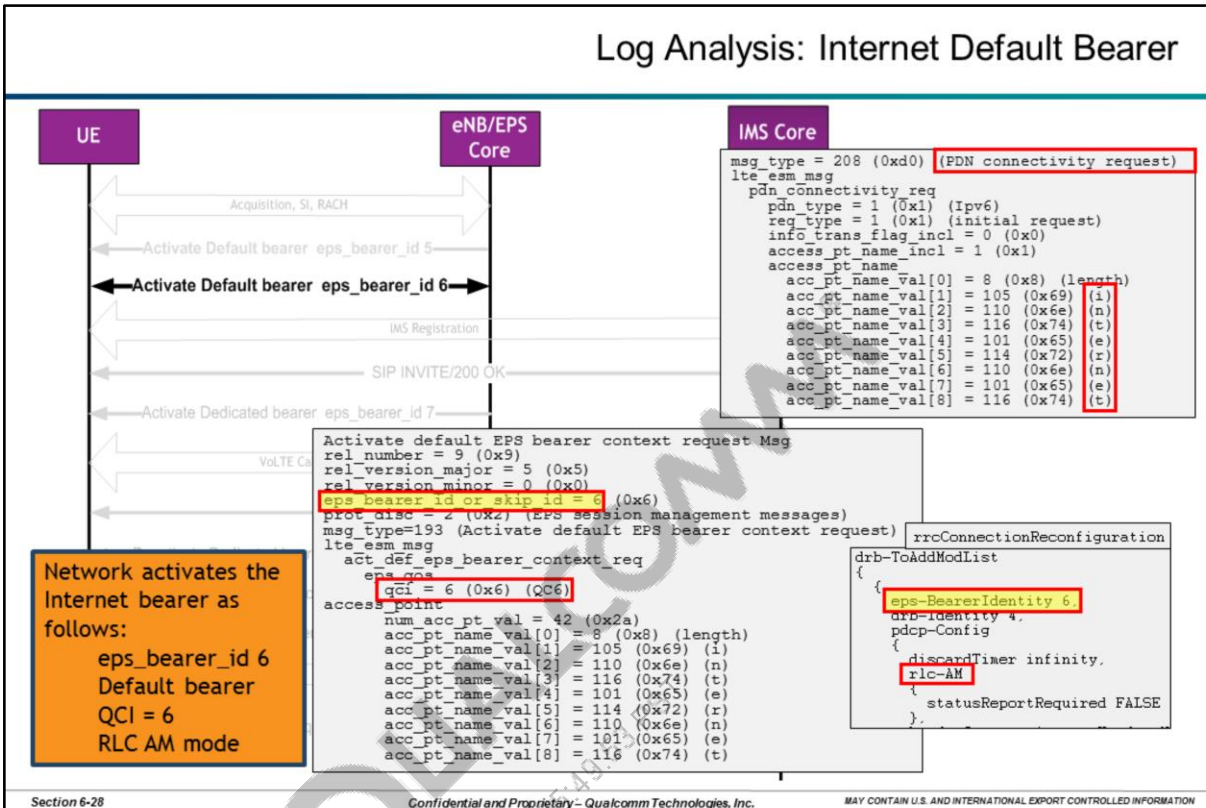
Notes


Log Analysis: Internet Default Bearer
UE
eNB/EPS Core
IMS Core
Acquisition, SI, RACH
Activate Default bearer eps_bearer_id 5
Activate Default bearer eps_bearer_id 6
IMS Registration
SIP INVITE/200 OK
Activate Dedicated bearer eps_bearer_id 7
msg_type = 208 (0xd0) (PDN connectivity request)
lte_esm_msg
pdn_connectivity_req
pdn_type = 1 (0x1) (Ipv6)
req_type = 1 (0x1) (initial request)
info_trans_flag_incl = 0 (0x0)
access_pt_name_incl = 1 (0x1)
access_pt_name
acc_pt_name_val[0] = 8 (0x8) (length)
acc_pt_name_val[1] = 105 (0x69) (i)
acc_pt_name_val[2] = 110 (0x6e) (n)
acc_pt_name_val[3] = 116 (0x74) (t)
acc_pt_name_val[4] = 101 (0x65) (e)
acc_pt_name_val[5] = 114 (0x72) (r)
acc_pt_name_val[6] = 110 (0x6e) (n)
acc_pt_name_val[7] = 101 (0x65) (e)
acc_pt_name_val[8] = 116 (0x74) (t)
Activate default EPS bearer context request Msg
rel_number = 9 (0x9)
rel_version_major = 5 (0x5)
rel_version_minor = 0 (0x0)
eps_bearer_id_or_skip_id = 6 (0x6)
prot_disc = 2 (0x2) (EPS session management messages)
msg_type=193 (Activate default EPS bearer context request)
lte_esm_msg
act_def_eps_bearer_context_req
eps_qos
qci = 6 (0x6) (QC6)
access_point
num_acc_pt_val = 42 (0x2a)
acc_pt_name_val[0] = 8 (0x8) (length)
acc_pt_name_val[1] = 105 (0x69) (i)
acc_pt_name_val[2] = 110 (0x6e) (n)
acc_pt_name_val[3] = 116 (0x74) (t)
acc_pt_name_val[4] = 101 (0x65) (e)
acc_pt_name_val[5] = 114 (0x72) (r)
acc_pt_name_val[6] = 110 (0x6e) (n)
acc_pt_name_val[7] = 101 (0x65) (e)
acc_pt_name_val[8] = 116 (0x74) (t)
rrcConnectionReconfiguration
drb-ToAddModList
{
{
eps-BearerIdentity 6,
drb-Identity 4,
pdcp-Config
{
discardTimer infinity,
rlc-AM
{
statusReportRequired FALSE
},
Network activates the Internet bearer as follows:
eps_bearer_id 6
Default bearer
QCI = 6
RLC AM mode
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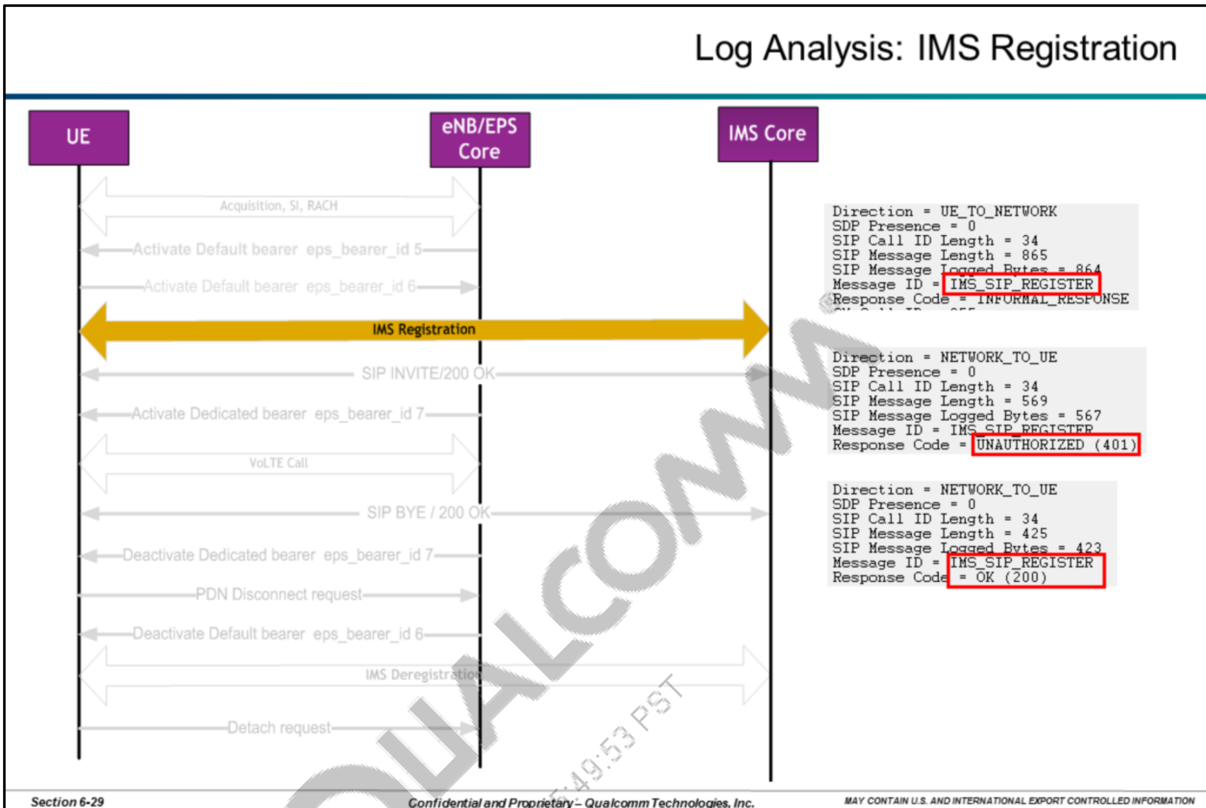
Notes


Log Analysis: IMS Registration
UE
eNB/EPS Core
IMS Core
Acquisition, SI, RACH
Activate Default bearer eps_bearer_id 5
Activate Default bearer eps_bearer_id 6
IMS Registration
SIP INVITE/200 OK
Activate Dedicated bearer eps_bearer_id 7
VoLTE Call
SIP BYE / 200 OK
Deactivate Dedicated bearer eps_bearer_id 7
PDN Disconnect request
Deactivate Default bearer eps_bearer_id 6
IMS Deregistration
Detach request
Direction = UE_TO_NETWORK
SDP Presence = 0
SIP Call ID Length = 34
SIP Message Length = 865
SIP Message Logged Bytes = 864
Message ID = IMS_SIP_REGISTER
Response Code = INFORMAL_RESPONSE
Direction = NETWORK_TO_UE
SDP Presence = 0
SIP Call ID Length = 34
SIP Message Length = 569
SIP Message Logged Bytes = 567
Message ID = IMS_SIP_REGISTER
Response Code = UNAUTHORIZED (401)
Direction = NETWORK_TO_UE
SDP Presence = 0
SIP Call ID Length = 34
SIP Message Length = 425
SIP Message Logged Bytes = 423
Message ID = IMS_SIP_REGISTER
Response Code = OK (200)
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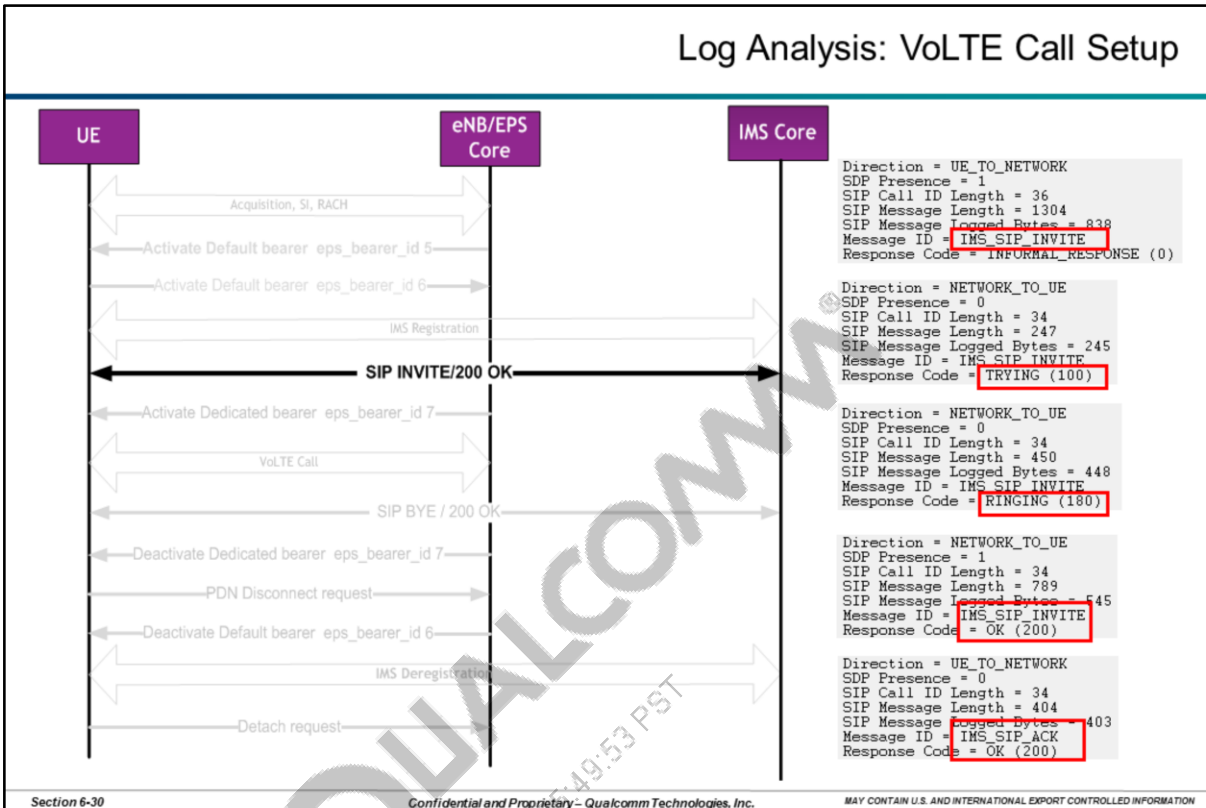
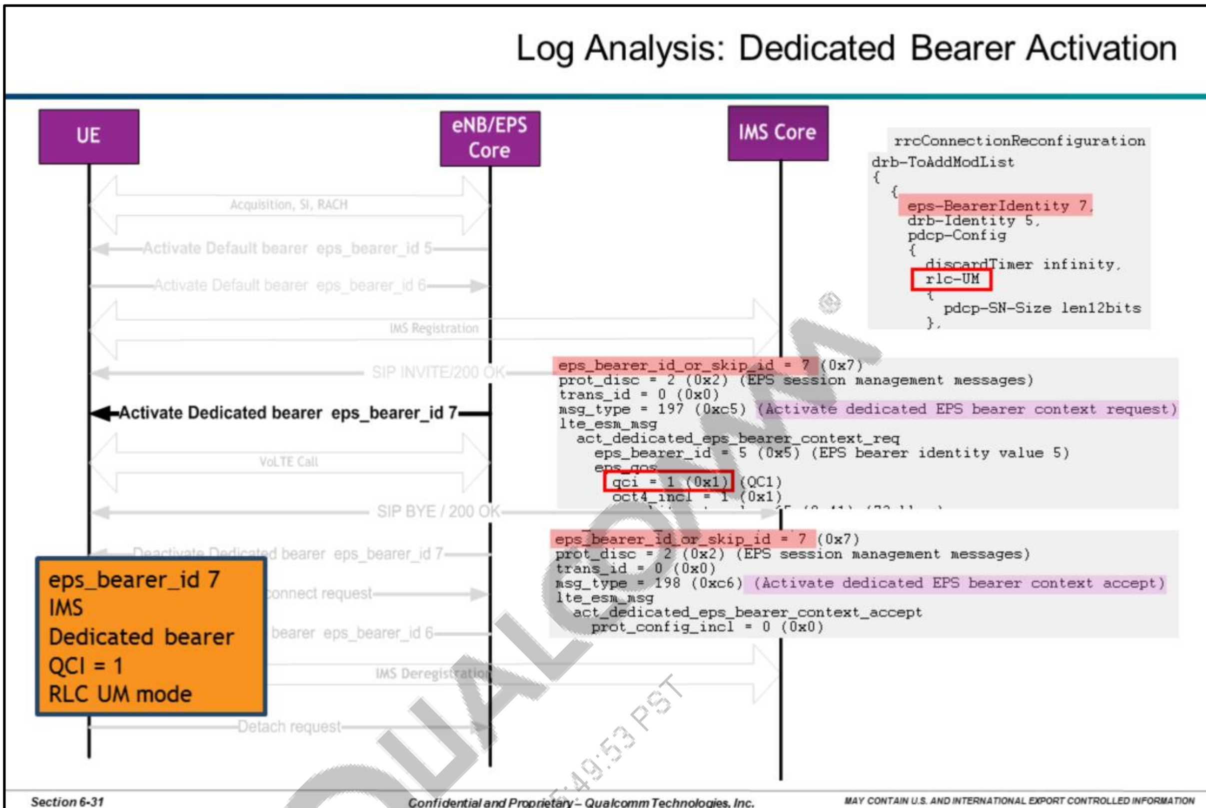
Notes

Section 6: VoLTE Call Termination & IMS De-registration



Notes


Log Analysis: Dedicated Bearer Activation
UE
eNB/EPS Core
IMS Core
Acquisition, SI, RACH
Activate Default bearer eps_bearer_id 5
Activate Default bearer eps_bearer_id 6
IMS Registration
SIP INVITE/200 OK
Activate Dedicated bearer eps_bearer_id 7
VoLTE Call
SIP BYE / 200 OK
Deactivate Dedicated bearer eps_bearer_id 7
IMS Deregistration
Detach request
rrcConnectionReconfiguration
drb-ToAddModList
{
{
eps-BearerIdentity 7,
drb-Identity 5,
pdcp-Config
{
discardTimer infinity,
rlc-UM
{
pdcp-SN-Size len12bits
},
eps_bearer_id_or_skip_id = 7 (0x7)
prot_disc = 2 (0x2) (EPS session management messages)
trans_id = 0 (0x0)
msg_type = 197 (0xc5) (Activate dedicated EPS bearer context request)
lte_esm_msg
act_dedicated_eps_bearer_context_req
eps_bearer_id = 5 (0x5) (EPS bearer identity value 5)
eps_qos
qci = 1 (0x1) (QC1)
oct4_incl = 1 (0x1)
eps_bearer_id_or_skip_id = 7 (0x7)
prot_disc = 2 (0x2) (EPS session management messages)
trans_id = 0 (0x0)
msg_type = 198 (0xc6) (Activate dedicated EPS bearer context accept)
lte_esm_msg
act_dedicated_eps_bearer_context_accept
prot_config_incl = 0 (0x0)
eps_bearer_id 7
IMS
Dedicated bearer
QCI = 1
RLC UM mode
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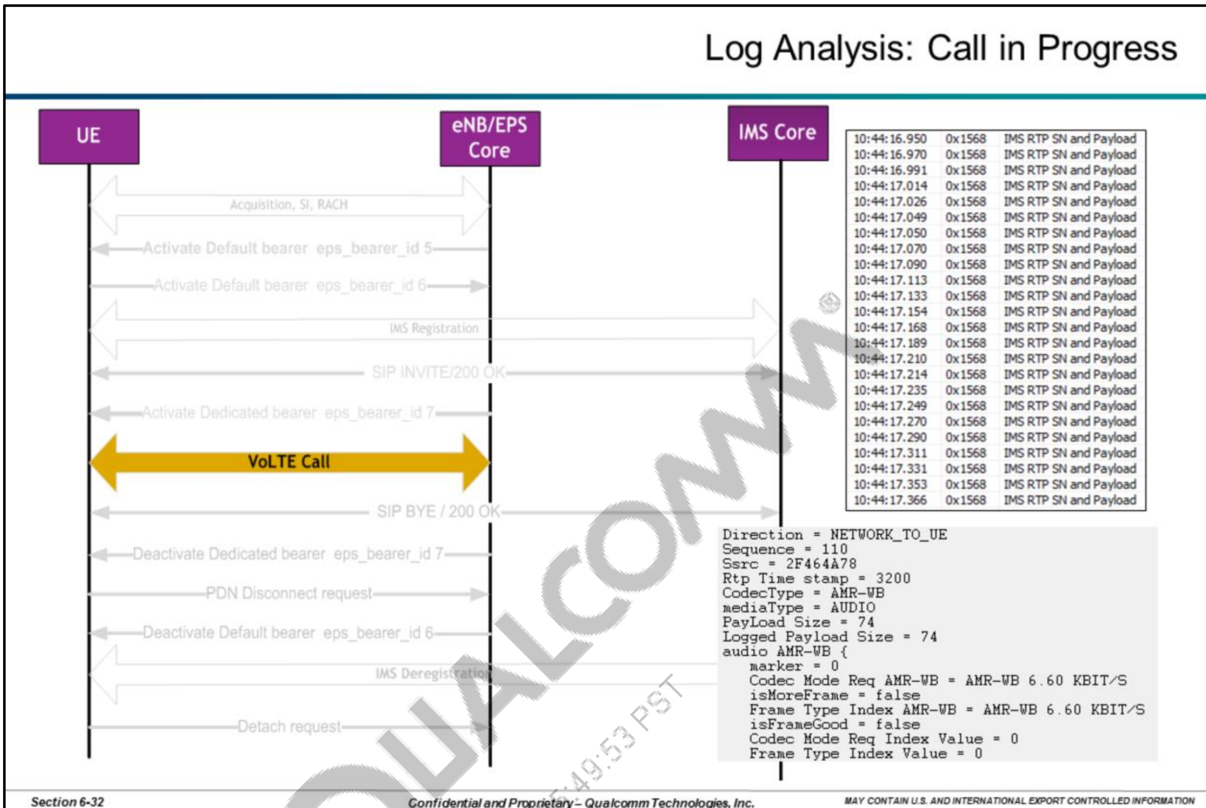
Log Analysis: Call in Progress
UE
eNB/EPS Core
IMS Core
Acquisition, SI, RACH
Activate Default bearer eps_bearer_id 5
Activate Default bearer eps_bearer_id 6
IMS Registration
SIP INVITE/200 OK
Activate Dedicated bearer eps_bearer_id 7
VoLTE Call
SIP BYE / 200 OK
Deactivate Dedicated bearer eps_bearer_id 7
PDN Disconnect request
Deactivate Default bearer eps_bearer_id 6
IMS Deregistration
Detach request
10:44:16.950 0x1568 IMS RTP SN and Payload
10:44:16.970 0x1568 IMS RTP SN and Payload
10:44:16.991 0x1568 IMS RTP SN and Payload
10:44:17.014 0x1568 IMS RTP SN and Payload
10:44:17.026 0x1568 IMS RTP SN and Payload
10:44:17.049 0x1568 IMS RTP SN and Payload
10:44:17.050 0x1568 IMS RTP SN and Payload
10:44:17.070 0x1568 IMS RTP SN and Payload
10:44:17.090 0x1568 IMS RTP SN and Payload
10:44:17.113 0x1568 IMS RTP SN and Payload
10:44:17.133 0x1568 IMS RTP SN and Payload
10:44:17.154 0x1568 IMS RTP SN and Payload
10:44:17.168 0x1568 IMS RTP SN and Payload
10:44:17.189 0x1568 IMS RTP SN and Payload
10:44:17.210 0x1568 IMS RTP SN and Payload
10:44:17.214 0x1568 IMS RTP SN and Payload
10:44:17.235 0x1568 IMS RTP SN and Payload
10:44:17.249 0x1568 IMS RTP SN and Payload
10:44:17.270 0x1568 IMS RTP SN and Payload
10:44:17.290 0x1568 IMS RTP SN and Payload
10:44:17.311 0x1568 IMS RTP SN and Payload
10:44:17.331 0x1568 IMS RTP SN and Payload
10:44:17.353 0x1568 IMS RTP SN and Payload
10:44:17.366 0x1568 IMS RTP SN and Payload
Direction = NETWORK_TO_UE
Sequence = 110
Ssrc = 2F464A78
Rtp Time stamp = 3200
CodecType = AMR-WB
mediaType = AUDIO
PayLoad Size = 74
Logged Payload Size = 74
audio AMR-WB {
marker = 0
Codec Mode Req AMR-WB = AMR-WB 6.60 KBIT/S
isMoreFrame = false
Frame Type Index AMR-WB = AMR-WB 6.60 KBIT/S
isFrameGood = false
Codec Mode Req Index Value = 0
Frame Type Index Value = 0
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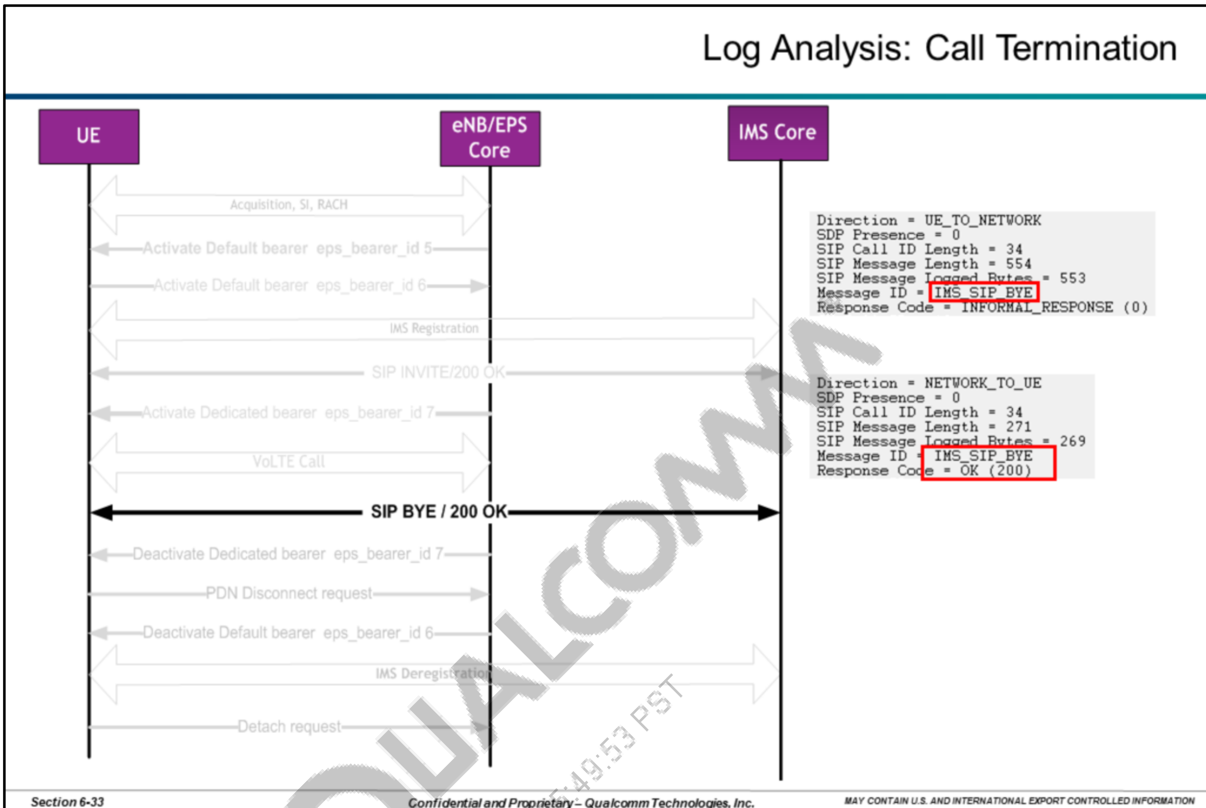
Notes


Log Analysis: Call Termination
UE
eNB/EPS Core
IMS Core
Acquisition, SI, RACH
Activate Default bearer eps_bearer_id 5
Activate Default bearer eps_bearer_id 6
IMS Registration
SIP INVITE/200 OK
Activate Dedicated bearer eps_bearer_id 7
VoLTE Call
SIP BYE / 200 OK
Deactivate Dedicated bearer eps_bearer_id 7
PDN Disconnect request
Deactivate Default bearer eps_bearer_id 6
IMS Deregistration
Detach request
Direction = UE_TO_NETWORK
SDP Presence = 0
SIP Call ID Length = 34
SIP Message Length = 554
SIP Message Logged Bytes = 553
Message ID = IMS_SIP_BYE
Response Code = INFORMAL_RESPONSE (0)
Direction = NETWORK_TO_UE
SDP Presence = 0
SIP Call ID Length = 34
SIP Message Length = 271
SIP Message Logged Bytes = 269
Message ID = IMS_SIP_BYE
Response Code = OK (200)
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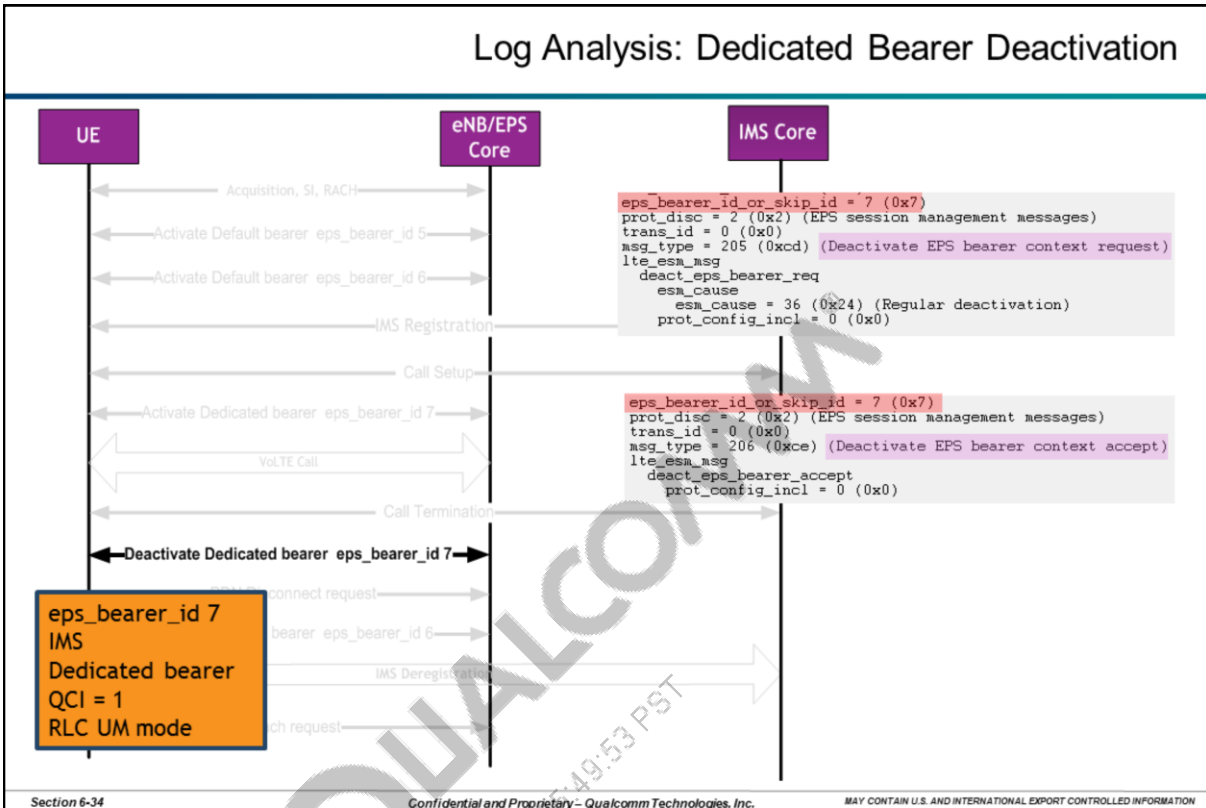
Notes


Log Analysis: Dedicated Bearer Deactivation
UE
eNB/EPS Core
IMS Core
Acquisition, SI, RACH
Activate Default bearer eps_bearer_id 5
Activate Default bearer eps_bearer_id 6
IMS Registration
Call Setup
Activate Dedicated bearer eps_bearer_id 7
VoLTE Call
Call Termination
Deactivate Dedicated bearer eps_bearer_id 7
IMS Deregistration
eps_bearer_id_or_skip_id = 7 (0x7)
prot_disc = 2 (0x2) (EPS session management messages)
trans_id = 0 (0x0)
msg_type = 205 (0xcd) (Deactivate EPS bearer context request)
lte_esm_msg
deact_eps_bearer_req
esm_cause
esm_cause = 36 (0x24) (Regular deactivation)
prot_config_incl = 0 (0x0)
eps_bearer_id_or_skip_id = 7 (0x7)
prot_disc = 2 (0x2) (EPS session management messages)
trans_id = 0 (0x0)
msg_type = 206 (0xce) (Deactivate EPS bearer context accept)
lte_esm_msg
deact_eps_bearer_accept
prot_config_incl = 0 (0x0)
eps_bearer_id 7
IMS
Dedicated bearer
QCI = 1
RLC UM mode
Section 6-34
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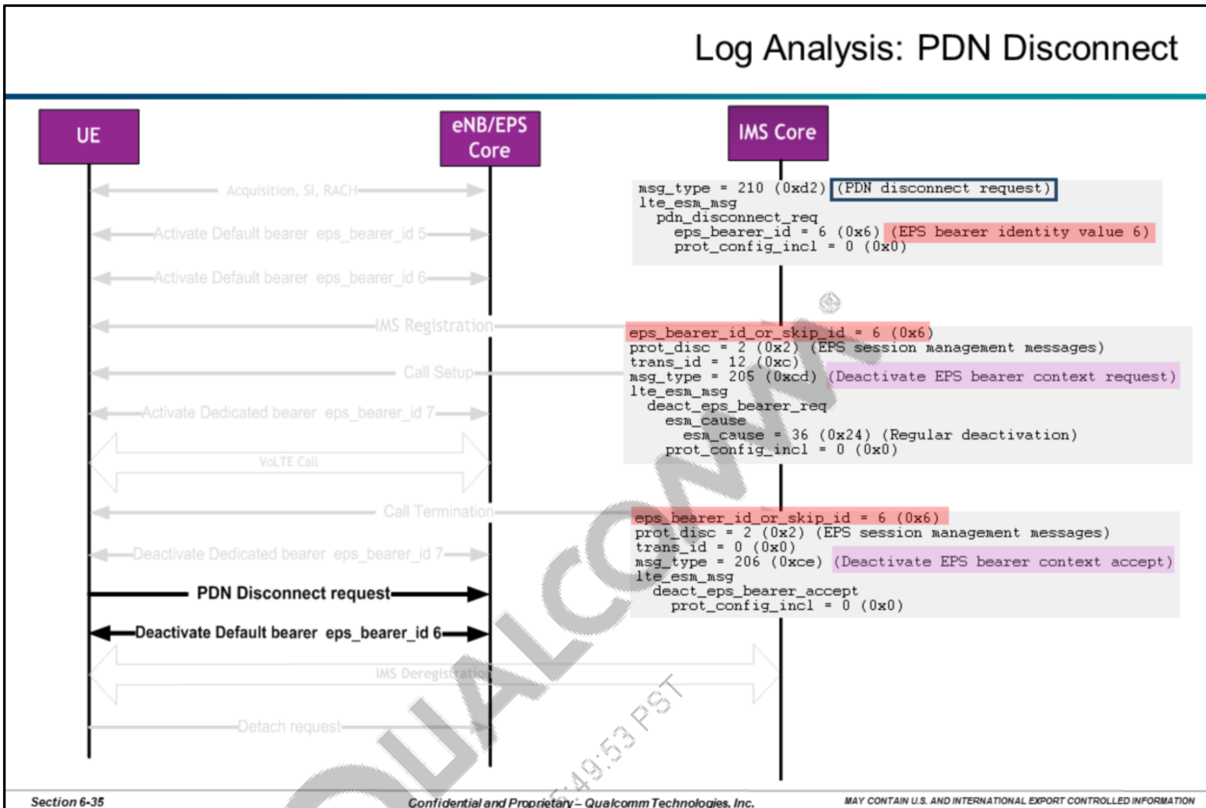
Notes


Log Analysis: PDN Disconnect
UE
eNB/EPS Core
IMS Core
Acquisition, SI, RACH
Activate Default bearer eps_bearer_id 5
Activate Default bearer eps_bearer_id 6
IMS Registration
Call Setup
Activate Dedicated bearer eps_bearer_id 7
VoLTE Call
Call Termination
Deactivate Dedicated bearer eps_bearer_id 7
PDN Disconnect request
Deactivate Default bearer eps_bearer_id 6
IMS Deregistration
Detach request
msg_type = 210 (0xd2) (PDN disconnect request)
lte_esm_msg
pdn_disconnect_req
eps_bearer_id = 6 (0x6) (EPS bearer identity value 6)
prot_config_incl = 0 (0x0)
eps_bearer_id_or_skip_id = 6 (0x6)
prot_disc = 2 (0x2) (EPS session management messages)
trans_id = 12 (0xc)
msg_type = 205 (0xcd) (Deactivate EPS bearer context request)
lte_esm_msg
deact_eps_bearer_req
esm_cause
esm_cause = 36 (0x24) (Regular deactivation)
prot_config_incl = 0 (0x0)
eps_bearer_id_or_skip_id = 6 (0x6)
prot_disc = 2 (0x2) (EPS session management messages)
trans_id = 0 (0x0)
msg_type = 206 (0xce) (Deactivate EPS bearer context accept)
lte_esm_msg
deact_eps_bearer_accept
prot_config_incl = 0 (0x0)
Section 6-35
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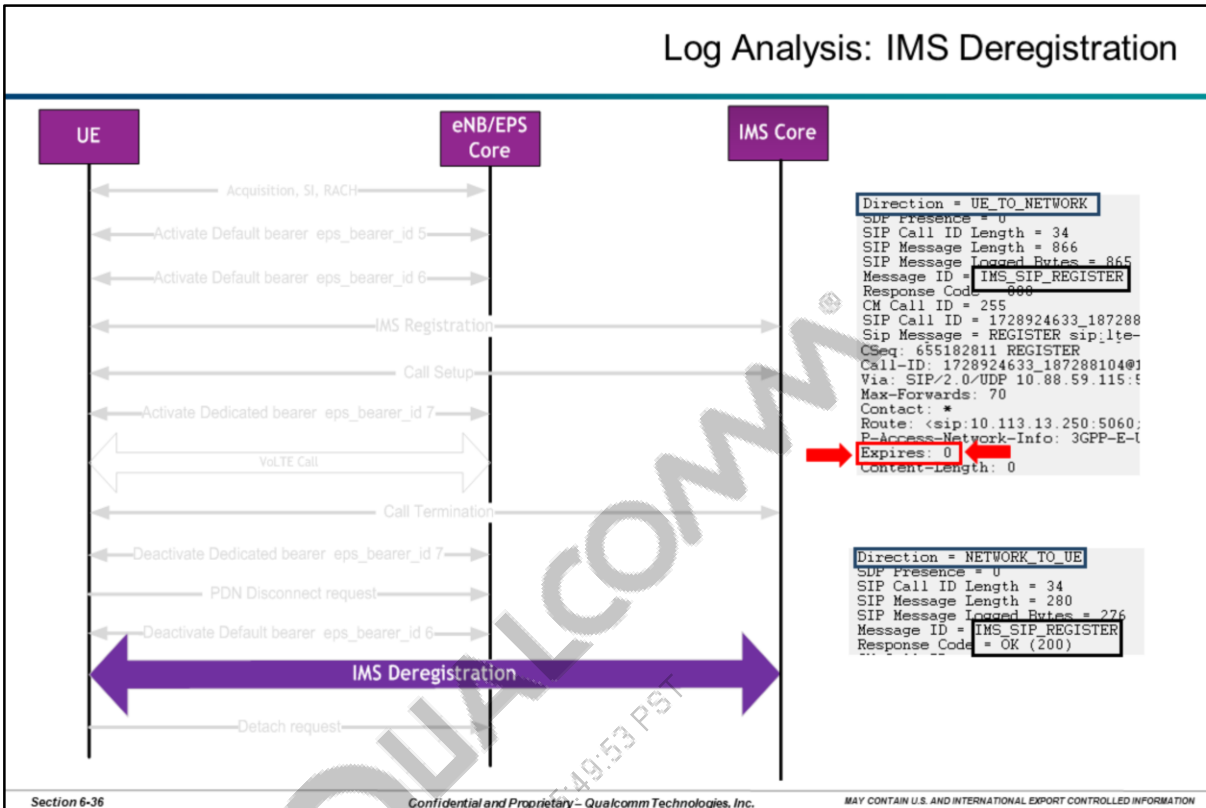
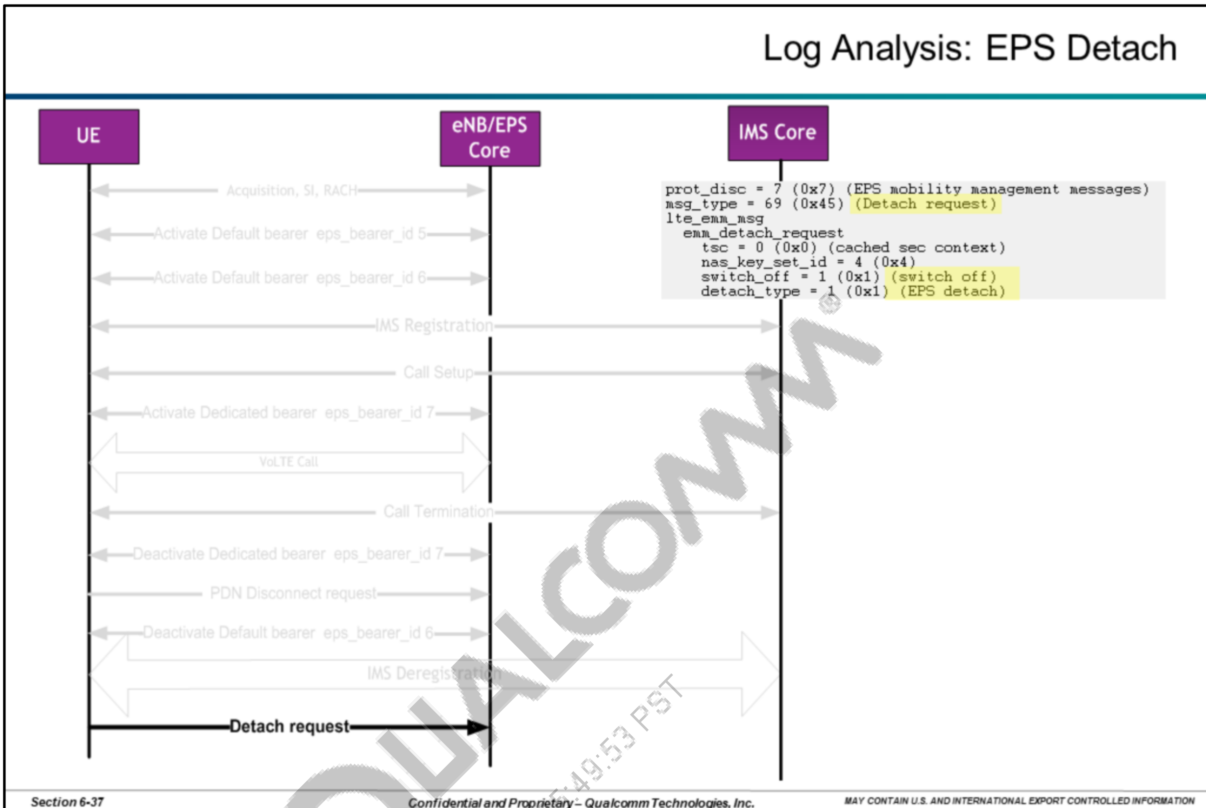
Notes



UE-Triggered IMS Deregistration: IMS Deregistration

IMS Deregistration is performed by sending a REGISTER message with Expired header set to ‘0’.


Log Analysis: EPS Detach
UE
eNB/EPS Core
IMS Core
prot_disc = 7 (0x7) (EPS mobility management messages)
msg_type = 69 (0x45) (Detach request)
lte_emm_msg
emm_detach_request
tsc = 0 (0x0) (cached sec context)
nas_key_set_id = 4 (0x4)
switch_off = 1 (0x1) (switch off)
detach_type = 1 (0x1) (EPS detach)
Acquisition, SI, RACH
Activate Default bearer eps_bearer_id 5
Activate Default bearer eps_bearer_id 6
IMS Registration
Call Setup
Activate Dedicated bearer eps_bearer_id 7
VoLTE Call
Call Termination
Deactivate Dedicated bearer eps_bearer_id 7
PDN Disconnect request
Deactivate Default bearer eps_bearer_id 6
IMS Deregistration
Detach request
Section 6-37
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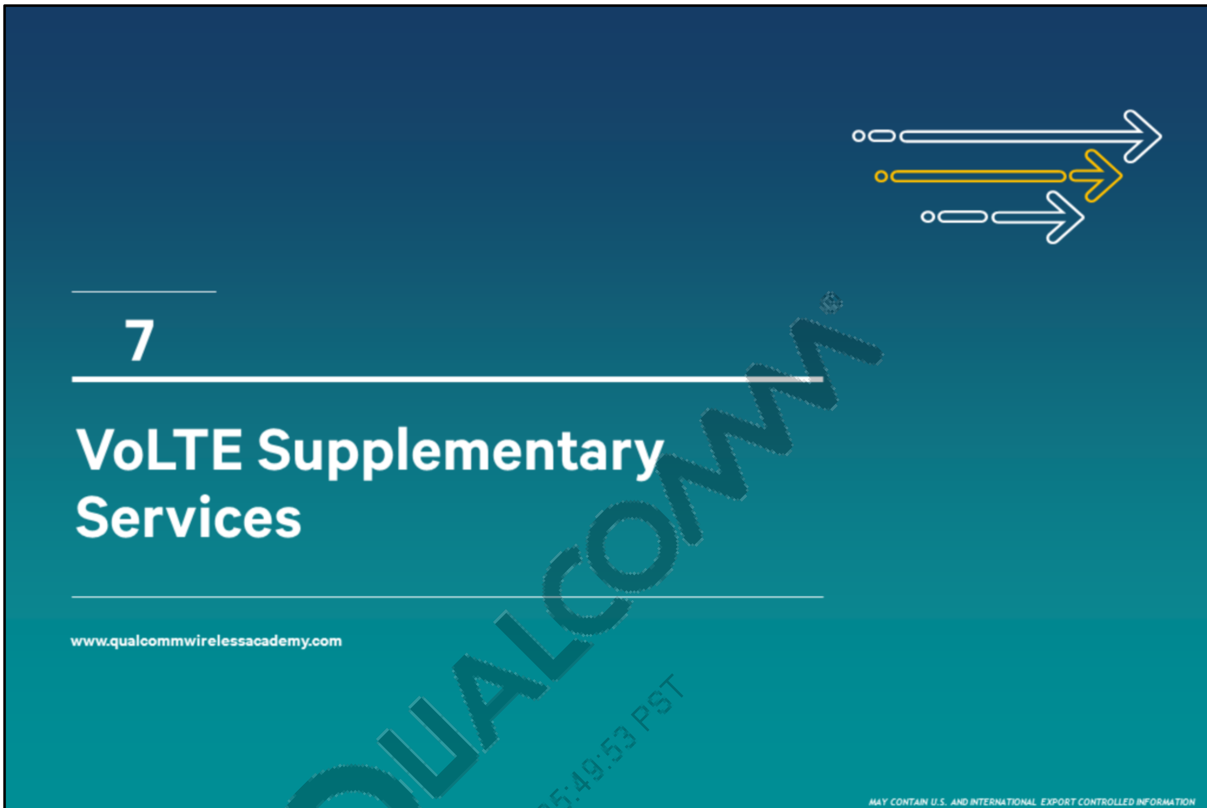
Notes

Reference Log: Acquisition to Deregistration

Reference log file: 06-03-Acquisition_to_PowerDown

Notes


7
VoLTE Supplementary Services
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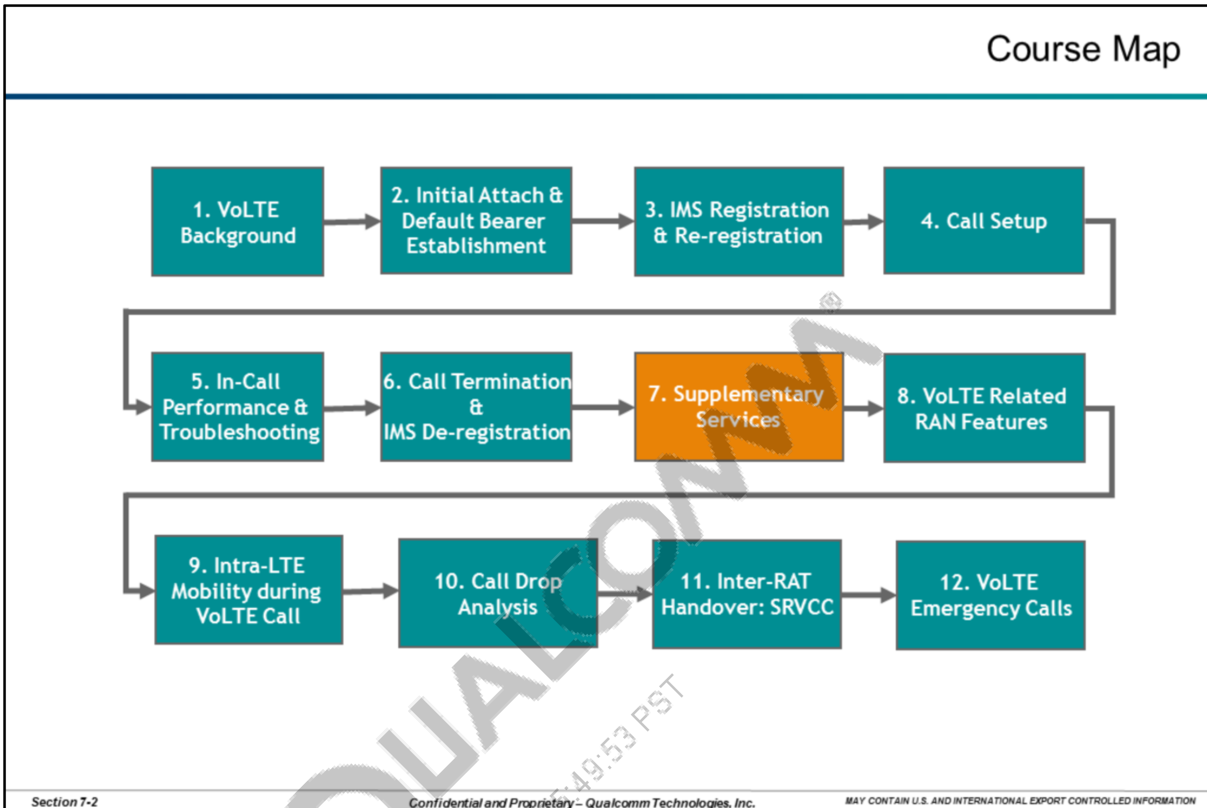
Course Map
1. VoLTE Background
2. Initial Attach & Default Bearer Establishment
3. IMS Registration & Re-registration
4. Call Setup
5. In-Call Performance & Troubleshooting
6. Call Termination & IMS De-registration
7. Supplementary Services
8. VoLTE Related RAN Features
9. Intra-LTE Mobility during VoLTE Call
10. Call Drop Analysis
11. Inter-RAT Handover: SRVCC
12. VoLTE Emergency Calls
Section 7-2
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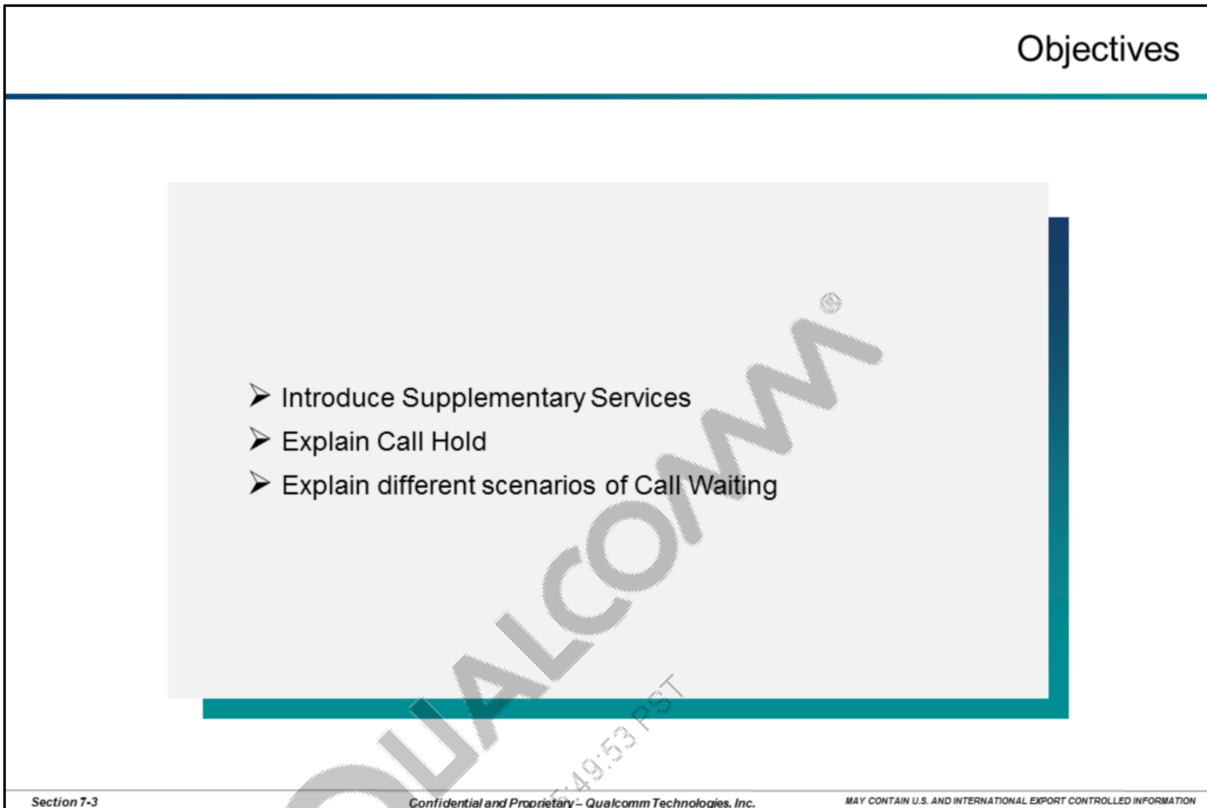
Notes


Objectives
Introduce Supplementary Services
Explain Call Hold
Explain different scenarios of Call Waiting
Section 7-3
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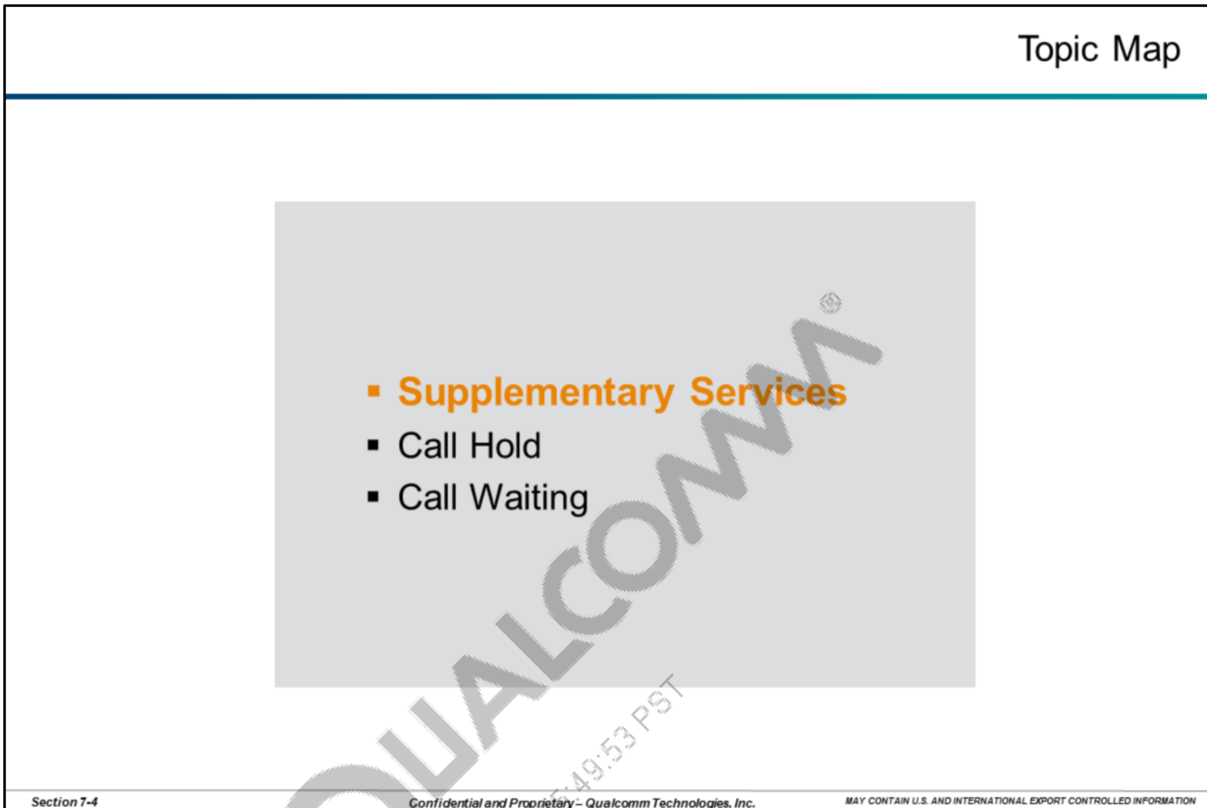
Notes


Topic Map
Supplementary Services
Call Hold
Call Waiting
Section 7-4
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Notes

Supplementary Services

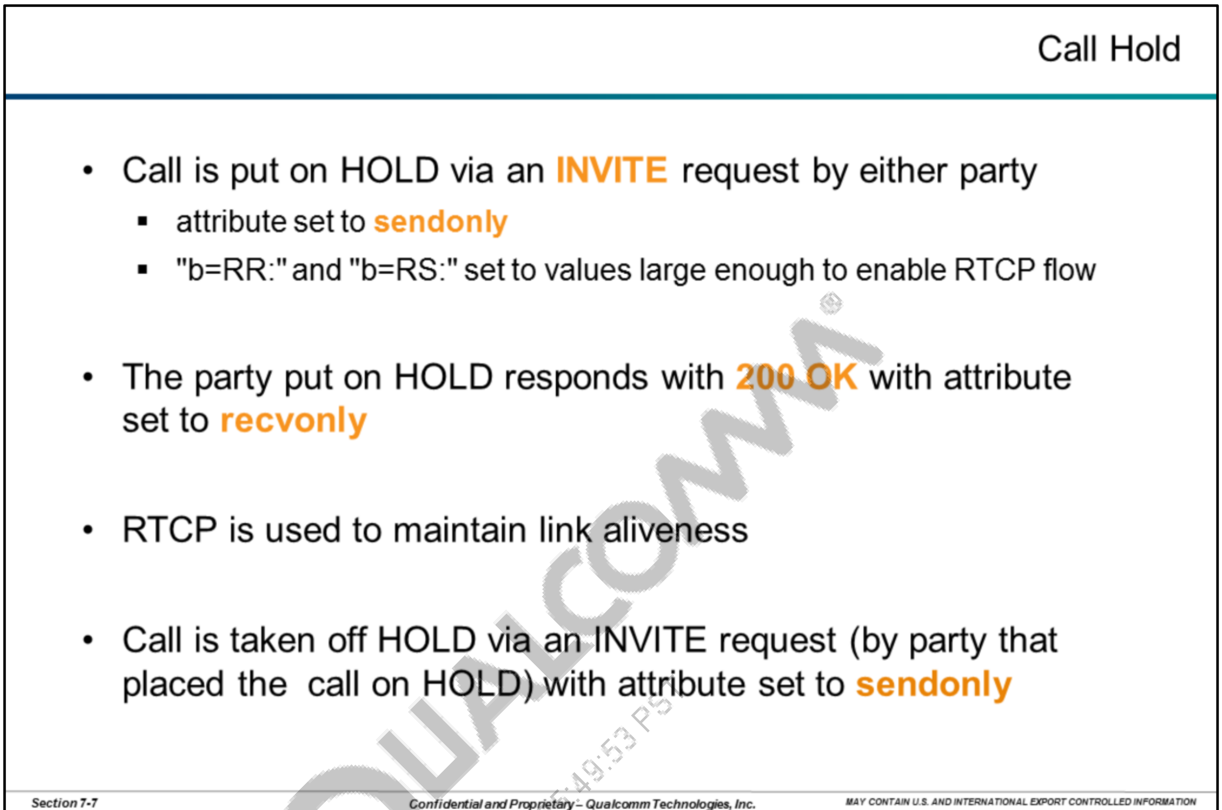
- GSMA PRD IR.92 specifies a **mandatory subset of supplementary services**
- These mandatory supplementary services include different scenarios of:
  - Caller ID presentation/restriction
  - Call forwarding
  - Call waiting/call hold
  - Call barring
  - Conference calls

Notes

Topic Map

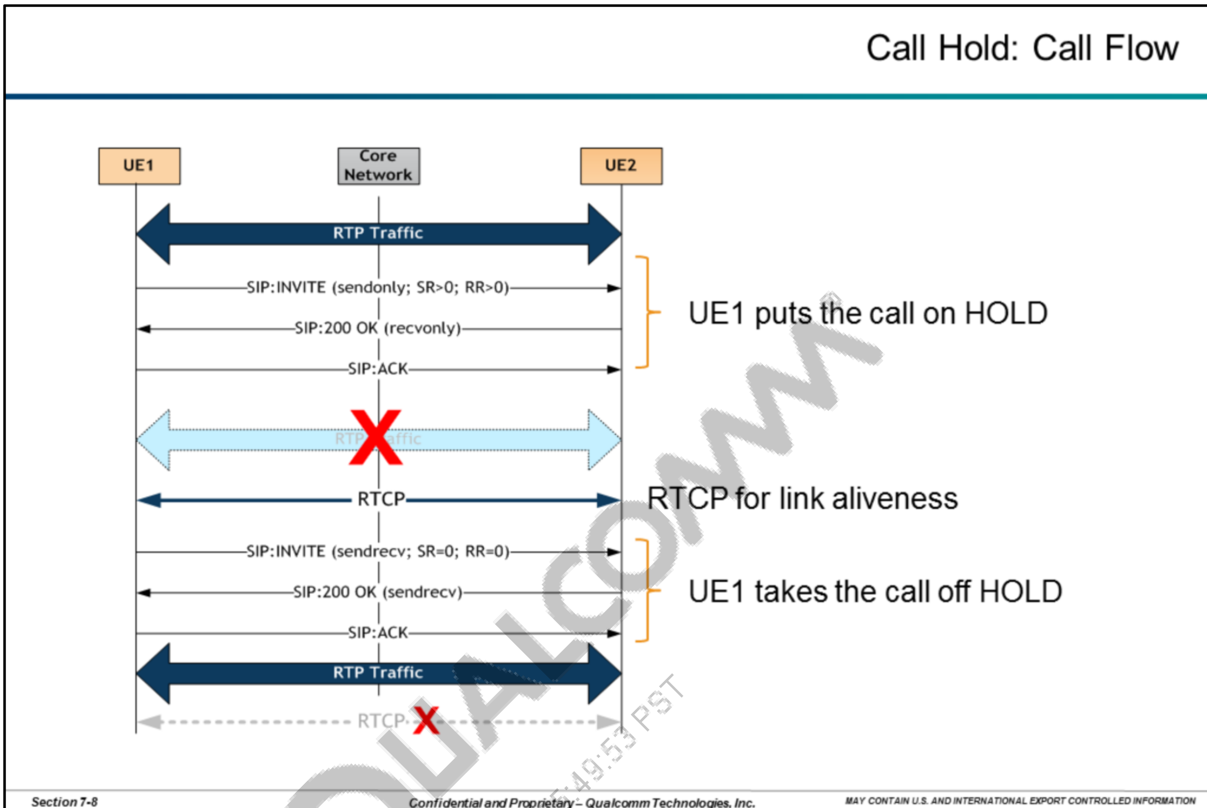
- Supplementary Services
- **Call Hold**
- Call Waiting

Notes



Reference

For details of Call HOLD, refer to 3GPP TS 24.610


Call Hold: Call Flow
UE1
Core Network
UE2
RTP Traffic
SIP:INVITE (sendonly; SR>0; RR>0)
SIP:200 OK (recvonly)
SIP:ACK
UE1 puts the call on HOLD
RTCP
RTCP for link aliveness
SIP:INVITE (sendrecv; SR=0; RR=0)
SIP:200 OK (sendrecv)
SIP:ACK
UE1 takes the call off HOLD
RTP Traffic
RTCP
Section 7-8
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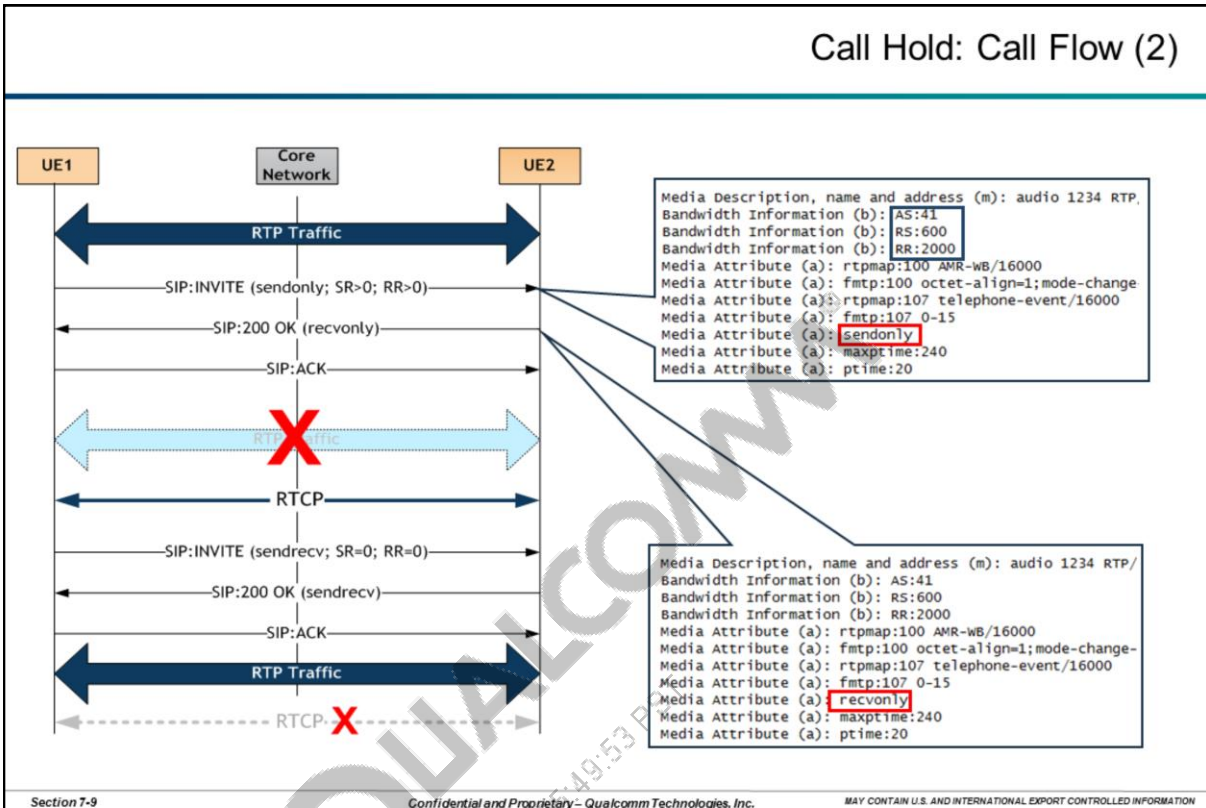
Notes


Call Hold: Call Flow (2)
UE1
Core Network
UE2
RTP Traffic
SIP:INVITE (sendonly; SR>0; RR>0)
SIP:200 OK (recvonly)
SIP:ACK
RTP Traffic
RTCP
SIP:INVITE (sendrecv; SR=0; RR=0)
SIP:200 OK (sendrecv)
SIP:ACK
RTP Traffic
RTCP
Media Description, name and address (m): audio 1234 RTP
Bandwidth Information (b): AS:41
Bandwidth Information (b): RS:600
Bandwidth Information (b): RR:2000
Media Attribute (a): rtpmap:100 AMR-WB/16000
Media Attribute (a): fmtp:100 octet-align=1;mode-change
Media Attribute (a): rtpmap:107 telephone-event/16000
Media Attribute (a): fmtp:107 0-15
Media Attribute (a): sendonly
Media Attribute (a): maxptime:240
Media Attribute (a): ptime:20
Media Description, name and address (m): audio 1234 RTP/
Bandwidth Information (b): AS:41
Bandwidth Information (b): RS:600
Bandwidth Information (b): RR:2000
Media Attribute (a): rtpmap:100 AMR-WB/16000
Media Attribute (a): fmtp:100 octet-align=1;mode-change-
Media Attribute (a): rtpmap:107 telephone-event/16000
Media Attribute (a): fmtp:107 0-15
Media Attribute (a): recvonly
Media Attribute (a): maxptime:240
Media Attribute (a): ptime:20
Section 7-9
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Notes

Log Analysis: Call Hold

Log Analysis Procedure: Call Hold

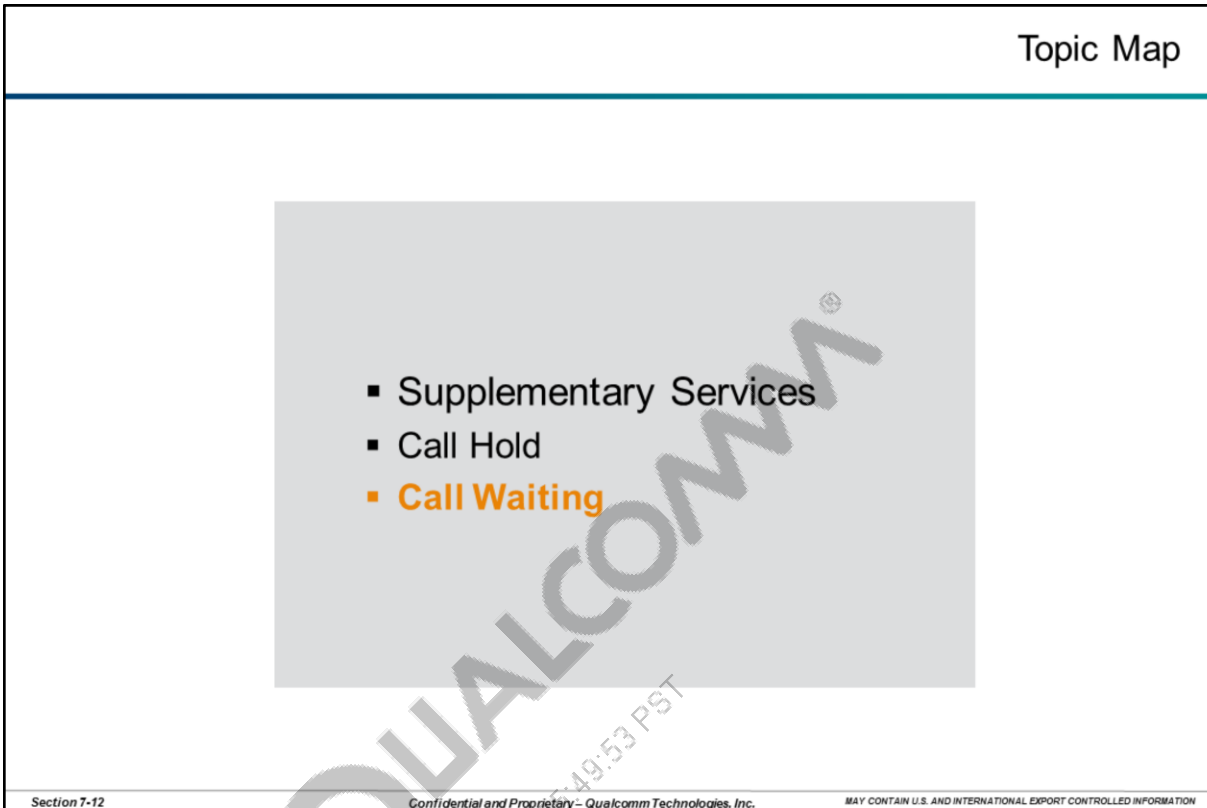
Open File: 07-01-Call_Hold

Notes

Call Hold: Log Walk-Through

Step	Look for	Packet No.	Time Stamp	Verify
1	SIP: INVITE SIP: 100 Trying SIP: 180 Ringing SIP: 200 OK SIP: ACK	1 – 5	23:55:51.620 through 23:55:57.645	Call between UE1 and UE2 is established
2	SIP: INVITE	6	23:56:10.695	UE1 puts UE2 on hold RS > 0 ; RR > 0 → enables RTCP a: sendonly
3	SIP: 200 OK	8	23:56:10.746	RS > 0 ; RR > 0 a: recvonly
4	SIP: INVITE	10	23:57:02.461	UE1 puts UE2 on hold RS: 0 ; RR: 0 → disables RTCP a: sendrecv
5	SIP: 200 OK	11	23:57:10.507	RS: 0 ; RR: 0 → disables RTCP a: sendrecv

Notes


Topic Map
Supplementary Services
Call Hold
Call Waiting
Section 7-12
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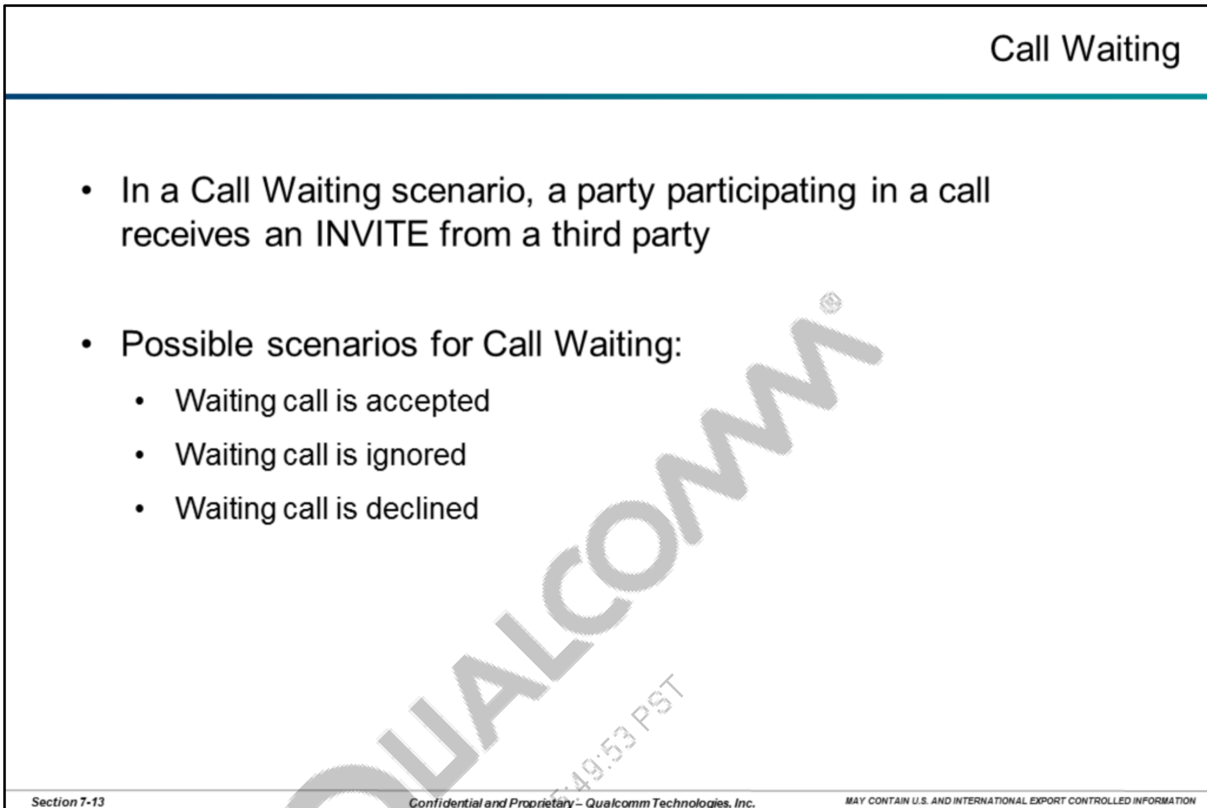
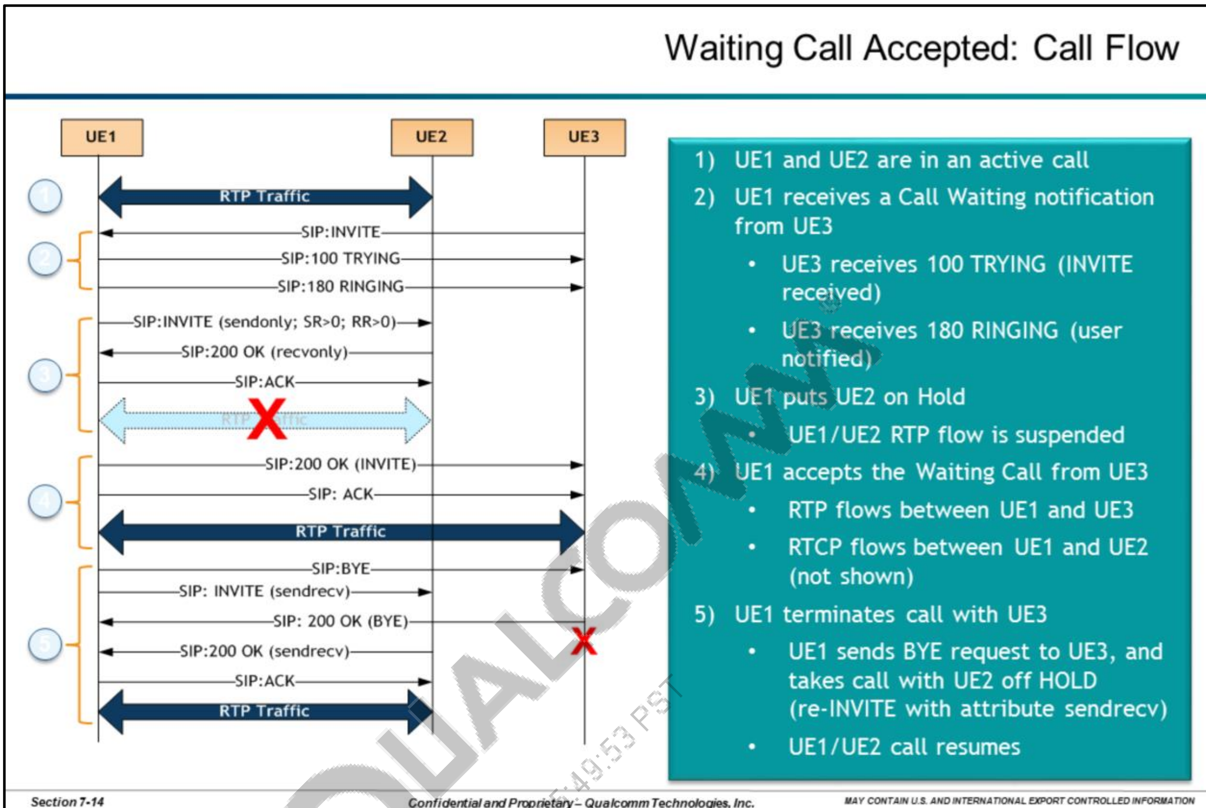
Notes



Call Waiting

For details of Call WAITING, refer to 3GPP TS 24.615

The next slides discuss the "Accepted Waiting call" case. Signalling for 'Ignored' and 'Declined' scenarios is operator specific.


Waiting Call Accepted: Call Flow
UE1
UE2
UE3
RTP Traffic
SIP:INVITE
SIP:100 TRYING
SIP:180 RINGING
SIP:INVITE (sendonly; SR>0; RR>0)
SIP:200 OK (recvonly)
SIP:ACK
SIP:200 OK (INVITE)
SIP: ACK
RTP Traffic
SIP:BYE
SIP: INVITE (sendrecv)
SIP: 200 OK (BYE)
SIP:200 OK (sendrecv)
SIP:ACK
RTP Traffic
1) UE1 and UE2 are in an active call
2) UE1 receives a Call Waiting notification from UE3
• UE3 receives 100 TRYING (INVITE received)
• UE3 receives 180 RINGING (user notified)
3) UE1 puts UE2 on Hold
• UE1/UE2 RTP flow is suspended
4) UE1 accepts the Waiting Call from UE3
• RTP flows between UE1 and UE3
• RTCP flows between UE1 and UE2 (not shown)
5) UE1 terminates call with UE3
• UE1 sends BYE request to UE3, and takes call with UE2 off HOLD (re-INVITE with attribute sendrecv)
• UE1/UE2 call resumes
Section 7-14
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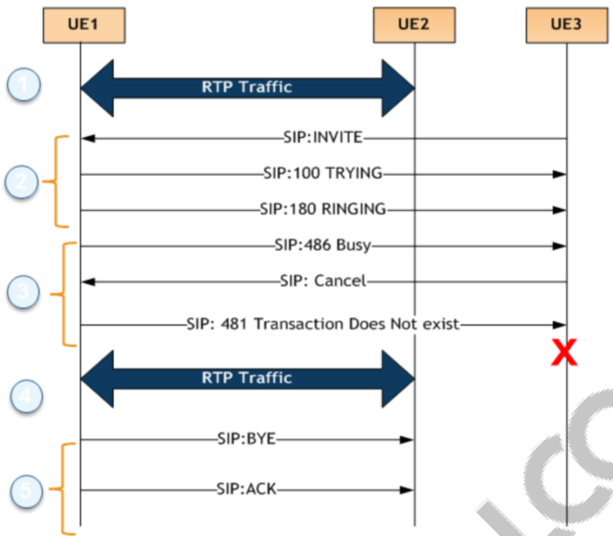
Notes

Waiting Call Declined: Call Flow



1) UE1 and UE2 are in an active call
2) UE1 receives a Call Waiting notification from UE3
   - UE3 receives 100 TRYING (INVITE received)
   - UE3 receives 180 RINGING (user notified)
3) UE1 Rejects the Waiting Call
4) UE1/UE2 RTP flow is still active
5) UE1/UE2 is terminated gracefully after UE1 sends a normal BYE request

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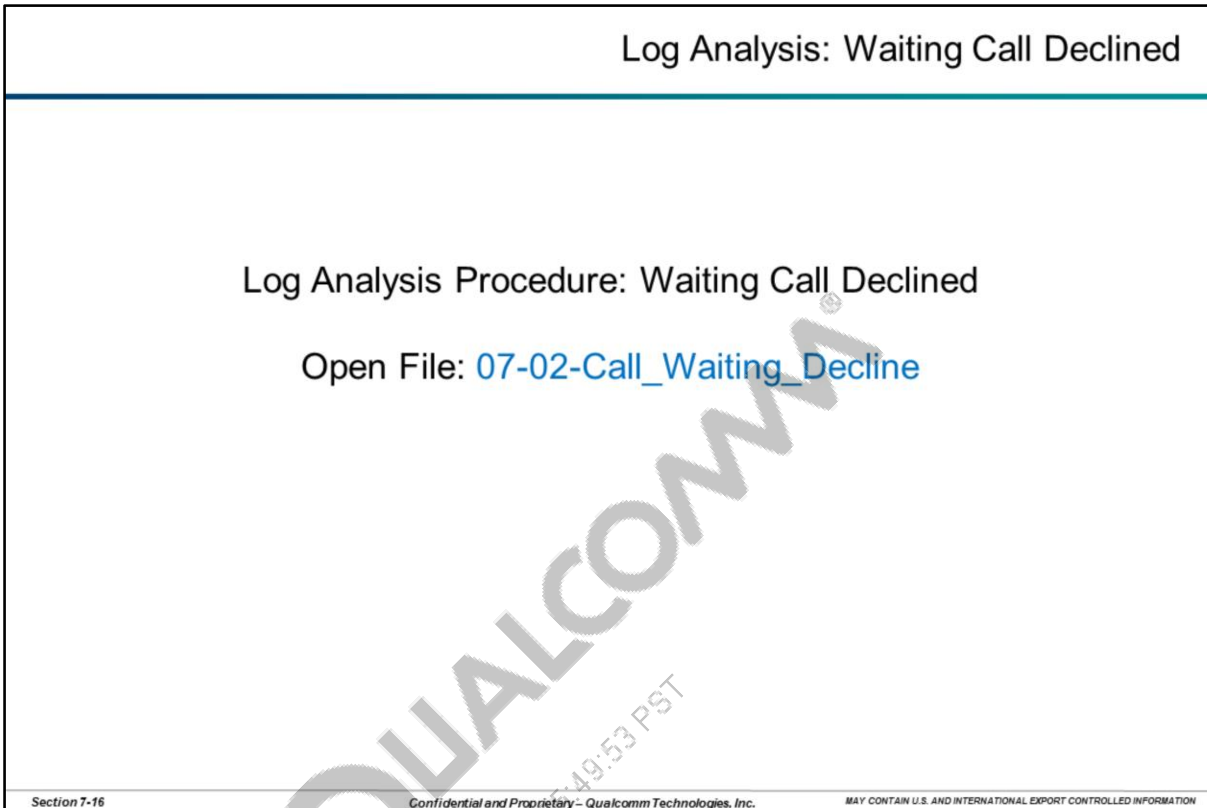
Notes


Log Analysis: Waiting Call Declined
Log Analysis Procedure: Waiting Call Declined
Open File: 07-02-Call_Waiting_Decline
Section 7-16
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Notes

Waiting Call Declined: Log Walk-Through

Step	Look for	Packet No.	Time Stamp	Verify
1	SIP: INVITE SIP: 100 Trying SIP: 180 Ringing SIP: 200 OK SIP: ACK	1 – 5	09:24:17.877 through 09:24:21.345	Call between UE1 and UE2 is established
2	SIP: INVITE	7	09:24:35.777	Waiting call (from UE3) notification received by UE1
3	SIP: 100 Trying SIP: 180 Ringing	8 – 9	09:24:35.800 09:24:35.975	UE1 user is alerted
4	SIP: 486 Busy	10	09:24:46.855	UE1 rejects the Waiting Call
5	SIP: CANCEL	11	09:24:56.252	UE3 cancels the request

Notes

Specifications References

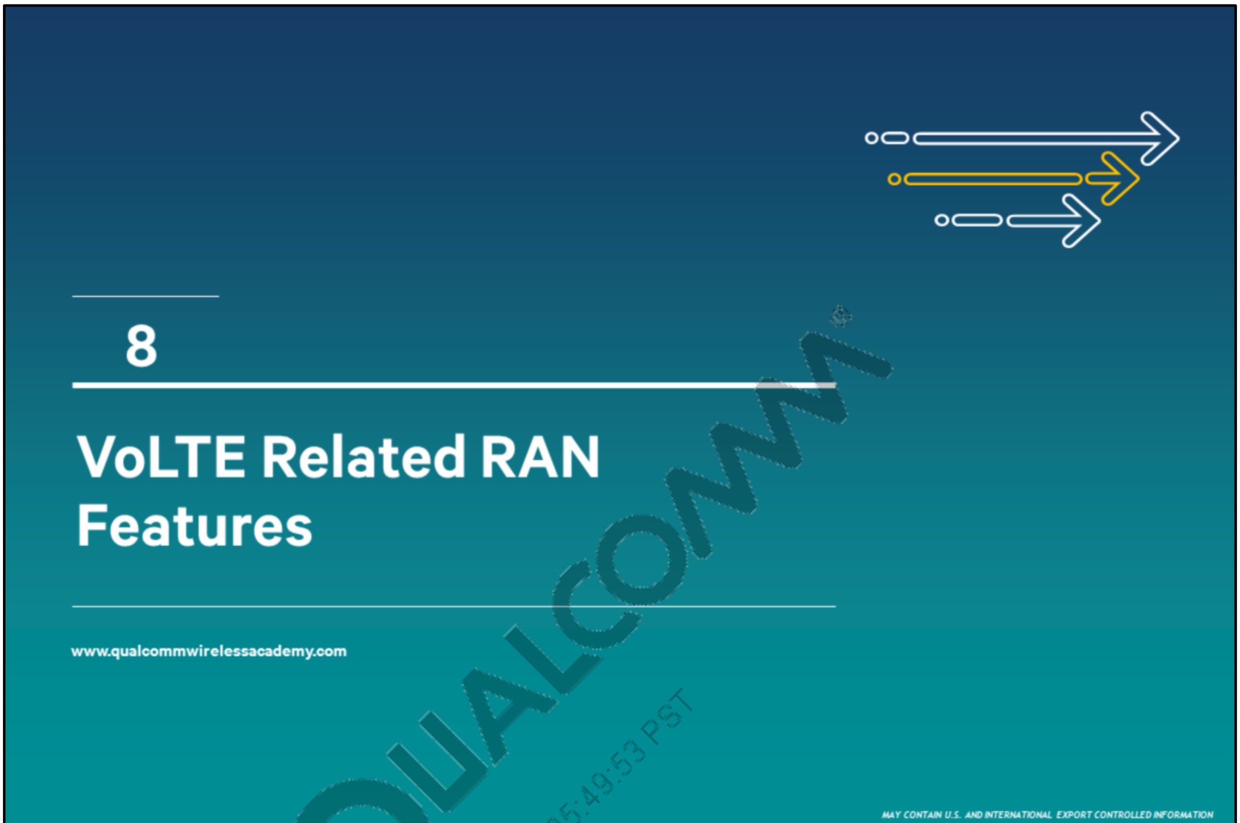
Specifications	Title
3GPP TS 24.173	IMS MMTel Supplementary Services
3GPP TS 24.610	Communication HOLD using IP Multimedia (IM) Core Network (CN) subsystem; Protocol specification
3GPP TS 24.615	Communication Waiting (CW) using IP Multimedia (IM) Core Network (CN) subsystem; Protocol specification
3GPP TS 24.605	Conference (CONF) using IP Multimedia (IM) Core Network (CN) subsystem; Protocol specification
3GPP TS 24.147	Conferencing using the IP Multimedia (IM) Core Network (CN) subsystem
RFC 3261	SIP: Session Initiation Protocol
RFC 5359	Session Initiation Protocol Service Examples
RFC 4566	SDP: Session Description Protocol
GSMA IR.92	IMS Profile for Voice and SMS
GSMA FCM.01	VoLTE Service Description and Implementation Guidelines

Specifications References

3GPP specifications are available at www.3gpp.org

IETF RFCs are available at www.ietf.org

GSMA documents are available at www.gsma.com


8
VoLTE Related RAN Features
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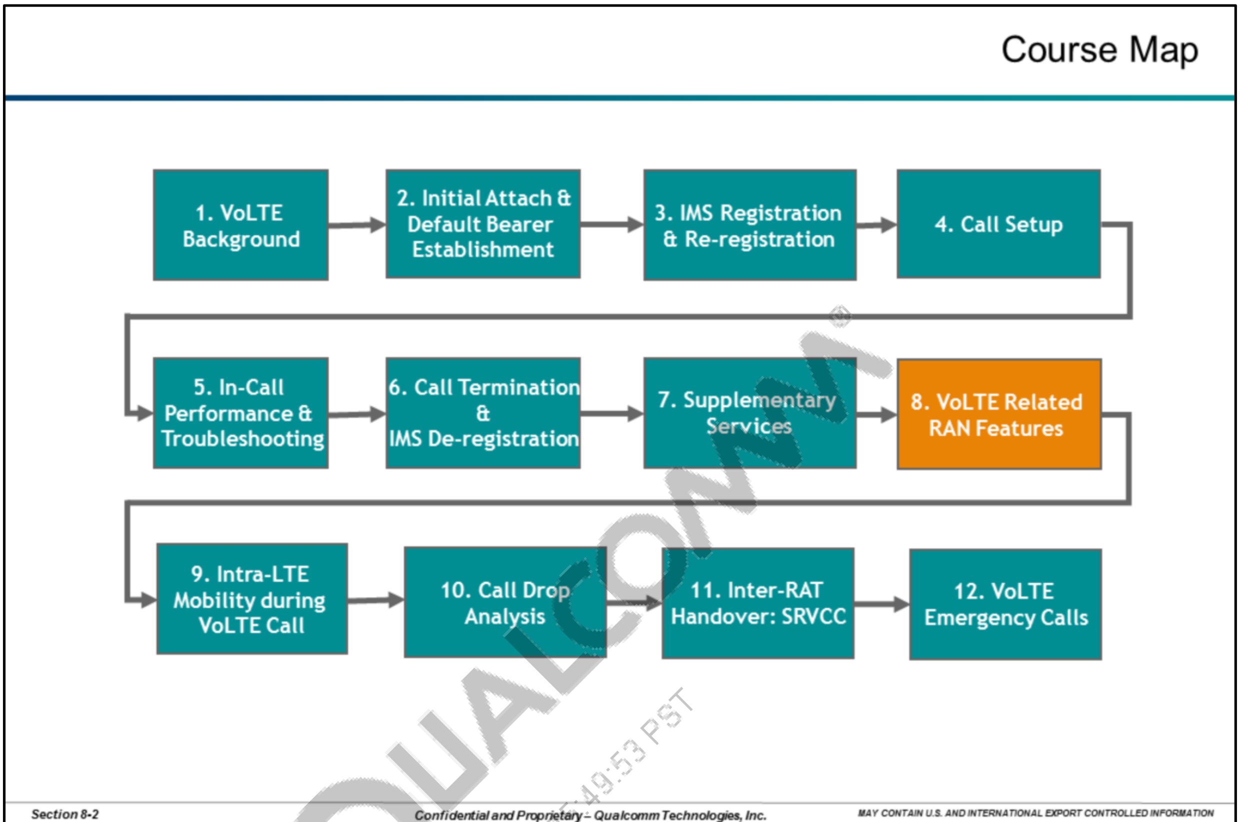
Course Map
1. VoLTE Background
2. Initial Attach & Default Bearer Establishment
3. IMS Registration & Re-registration
4. Call Setup
5. In-Call Performance & Troubleshooting
6. Call Termination & IMS De-registration
7. Supplementary Services
8. VoLTE Related RAN Features
9. Intra-LTE Mobility during VoLTE Call
10. Call Drop Analysis
11. Inter-RAT Handover: SRVCC
12. VoLTE Emergency Calls
Section 8-2
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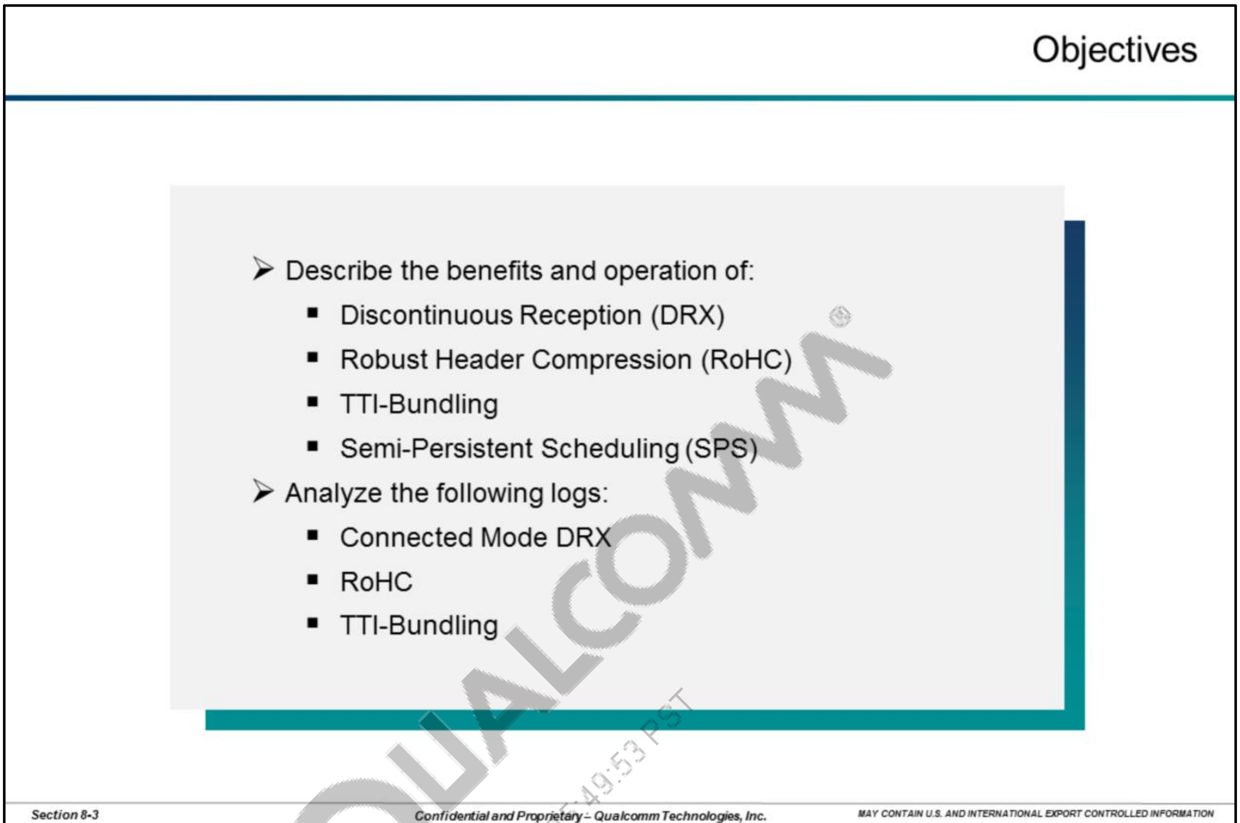
Notes


Objectives
Describe the benefits and operation of:
Discontinuous Reception (DRX)
Robust Header Compression (RoHC)
TTI-Bundling
Semi-Persistent Scheduling (SPS)
Analyze the following logs:
Connected Mode DRX
RoHC
TTI-Bundling
Section 8-3
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Notes


Topic Map
▪ C-DRX
▪ Robust Header Compression (RoHC)
▪ TTI-Bundling
▪ Semi-Persistent Scheduling (SPS)
Section 8-4
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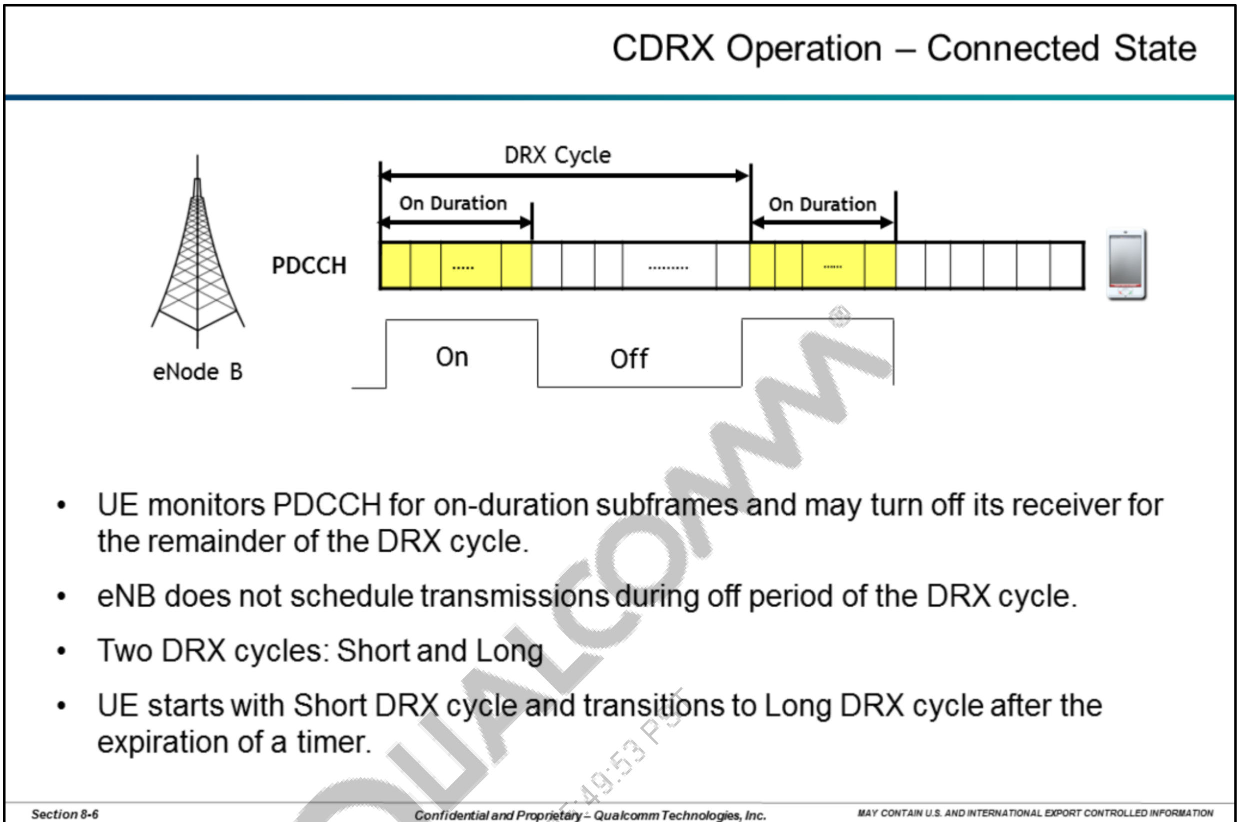
Notes

Discontinuous Reception (DRX)

- Used to reduce power consumption during periods of reduced activity.
- Network (eNB) defines a periodic interval at which no data transfer will occur so the UE can turn off its receiver and enter a lower power state.
- The UE wakes up at the defined interval to perform radio synchronization, check for scheduled data transmissions, network initiated pages, etc., then goes to sleep.
- DRX cycle can vary from a few milliseconds to a few seconds (2 - 2560 subframes).

Discontinuous Reception (DRX)

LTE power save protocols include Discontinuous Reception (DRX) and Discontinuous Transmission (DTX). Both involve reducing the transceiver duty cycle while in active operation. DRX assignments are different for Idle and Connected states.

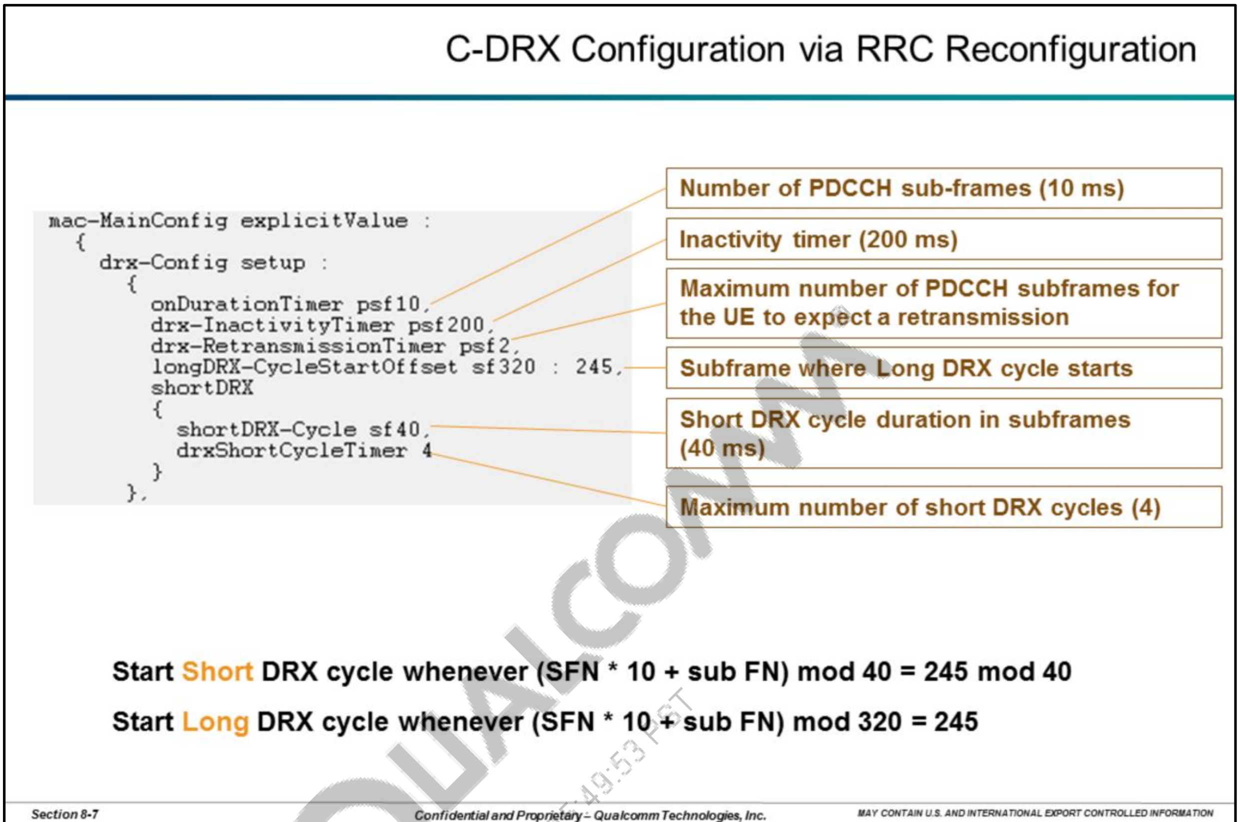


DRX Operation

During DRX, the UE maintains a DRX cycle that is defined as a number of subframes. The UE monitors the Downlink PDCCH for a specific number of subframes in a DRX cycle. This duration is called *on-duration* and can range from 1 to 200 subframes. The UE may turn off its receiver for the remainder of the DRX cycle.

The UE maintains two DRX cycles of different durations: the Short DRX cycle and the Long DRX cycle. The Short DRX cycle is optional and is targeted for applications that typically require relatively small transmissions of data at short but regular intervals (e.g., VoIP). If configured, the UE starts with a Short DRX cycle (2 to 640 subframes) when it enters DRX mode. When the configurable Short DRX timer expires (2 to 640 subframes), the UE transitions to the Long DRX cycle (10 to 2560 subframes).

Short DRX useful for applications where UE is expected to have frequent scheduling. Long DRX is useful for web browsing-like traffic.

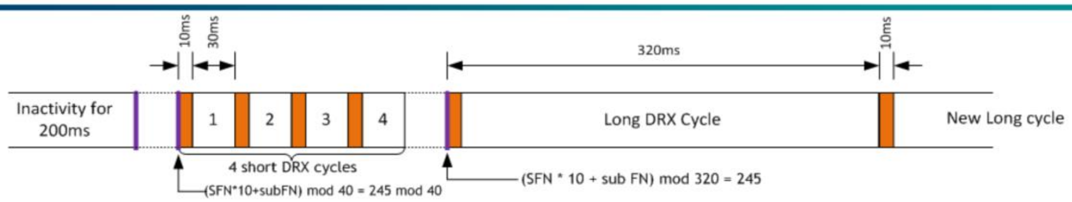


C-DRX Configuration Via RRC Reconfiguration

Details of DRX operation are found in 3GPP TS 36.321, Clause 5.7.

For ranges of values assumed by different DRX parameters, refer to 3GPP TS 36.331, Clause 6.3.2, under *MAC-MainConfig*

C-DRX Operation Details



- After any activity, UE starts/restarts **drx-InactivityTimer**
- After 200 ms (**drx-InactivityTimer)** of no activity, the UE starts the Short DRX cycle, based on subframe number calculations
- Upon wakeup, UE stays awake for 10 ms (**onDurationTimer**) to monitor PDCCH
- If no PDCCH data, the UE goes back to sleep
- UE wakes up after 40 ms from the last ON duration, or 30 ms from the last time it went to sleep (40 ms = **shortDRX-Cycle**)
- This is repeated 4 times (4 = **shortDRX-Cycle**)
- UE starts the Long DRX cycle, based on subframe number calculations
- UE sleeps for 310 ms (320 — **onDurationTimer**) then wakes up to monitor PDCCH

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Notes

C-DRX – Inactivity Timer and Short DRX Cycle

```
-----------------------------------------------
|SFN |Sub-fn|CDRX Event                        |
-----------------------------------------------
| 540|     1|    INACTIVITY_TIMER_START|
| 540|     6|       UL_RETX_TIMER_START|
| 540|     7|         UL_RETX_TIMER_END|
| 541|     4|       UL_RETX_TIMER_START|
| 541|     5|         UL_RETX_TIMER_END|
| 542|     2|       UL_RETX_TIMER_START|
| 542|     2|    INACTIVITY_TIMER_START|
| 542|     3|         UL_RETX_TIMER_END|
| 542|     7|       UL_RETX_TIMER_START|
| 542|     8|         UL_RETX_TIMER_END|
| 543|     2|    INACTIVITY_TIMER_START|
| 543|     5|       UL_RETX_TIMER_START|
| 543|     6|         UL_RETX_TIMER_END|
| 544|     3|       UL_RETX_TIMER_START|
| 544|     4|         UL_RETX_TIMER_END|
| 545|     7|    INACTIVITY_TIMER_START|
| 546|     3|    INACTIVITY_TIMER_START|
| 547|     2|    INACTIVITY_TIMER_START|
| 547|     7|       UL_RETX_TIMER_START|
| 547|     8|         UL_RETX_TIMER_END|
| 548|     5|       UL_RETX_TIMER_START|
| 548|     6|         UL_RETX_TIMER_END|
| 549|     3|       UL_RETX_TIMER_START|
| 549|     4|         UL_RETX_TIMER_END|
| 567|     2|      INACTIVITY_TIMER_END|
| 567|     2|            CDRX_ON_2_OFF|
| 568|     5|        SHORT_CYCLE_START|
| 568|     3|            CDRX_OFF_2_ON|
| 568|     5|  ON_DURATION_TIMER_START|
| 569|     5|    ON_DURATION_TIMER_END|
| 569|     5|            CDRX_ON_2_OFF|
| 572|     5|        SHORT_CYCLE_START|
| 572|     3|            CDRX_OFF_2_ON|
| 572|     5|  ON_DURATION_TIMER_START|
| 573|     5|    ON_DURATION_TIMER_END|
| 573|     5|            CDRX_ON_2_OFF|
| 576|     5|        SHORT_CYCLE_START|
| 576|     3|            CDRX_OFF_2_ON|
| 576|     5|  ON_DURATION_TIMER_START|
| 577|     5|    ON_DURATION_TIMER_END|
| 577|     5|            CDRX_ON_2_OFF|
| 580|     5|        SHORT_CYCLE_START|
| 580|     3|            CDRX_OFF_2_ON|
| 580|     5|  ON_DURATION_TIMER_START|
| 581|     5|    ON_DURATION_TIMER_END|
| 581|     5|            CDRX_ON_2_OFF|
| 600|     5|         LONG_CYCLE_START|
| 600|     3|            CDRX_OFF_2_ON|
| 600|     5|  ON_DURATION_TIMER_START|
| 601|     5|    ON_DURATION_TIMER_END|
```

- Inactivity timer lasted from 547/2 till 567/2 → 200 ms
- UE started short DRX Cycle at 568/5 → 13 subframes later

[(SFN * 10) + subframe number] modulo (*shortDRX-Cycle (40)*)
= (*drxStartOffset (245)*) modulo (*shortDRX-Cycle (40)*)

	Qty1	Qty2
5672	32	5
5673	33	5
5674	34	5
5675	35	5
5676	36	5
5677	37	5
5678	38	5
5679	39	5
5680	0	5
5681	1	5
5682	2	5
5683	3	5
5684	4	5
5685	5	5

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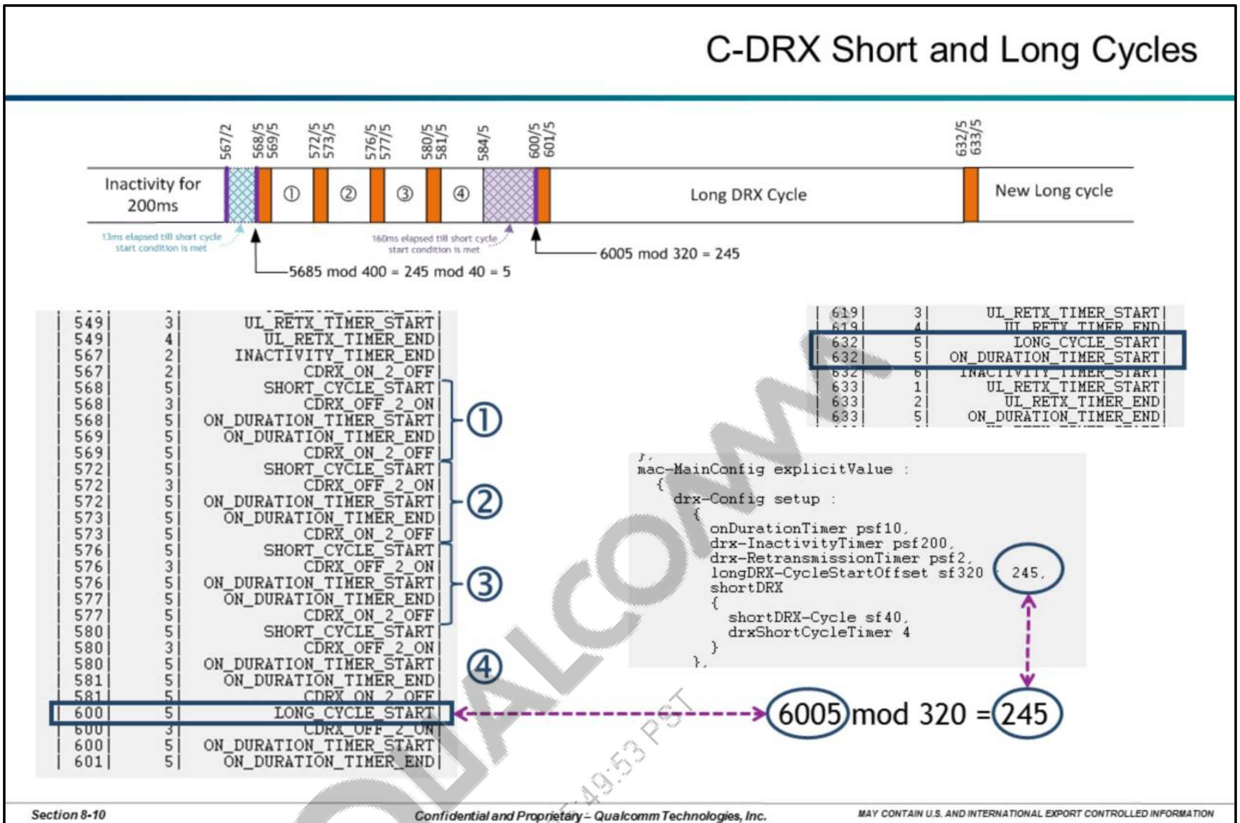
Notes


C-DRX Short and Long Cycles
567/2
568/5
569/5
572/5
573/5
576/5
577/5
580/5
581/5
584/5
600/5
601/5
632/5
633/5
Inactivity for 200ms
①
②
③
④
Long DRX Cycle
New Long cycle
13ms elapsed till short cycle start condition is met
160ms elapsed till short cycle start condition is met
5685 mod 400 = 245 mod 40 = 5
6005 mod 320 = 245
549	3	UL_RETX_TIMER_START
549	4	UL_RETX_TIMER_END
567	2	INACTIVITY_TIMER_END
567	2	CDRX_ON_2_OFF
568	5	SHORT_CYCLE_START
568	3	CDRX_OFF_2_ON
568	5	ON_DURATION_TIMER_START
569	5	ON_DURATION_TIMER_END
569	5	CDRX_ON_2_OFF
572	5	SHORT_CYCLE_START
572	3	CDRX_OFF_2_ON
572	5	ON_DURATION_TIMER_START
573	5	ON_DURATION_TIMER_END
573	5	CDRX_ON_2_OFF
576	5	SHORT_CYCLE_START
576	3	CDRX_OFF_2_ON
576	5	ON_DURATION_TIMER_START
577	5	ON_DURATION_TIMER_END
577	5	CDRX_ON_2_OFF
580	5	SHORT_CYCLE_START
580	3	CDRX_OFF_2_ON
580	5	ON_DURATION_TIMER_START
581	5	ON_DURATION_TIMER_END
581	5	CDRX_ON_2_OFF
600	5	LONG_CYCLE_START
600	3	CDRX_OFF_2_ON
600	5	ON_DURATION_TIMER_START
601	5	ON_DURATION_TIMER_END
619	3	UL_RETX_TIMER_START
619	4	UL_RETX_TIMER_END
632	5	LONG_CYCLE_START
632	5	ON_DURATION_TIMER_START
632	6	INACTIVITY_TIMER_START
633	1	UL_RETX_TIMER_START
633	2	UL_RETX_TIMER_END
633	5	ON_DURATION_TIMER_END
mac-MainConfig explicitValue :
{
drx-Config setup :
{
onDurationTimer psf10,
drx-InactivityTimer psf200,
drx-RetransmissionTimer psf2,
longDRX-CycleStartOffset sf320 : 245,
shortDRX
{
shortDRX-Cycle sf40,
drxShortCycleTimer 4
}
},
6005 mod 320 = 245
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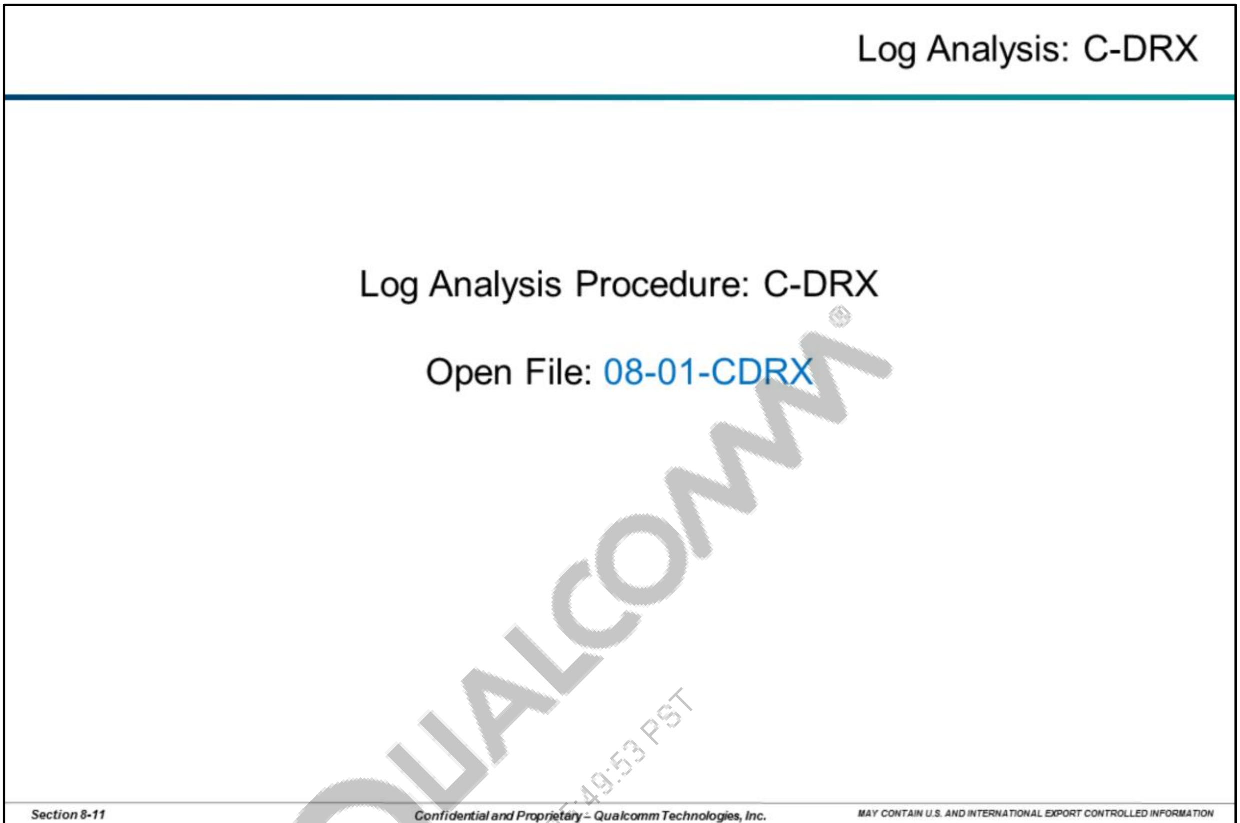
Notes



Log Analysis: C-DRX

Log provided for demonstration. Parameter values given in the log are neither an endorsement nor a recommendation by Qualcomm.

C-DRX: Log Walk-Through

Step	Look for…	Log Packet	Timestamp	Verify…
1	LTE RRC OTA Packet	0xB0C0	18:37:25.637	RRC Connection Reconfiguration DRX configuration included
2	LTE ML1 CDRX Events Info	0xB198	18:37:26.264	• Multiple INACTIVITY_TIMER_START events with no expiration • INACTIVITY_TIMER_START at 547-2 ends 200ms later, at 567-2 → INACTIVITY_TIMER_END • SHORT_CYCLE_START at 568-5 (See previous slides for subframe number calculation) • Four Start/End short cycles: 1. 568-5 / 569-5 2. 572-5 / 573-5 3. 576-5 / 577-5 4. 580-5 / 581-5 • LONG_CYCLE_START at 600-5 (See previous slides for subframe number calculation)
3	LTE ML1 CDRX Events Info	0xB198	18:37:27.544	Next DRX Cycle. LONG_CYCLE_START at 632-5, 320 ms after the start of the previous long DRX cycle

Analysis Summary

The arrival of messages during logging could impact the order in which time stamps are shown.

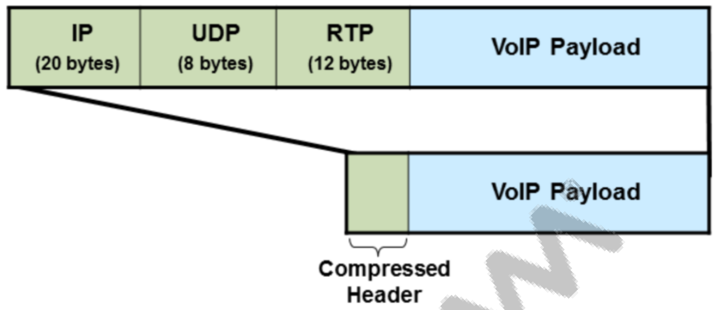
If needed while analyzing a log file in the browser, use the menu “Edit” + “Find on this Page” (Ctrl+F) to find a specific timestamp.

Topic Map

- C-DRX
- **Robust Header Compression (RoHC)**
- TTI-Bundling
- Semi-Persistent Scheduling (SPS)

Notes

Upper Layer Header Implications



For a typical VoIP packet, the overhead of IP, UDP, and RTP is 40 bytes for IPv4, or 60 bytes for IPv6.

- For VoIP, this corresponds to nearly 60% of the total amount of data sent.

PDCP uses Robust Header Compression (RoHC) to reduce this overhead.

- RoHC compresses these 40 or 60 bytes of overhead typically into only 1 or 3 bytes.
- RoHC profiles and parameters are signaled by higher layers (RRC).

Header Implications

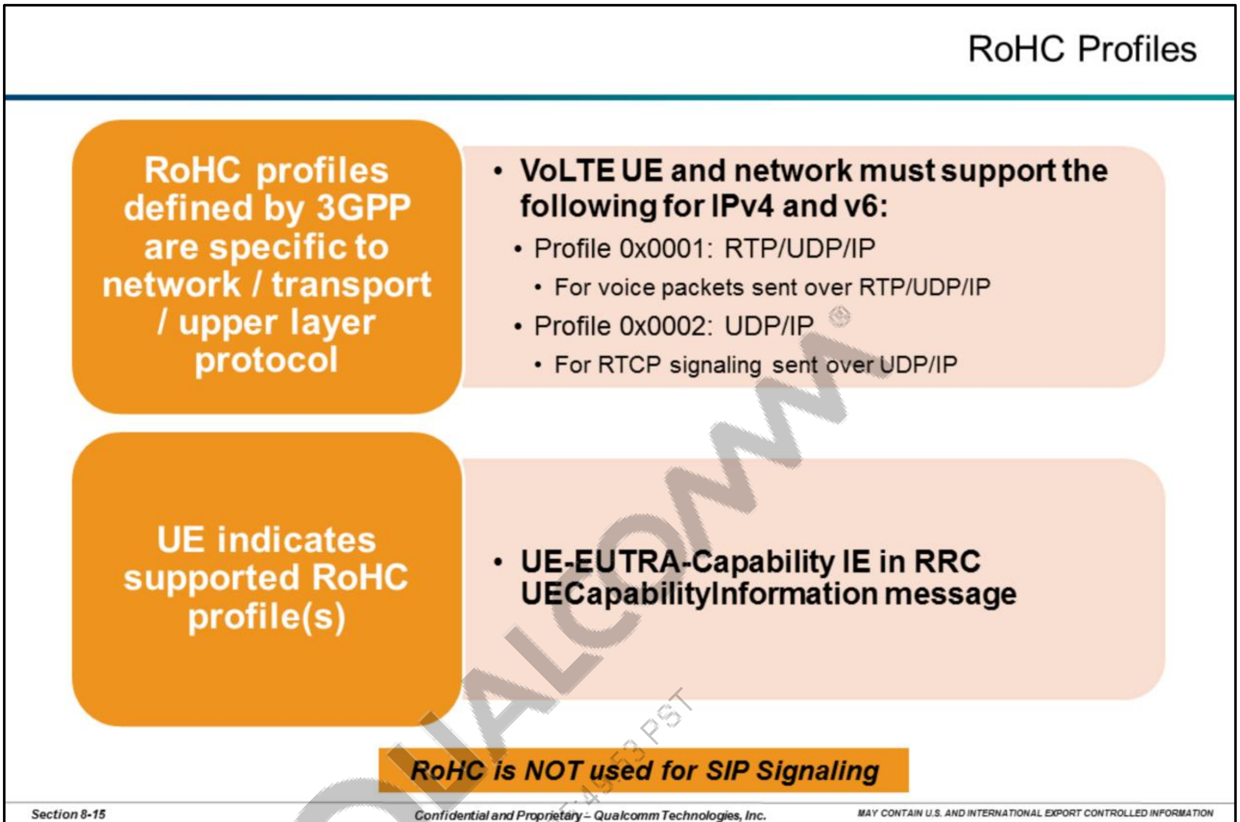
Robust Header Compression (RoHC) is a standardized method to compress the IP, UDP, RTP, and TCP packet headers. This compression scheme performs well over wireless links where the packet loss rate is high.

For VoIP, the overhead for IPv4 or IPv6 is large compared to the actual voice data. To keep the data rate as low as possible to conserve system capacity, header compression must be used. Header compression also reduces transmission delay and packet loss rate.

PDCP performs header compression and decompression to reduce overhead due to large headers. Header compression also reduces transmission delay and packet loss rate. An example for Voice over IP with IP/UDP/RTP headers is shown in the figure. The header compression is based on Robust Header Compression (RoHC) framework.

There is one instance of RoCH for each PDCP entity. That means there is one RoHC instance for each Radio Bearer (RB). The RoHC compressor entity is implemented at the transmitter; the and decompressor entity is implemented at the receiver.

LTE defines IP flows; each IP flow refers to an application stream. For example, there are three streams for video applications: audio, video, and control. Multiple IP flows can be sent over the same RoHC instance. Each IP flow can be associated with an RoHC context, identified by a Connection ID (CID). An RoHC profile can be associated with each context. An RoHC profile indicates which headers are compressed. The RoHC profiles and parameters are signaled and configured by higher layers.



RoHC Profiles

A set of RoHC profiles is defined in 3GPP TS36.323. As per GSMA IR.92, the UE and the network must support Robust Header Compression (RoHC) as specified in 3GPP TS 36.323, IETF RFC 3095, and IETF RFC 4815. The UE and the network must be able to apply the compression to packets that are carried over the radio bearer dedicated for the voice media. At a minimum, the UE and the network must support “RTP/UDP/IP” profile (0x0001) to compress RTP packets and “UDP/IP” profile (0x0002) to compress RTCP packets. The UE and the network must support these profiles for both IPv4 and IPv6.

3GPP TS36.323 Table 5.5.1.1

Profile Identifier	Usage	Reference
0x0000	No compression	RFC 4995
0x0001	RTP/UDP/IP	RFC 3095, RFC 4815
0x0002	UDP/IP	RFC 3095, RFC 4815
0x0003	ESP/IP	RFC 3095, RFC 4815
0x0004	IP	RFC 3843, RFC 4815
0x0006	TCP/IP	RFC 4996
0x0101	RTP/UDP/IP	RFC 5225
0x0102	UDP/IP	RFC 5225
0x0103	ESP/IP	RFC 5225
0x0104	IP	RFC 5225

3GPP TS36.331 Section 6.3.6: UE-EUTRA-Capability information element

```
PDCP-Parameters ::=                 SEQUENCE {
    supportedROHC-Profiles                  SEQUENCE {
        profile0x0001                       BOOLEAN,
        profile0x0002                       BOOLEAN,
        profile0x0003                       BOOLEAN,
        profile0x0004                       BOOLEAN,
        profile0x0006                       BOOLEAN,
        profile0x0101                       BOOLEAN,
        profile0x0102                       BOOLEAN,
        profile0x0103                       BOOLEAN,
        profile0x0104                       BOOLEAN
    },
```

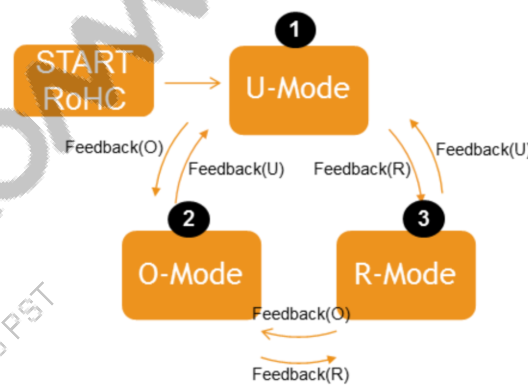
In the case of SIP messages, the header is small compared to the typical message sizes and hence the compression gain is smaller and the processing overhead is larger. It should be noted, however, that Signaling Compression (SigComp) may be used for SIP Signaling compression as defined in IETF RFC 3320, 4896.

RoHC Operation Modes

Robust Header Compression (RoHC) has three modes of operation.

	Unidirectional (U-) Mode	Optimistic (O-) Mode	Reliable (R-) Mode
Packet Direction	Unidirectional	Bidirectional	Bidirectional
Error Feedback	No	Some	Intensive
Efficiency	Low	High	High

- **The optimal RoHC operation mode depends on the following:**
  - RoHC always starts in U-mode and transitions to another mode based on Decompressor feedback.
  - Feedback abilities, error probabilities and distributions, effects of header size variation, etc.
- **All RoHC implementations must support all three operation modes.**



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RoHC Operation Modes

RoHC has three modes of operation:

- **Unidirectional mode (U-mode)**
  - One direction only. No feedback; state changes are based on periodic refreshes.
  - Less efficient and slightly higher loss probability compared to Bidirectional modes.
  - RoHC always starts in U-mode and transitions to Bidirectional mode(s).
- **Bidirectional Optimistic mode (O-mode)**
  - Two directions. Feedback channel is available to send error recovery requests and ACKs of significant context updates despite sparse usage.
  - No periodic refreshes.
  - More efficient compared to Unidirectional mode.
- **Bidirectional Reliable mode (R-mode)**
  - More intensive usage of the feedback channel.
    - Acknowledge all context updates including updates of the sequence number field.
  - More robust, with stricter logic to prevent loss of context synchronization except for very high residual bit error rate, and lower probability of context invalidation than O-mode.

The compressor and de-compressor each establish a context for the packet flow and identify the context with a Context Identifier (CID) included in each RoHC compressed header when a logical channel supports RoHC transport with multiple header-compressed flows. RoHC uses a distinct CID space per logical channel, and the CID can only be omitted for one of the flows over the RoHC channel when configured to use a small CID space. See RFC 3095 for details.

RoHC States

Robust Header Compression (RoHC) has three states:

Header Information Sent	Compressor State	Decompressor State	Compression
Initial State (full uncompressed headers are sent)	Initialization & Refresh (IR)	No Context (NC)	None
Static fields not sent (IP addresses, port numbers.,...etc.)	First Order (FO)	Static Context (SC)	Partial
Only SN sent	Second Order (SO)	Full Context (FC)	Optimal

- Compressor always starts in IR state.
- After context is established, it transitions to FO or SO.
- Compressor transitions to a lower state when:
  – An error is detected, or
  – A timer expires, forcing it to go to lower state to ensure context validity.

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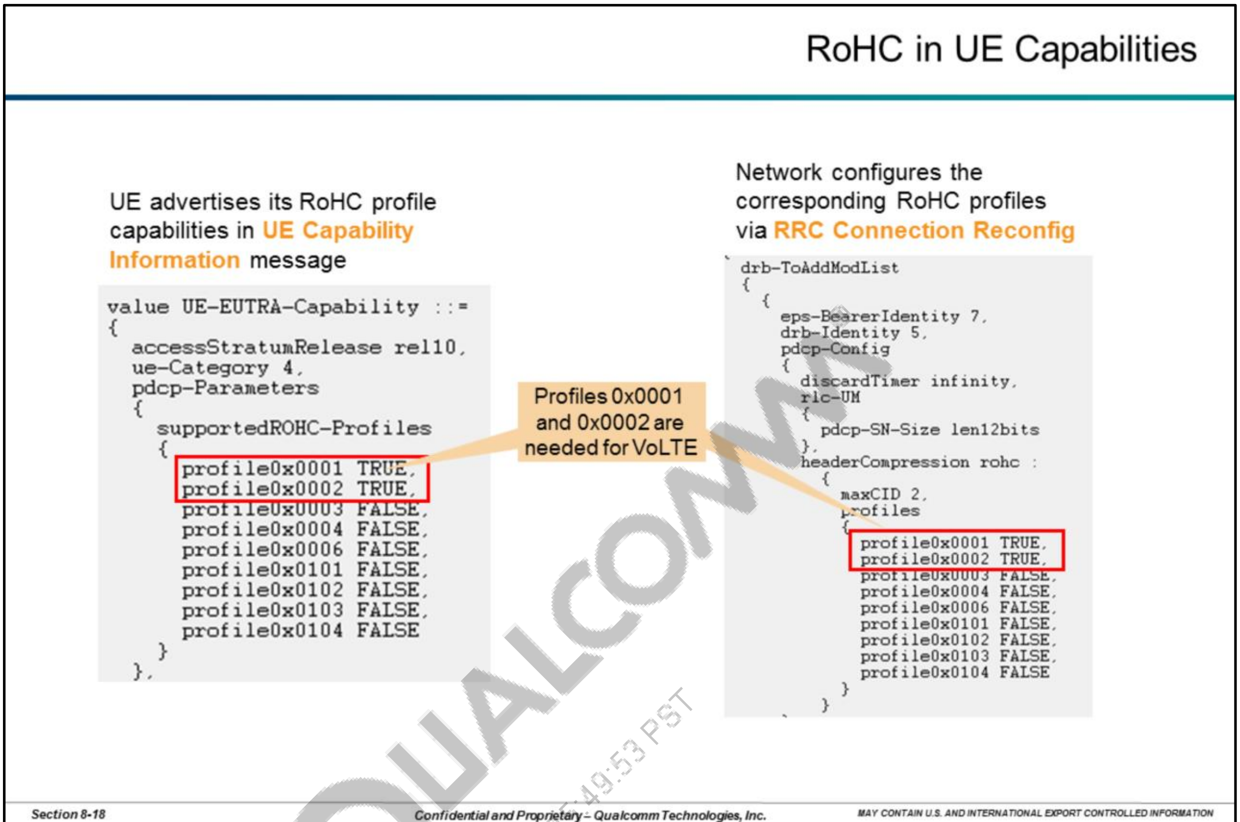
RoHC States

RoHC Compressor has three states:

- **Initialization and Refresh (IR)**
  – Full (uncompressed) packets are sent in order to establish a context at the decompressor.
  – RoHC enters this state during initialization or when repeated errors are detected.
- **First Order (FO)**
  – Only dynamic fields are sent.
  – Compressor is confident the decompressor is able to form the full header given the dynamic fields.
- **Second Order (SO)**
  – This is the state where compression is optimal.
  – The compressor enters the SO state when the header to be compressed is completely predictable given the RTP Sequence Number (SN) and the compressor is confident that the decompressor has acquired all parameters of the functions from SN to other fields.

Corresponding RoHC Decompressor states are:

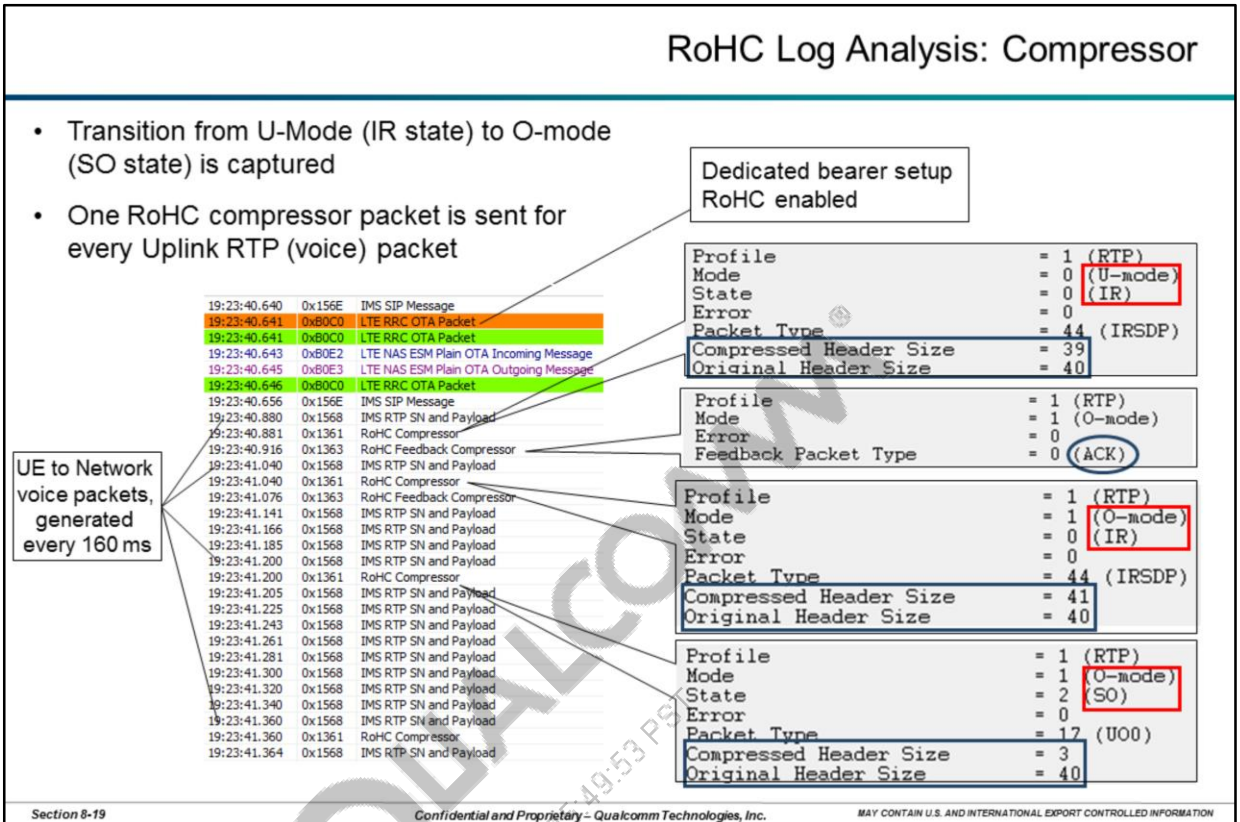
- No Context (NC)
- Static Context (SC)
- Full Context (FC)



RoHC in UE Capabilities

UE advertises its support for specific RoHC profiles in the UE Capability Information message. At a minimum, profile 0x0001 (RTP voice packets) and profile 0x0002 (for RTCP packets) must be supported for VoLTE.

Upon receiving the UE Capability Information, the eNB will enable the corresponding RoHC profiles through RRC signaling (RRC Connection Reconfiguration message).



RoHC Log Analysis: Compressor

As outlined earlier, the RoHC compressor always starts in U-mode and IR state. Notice the compressor mode transitions to O-mode and stays in this mode. O-mode is often the preferred mode as operation in R-mode requires intensive feedback messaging.

In this log, the compressor transitioned from Initialization & Refresh (IR) state to Second Order (SO) state directly, which is allowed. The compressor transitions back to First Order (FO) state upon encountering an error or if the compressor chooses so, in order to periodically validate the context.

It is normal for the compressed header size to exceed the uncompressed header size in IR state. As outlined in RFC 3095, clause 4.3.1.1:

- The purpose of the IR state is to initialize the static parts of the context at the decompressor or to recover after failure. In this state, the compressor sends complete header information. This includes all static and nonstatic fields in uncompressed form plus some additional information.

Log Analysis: RoHC

Log Analysis Procedure: RoHC

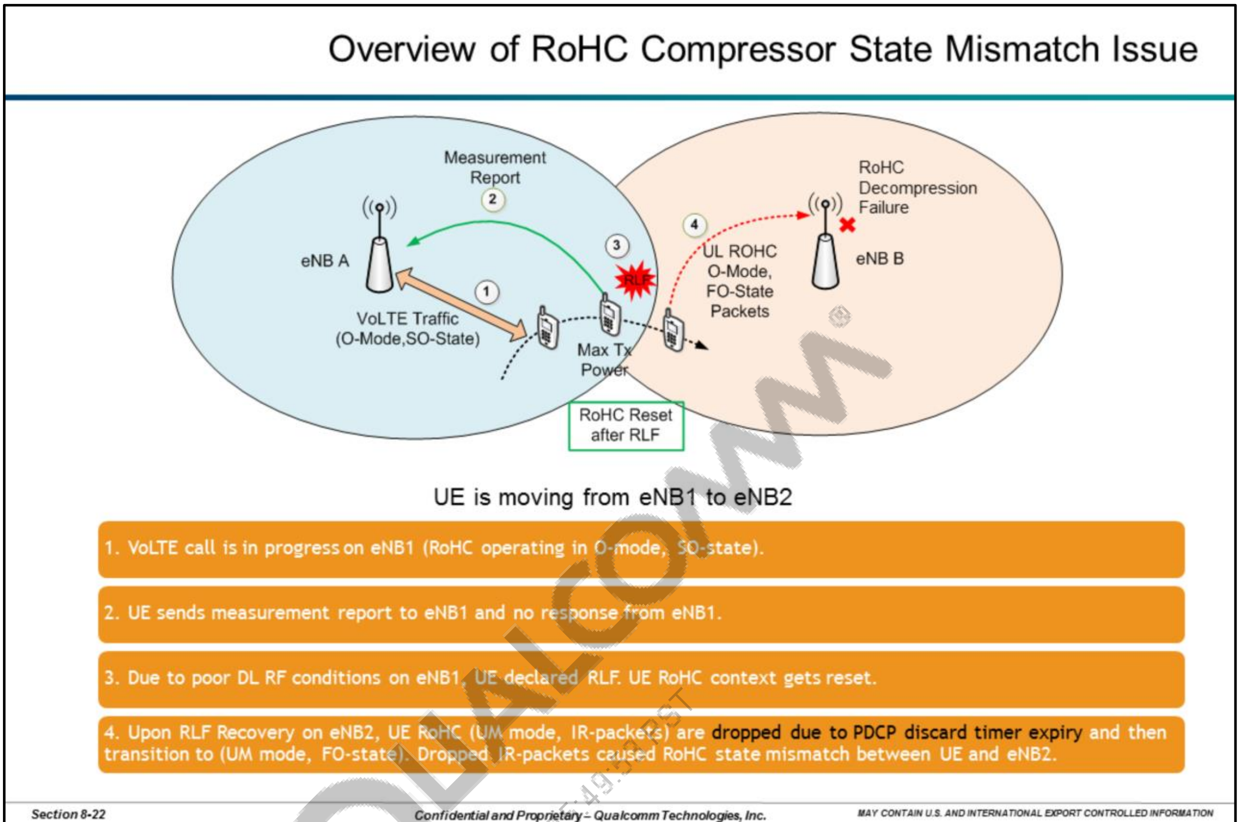
Open File: 08-02-RoHC

Notes

RoHC: Log Walk-Through

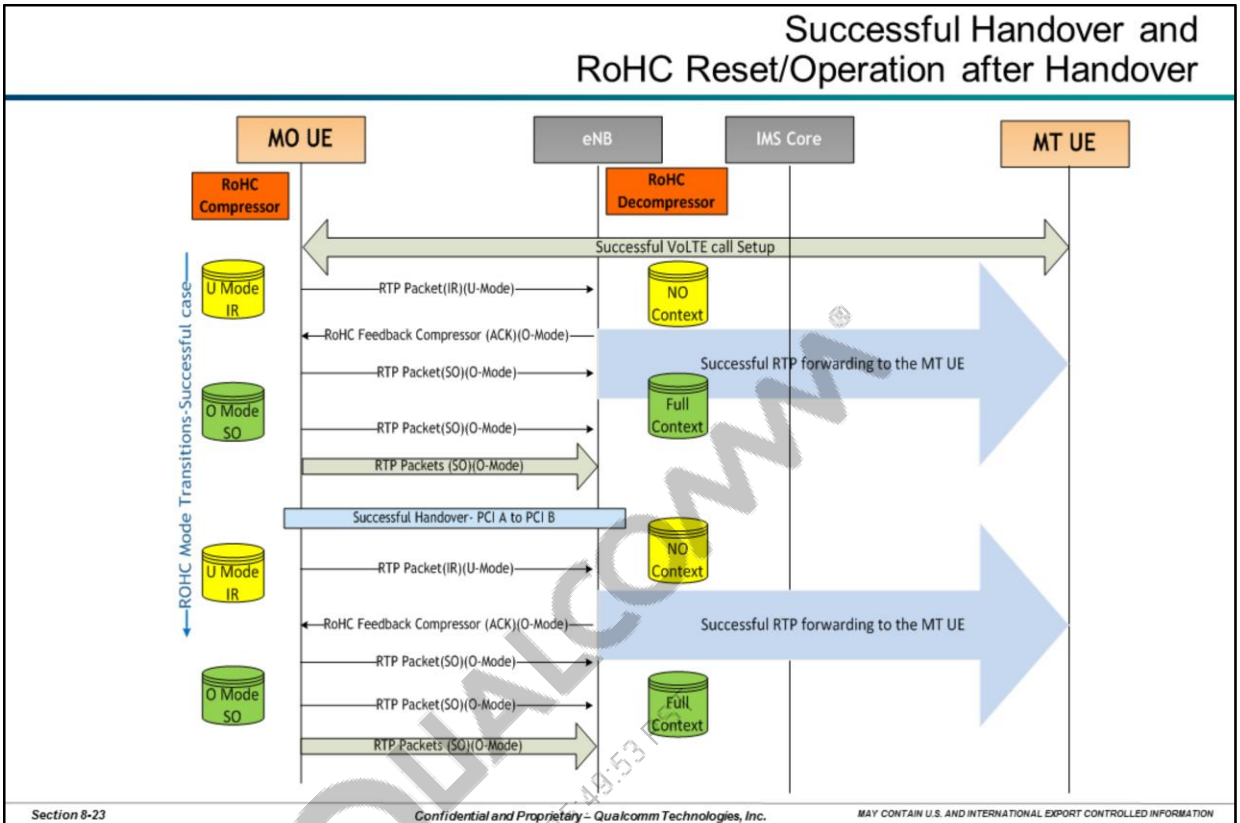
Step	Look for…	Log Packet	Timestamp	Verify…
1	LTE RRC OTA Packet	0xB0C0	19:23:40.641	Rrc Connection Reconfiguration RoHC profiles 0x0001 and 0x00012 are supported
2	RoHC Compressor	0x1361	19:23:40.881	Profile: 1 Mode: U-mode State: IR
3	RoHC Feedback Compressor	0x1363	19:23:40.916	Feedback Packet Type = 0 (ACK) Note the same RTP SN as the compressor message
4	RoHC Compressor	0x1361	19:23:40.881	Profile: 1 Mode: transitioned to O-mode State: IR
5	RoHC Feedback Compressor	0x1363	19:23:41.076	Feedback Packet Type = 0 (ACK) Note the same RTP SN as the compressor message
6	RoHC Compressor	0x1361	19:23:41.200	Profile: 1 Mode: O-mode State transitioned to SO Compressed Header Size = 3 Original Header Size = 40

Notes



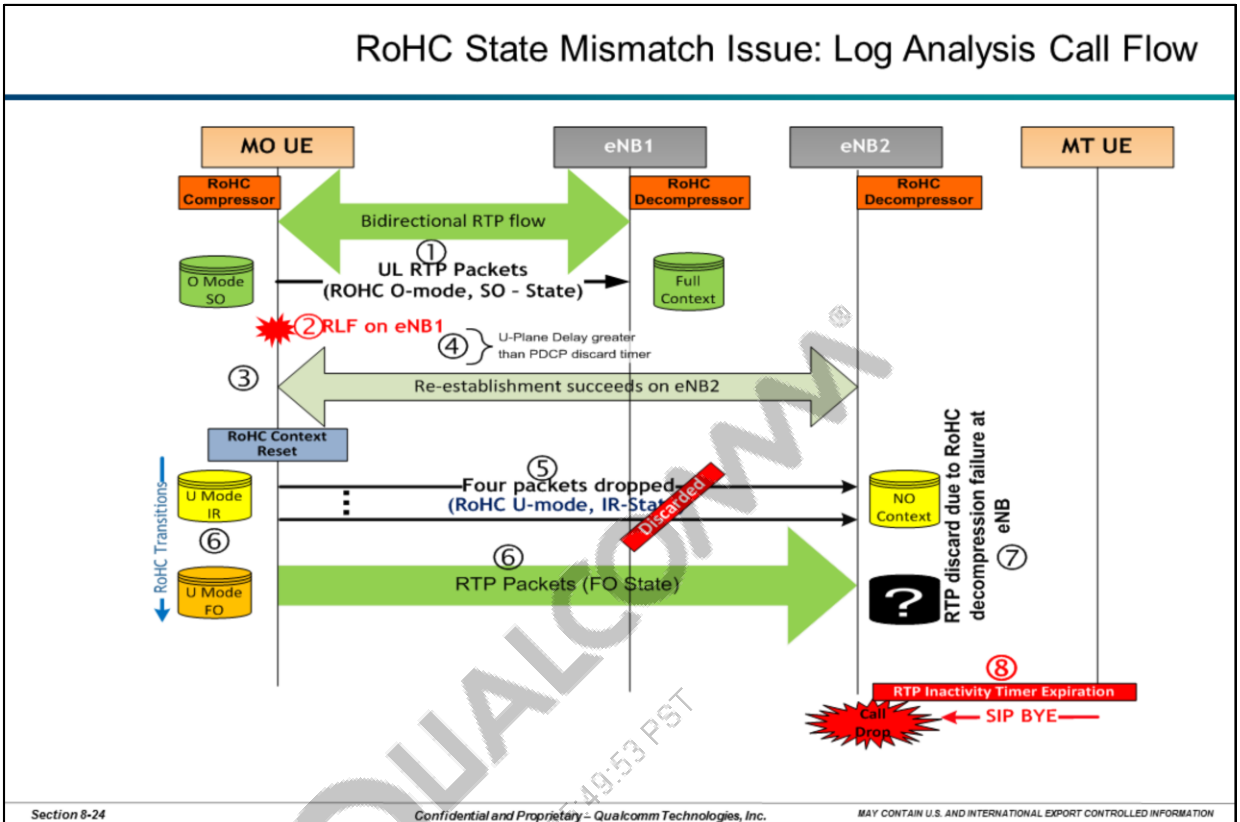
Overview of RoHC Compressor State Mismatch Issue

- Initially UE is on PCI 327 and VoLTE call is in progress.
- On PCI 327, UE RoHC compressor is operating in O-Mode and SO State.
- At PCI 327 cell edge, UE is measuring neighbor PCI 381 and reporting to Serving cell 327.
- UE did not receive any HO Message and UE declared RLF on PCI 327 (due to High DL BLER).
- Successful RLF Recovery happened on PCI 381.
- Due to RLF and RLF Recovery procedure, there is an interruption of 493 ms for User Plane.
- Due to this Interruption, UE PDCP Discard Timer (150 ms) expiry caused PDCP Packets getting discarded.
- After RLF Recovery on PCI 381, UE RoHC Context got reset and started using Compressor U-Mode and IR State.
- UE Compressor U-Mode and IR-Packets were dropped due to PDCP Discard Timer expiry and eNB Decompressor failed to receive any IR State packets from UE.
- UE transitioned from U-Mode/IR State to U-Mode/FO State (after 4 IR State packets generated by RoHC Compressor).
- eNB can not decompress FO State packets sent by UE due to missing RoHC Context.
- This kind of RoHC State Mismatch occurs due to dropped packets during RLF, HO cases and may lead to VoLTE dropped calls as well.



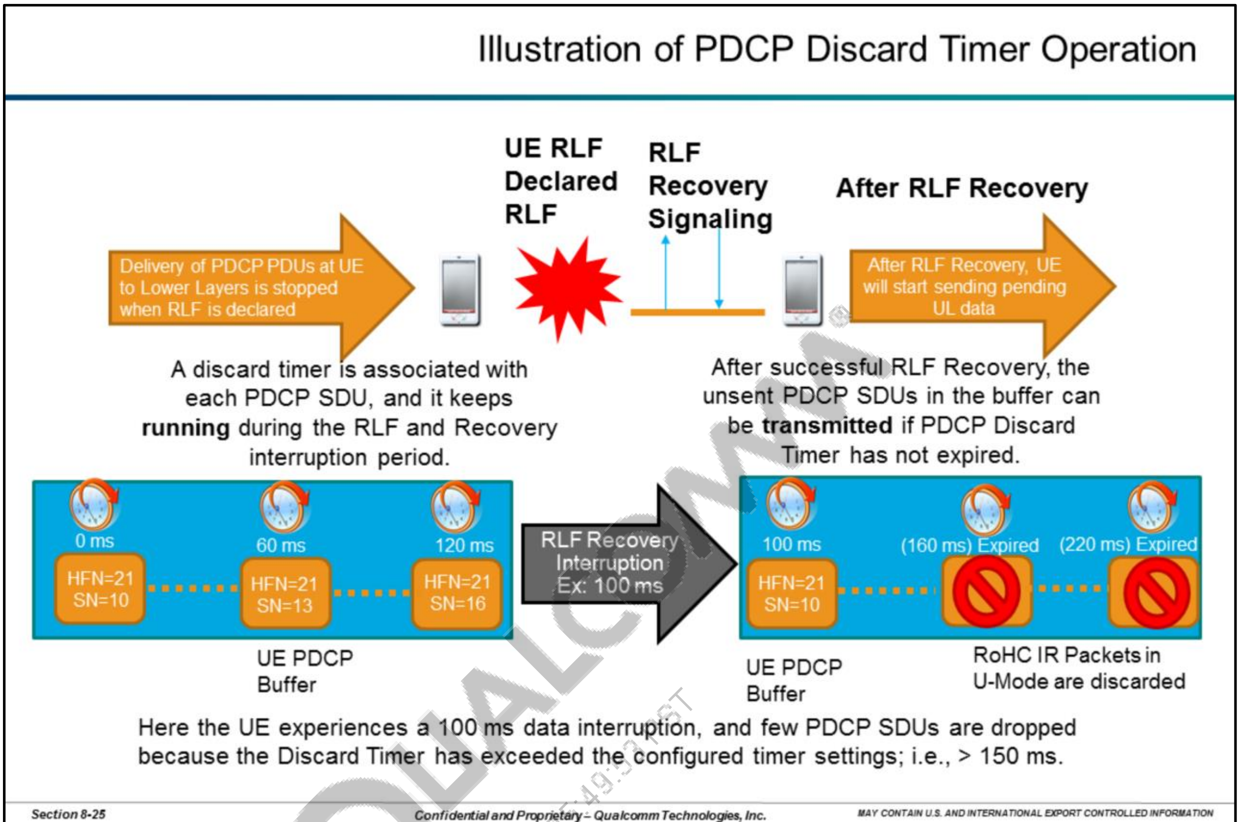
Successful Handover and RoHC Reset/Operation after Handover.

- When VoLTE Call is established, RTP Packets will start flowing between UE and Network.
- UE PDCP Layer will use RoHC Protocol to compress RTP Traffic header.
- Initially UE RoHC compressor starts in U-Mode (IR State → FO State → SO State) and based on feedback from eNB RoHC decompressor, UE will switch its mode to O-Mode.
- In O-Mode, RoHC Compressor starts transmitting non-compressed IR packets to establish RoHC Context at eNB Decompressor.
- The Compressor will then transition to Compressed FO/SO-State. When UE is camped on eNB and during on-going VoLTE Call, in RoHC steady state, UE RoHC Compressor will transmit packets in O-mode, SO-State.
- Upon UE handover, UE RoHC context will get reset. After successful handover, UE RoHC Compressor resets to U-Mode. In U-Mode, it transitions from IR → FO → SO States.
- Based on new eNB Decompressor feedback, UE changes from U- to O-Mode. Within O-Mode, it starts with IR State then transitions to FO/SO-States.



RoHC State Mismatch Issue: Log Analysis Call Flow

1) UE is on eNB1 and VoLTE call is in progress. UE RoHC Compressor is operating in O-Mode / SO-State.
2) UE declares RLF on eNB1 and recovery (re-establishment) occurs on eNB2.
3) After RLF Recovery on eNB2, UE RoHC Context is reset and compressor starts in U-Mode and IR State.
4) The RLF and RLF Recovery procedure introduces a user-plane delay in excess of the UE PDCP discard timer.
5) Due to this Interruption, UE PDCP Discard Timer expiry caused PDCP packets to get discarded. During RLF Interruption, PDCP Layer will be continue to run PDCP Discard Time for each packet received from Upper Layers. Packets received from Upper Layers will be processed by RoHC and for each packet PDCP Discard timer will run. Upon RoHC context reset during RLF, UE RoHC compressor will Initialize to U-Mode. In U-Mode, 4 IR-state packets are transmitted by UE to establish synchronization with eNB2 decompressor. Due to RLF interruption, the 4 IR-State packets are discarded by PDCP Layer when discard timer expires. That means there is no RoHC context established at eNB2 decompressor.
6) UE transitions from U-Mode/IR-State to U-Mode/FO-State after 4 IR-State packets generated by compressor.
7) Decompressor at eNB is unable to decompress FO-State packets sent by UE due to missing RoHC Context.
8) The eNB2 failure to decompress RoHC-compressed packets from UE caused the MT UE RTP Inactivity timer to expires, causing the MT UE to terminate the call due to UE RTP Inactivity timer expiration.



PDCP Discard Timer Operation

After RLF Recovery, unsent voice packets can be transmitted in sequence provided that the Discard Timer at the UE has not expired. Note that the Discard Timer is not restarted after RLF Recovery (no additional time allowed). Stale packets are flushed out of the UE buffer continuously to keep up with the vocoder timing.

After RLF is declared, UE RoHC context will reset. Upon RoHC Context reset, Compressor will enter in U-Mode and start transmitting IR Packets. If these IR Packets can not transmitted by UE due to RLF Recovery interruption and associated PDCP Discard timer expiry leads to UE dropping RoHC Compressor IR Packets.

Potential Issues Due to RoHC State Mismatch Problem

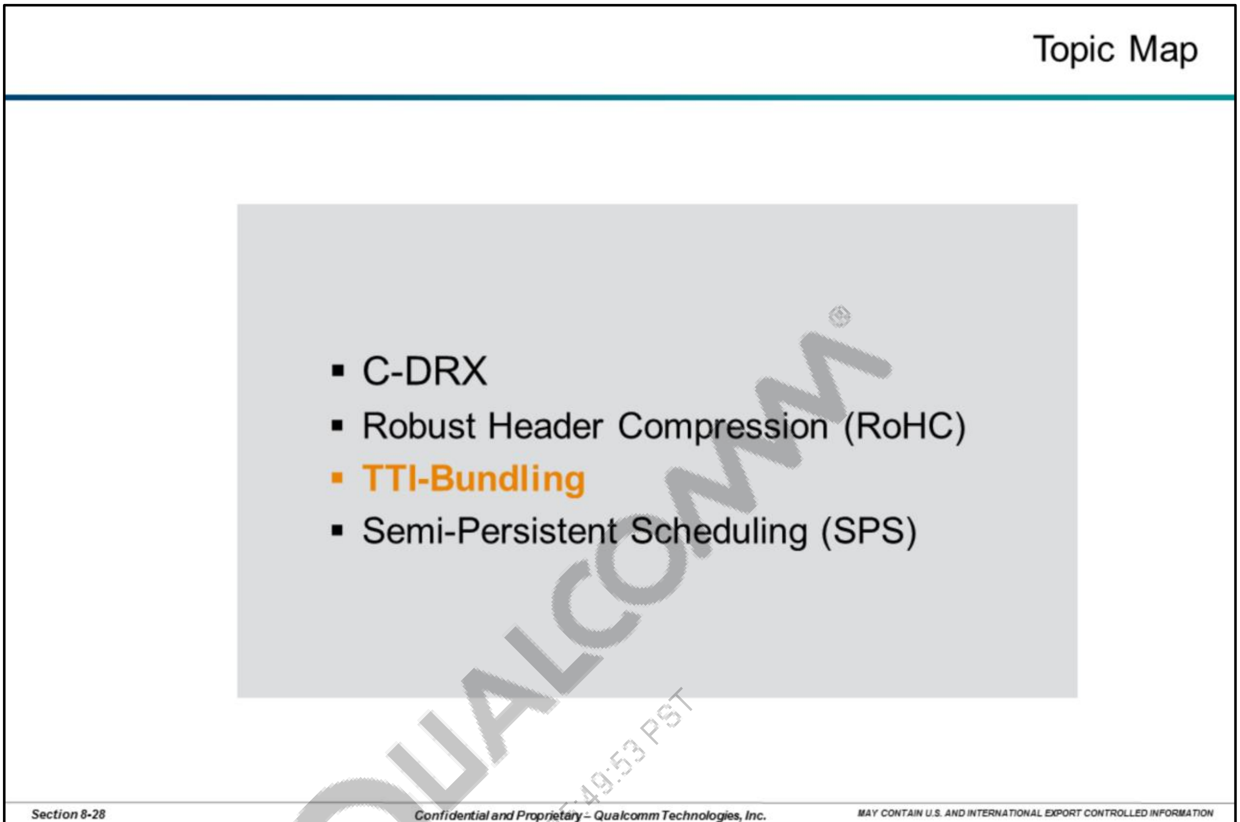
- RoHC State mismatch leads to Decompressor failure and results in VoLTE RTP Packet loss and Voice Quality degradation.
- Typically, RoHC Compressor in U-Mode will re-sync with Decompressor periodically by sending IR Packets.
- If RoHC Synchronization does not occur within RTP inactivity timer expiry, then loss of RTP packets could cause VoLTE call drop as well.
  - Depends on RTP Inactivity Timer setting and frequency of U-Mode Re-sync.

Notes

How to Avoid RoHC State Mismatch Issue?

- Optimize network to reduce handover interruption time by properly configuring handover trigger thresholds and improving coverage.
- Optimize network to avoid/reduce RLF occurrences and associated user plane interruptions.
- Increase the number of compressor IR-State packets, to increase the chance of Decompressor receiving IR-State packets in case of interruption.
  - If number of IR-State packets used is too high before transition to FO/SO-State, it can cause RoHC compressor to operate in inefficient uncompressed mode and could result in capacity loss.
  - To avoid RoHC synchronization issues, RoHC compressor in U-Mode will try to re-sync by sending IR-State packets after transmitting a specific number of compressed packets.

Notes


Topic Map
C-DRX
Robust Header Compression (RoHC)
TTI-Bundling
Semi-Persistent Scheduling (SPS)
Section 8-28
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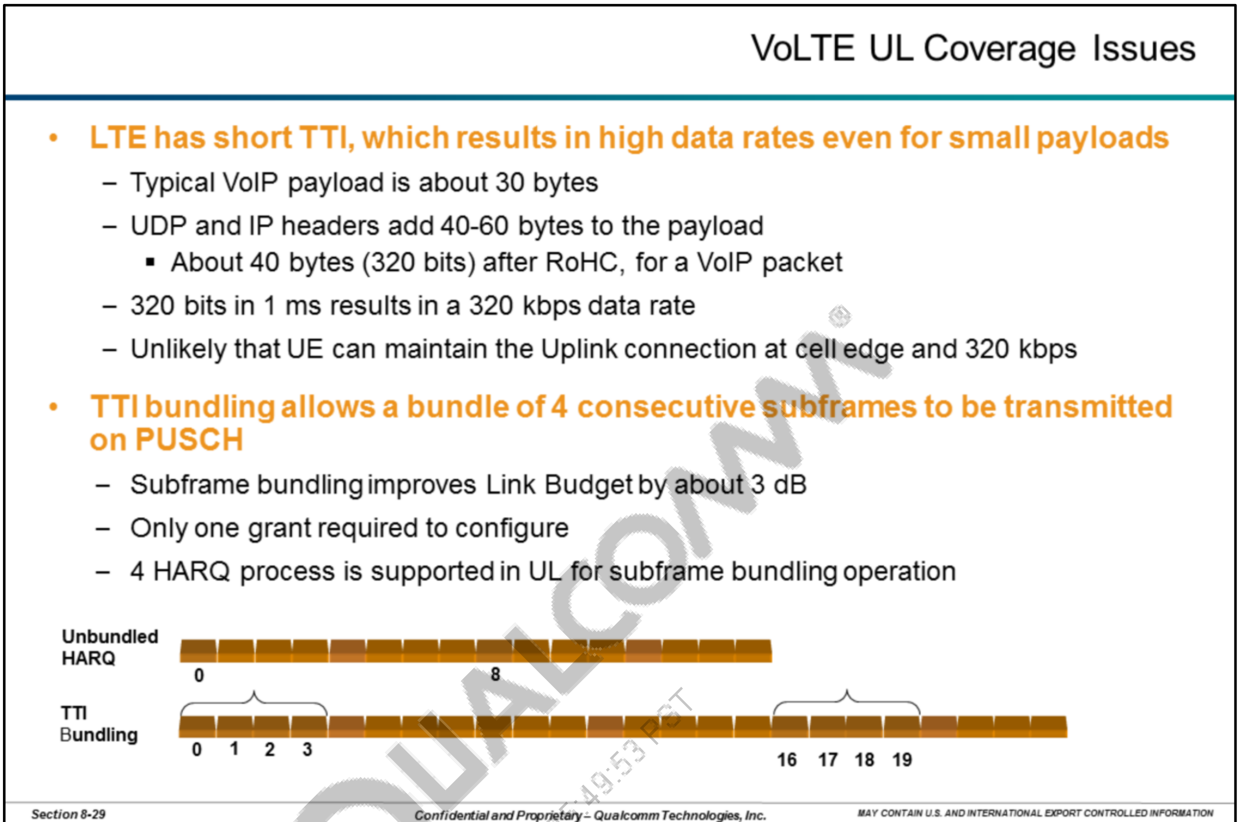


Coverage Issues

Having a short TTI can be a problem when the user is at the cell edge and has limited transmission power. The high data rate of small packets makes it difficult for the UE to have enough power for successful transmission.

The 3GPP solution to this problem is to bundle a set of TTIs for the UE. The transport block is consecutively transmitted 4 times to increase the receive power at the eNB and increase the ability of the UE to close the Uplink. The Node B waits for all 4 TTIs to be received and decoded before sending the HARQ feedback.

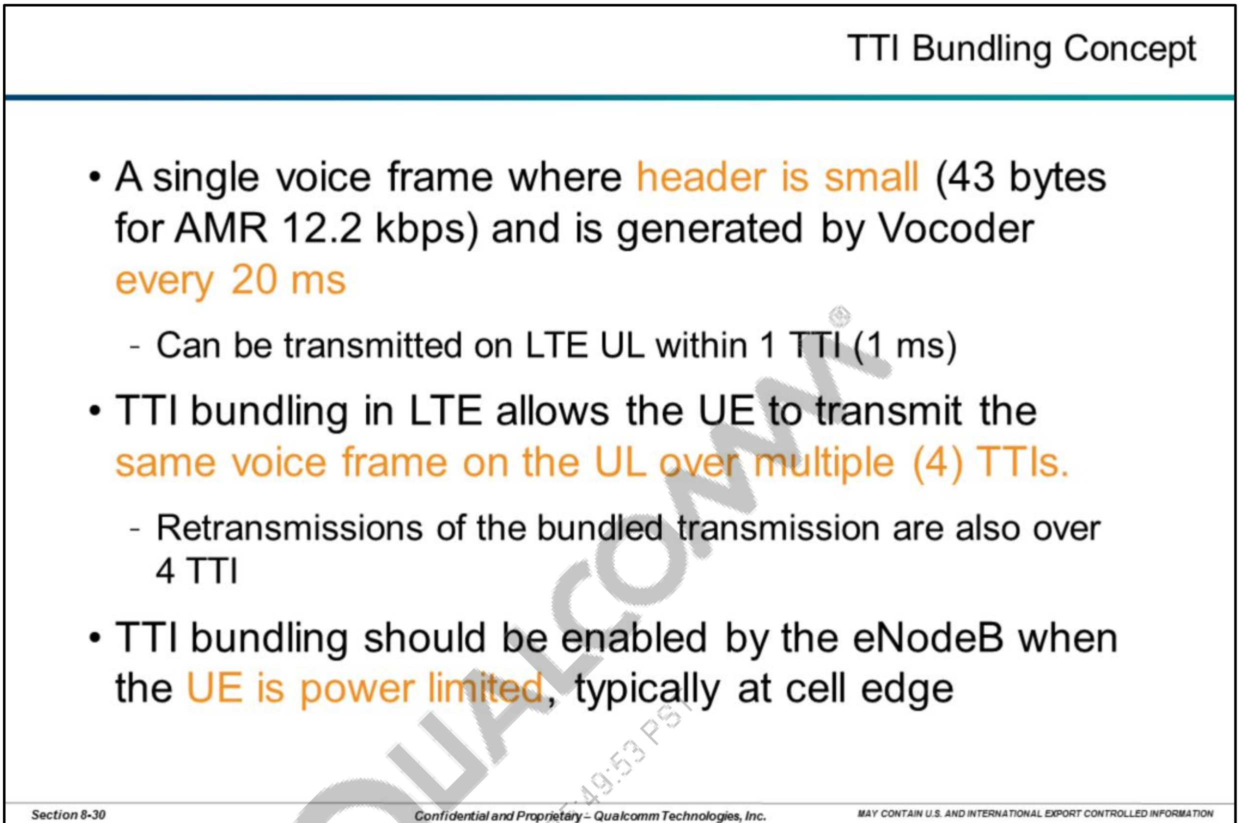
Bundling is limited to a maximum of 3 Physical Resource Blocks (PRBs) and the modulation must be QPSK.

Pros

- Allows UE to operate at a lower spectrum efficiency, which is needed under power limited conditions
- Allows assignment of UL resources over multiple TTIs with a single grant
- Has only one HARQ feedback message per bundle
- Improves VoLTE UL coverage
- Decreases PDCCH signaling overhead
- Decreases PHICH signaling overhead

Cons

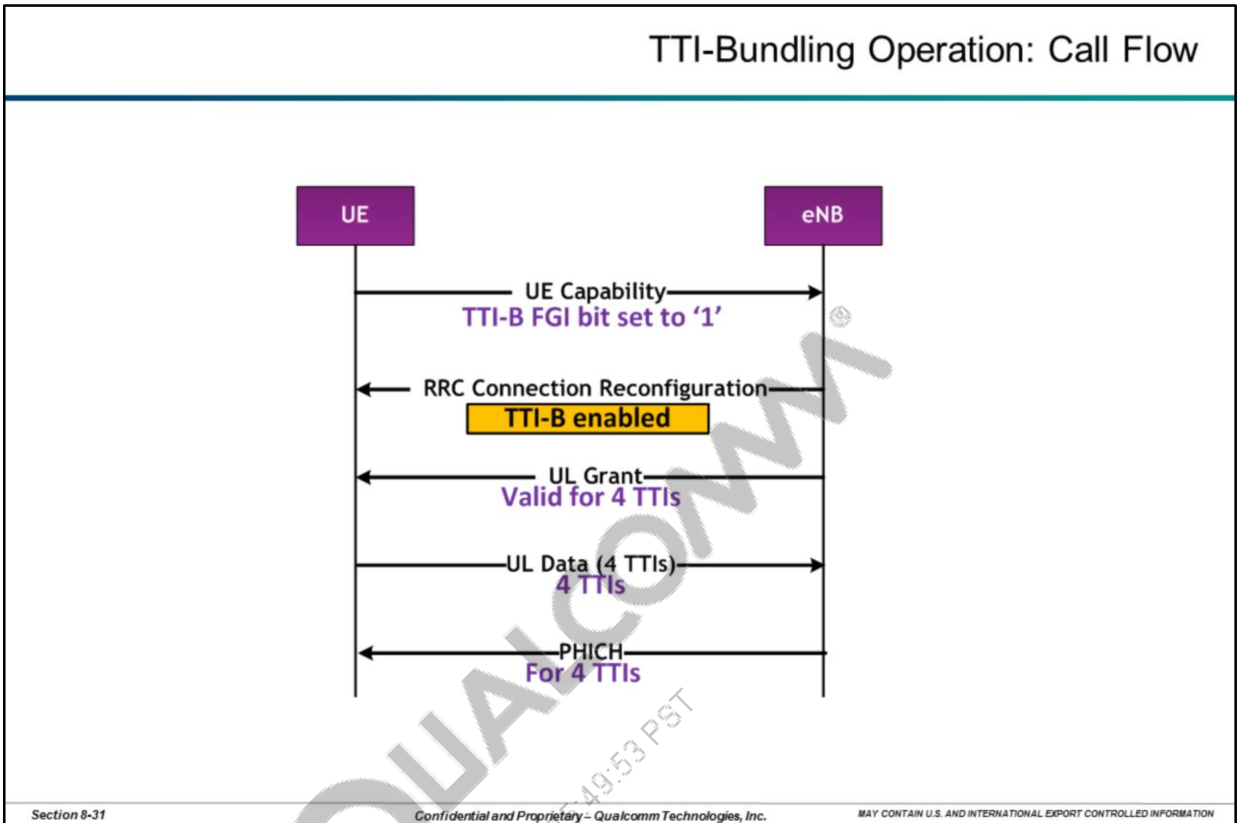
Decreases the channel efficiency (bits/Hz) by not taking advantage of the early termination of transmission.



TTI Bundling Concept

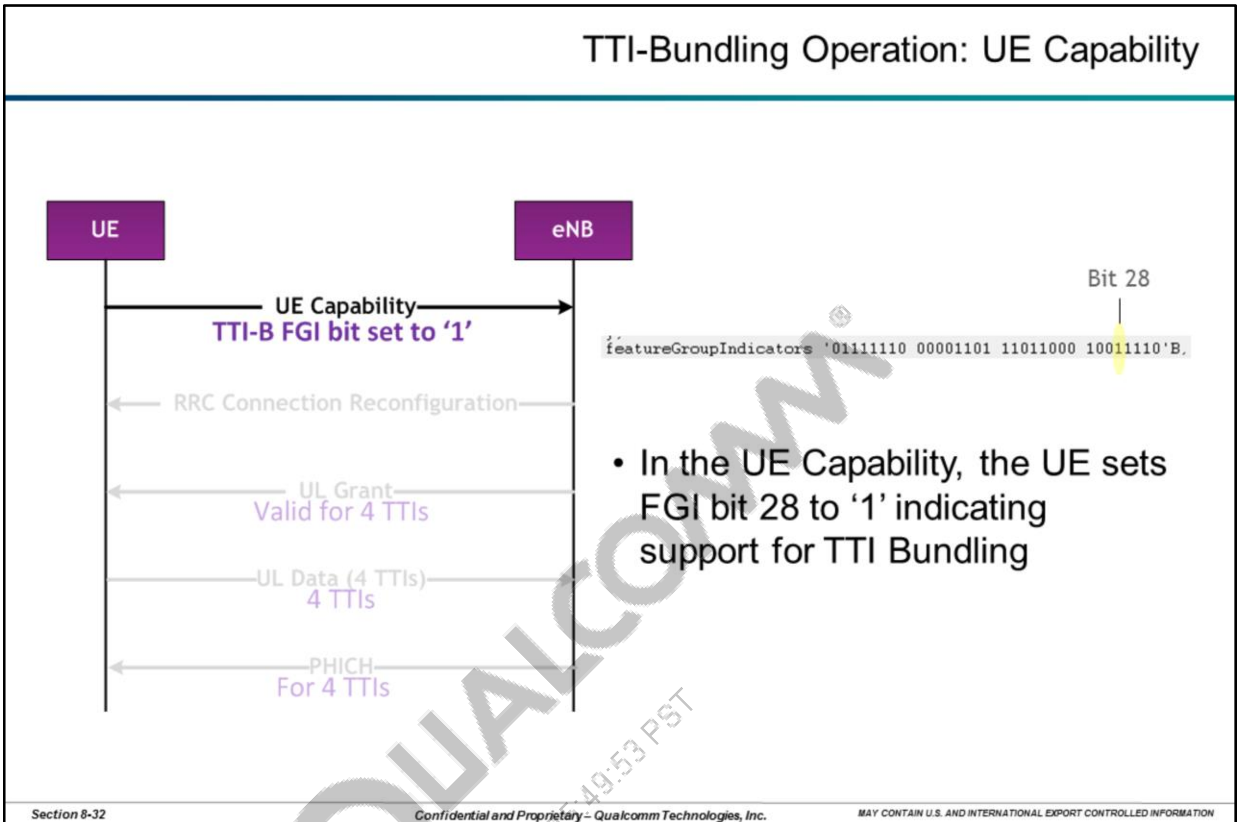
When comparing the TTI bundling mechanism with the conventional TTI transmission:

- Uplink resources over multiple TTIs can be assigned with a single grant, which decreases the signaling overhead. To trigger a transmission of a TTI bundle, the same grant format can be used as for ordinary HARQ transmissions. Whether the UE should transmit using a single TTI or TTI bundling is configured by the Radio Resource Control (RRC) protocol.
- There is a single HARQ feedback on the PHICH after each TTI bundle transmission. This decreases control signaling and vulnerability to NACK-to-ACK errors, which can lead to data loss.
- For power limited UE where retransmission is inevitable, TTI bundling provides the UE with the four redundant versions of the PDU in one shot, saving time and resources.



TTI-Bundling Operation

- UE indicated support for TTI-B by setting FGI bit 28 to '1'
- eNB enabled TTI-Bundling through RRC Connection Reconfiguration
- eNB assigned UL grants that are valid for 4 TTIs
- UE uses the grant 4 subframes later and transmits for 4 TTIs
- eNB sends the PHICH response for all 4 TTIs, four subframes later


TTI-Bundling Operation: UE Capability
UE
eNB
UE Capability
TTI-B FGI bit set to '1'
RRC Connection Reconfiguration
UL Grant
Valid for 4 TTIs
UL Data (4 TTIs)
4 TTIs
PHICH
For 4 TTIs
Bit 28
featureGroupIndicators '01111110 00001101 11011000 10011110'B,
• In the UE Capability, the UE sets FGI bit 28 to '1' indicating support for TTI Bundling
Section 8-32
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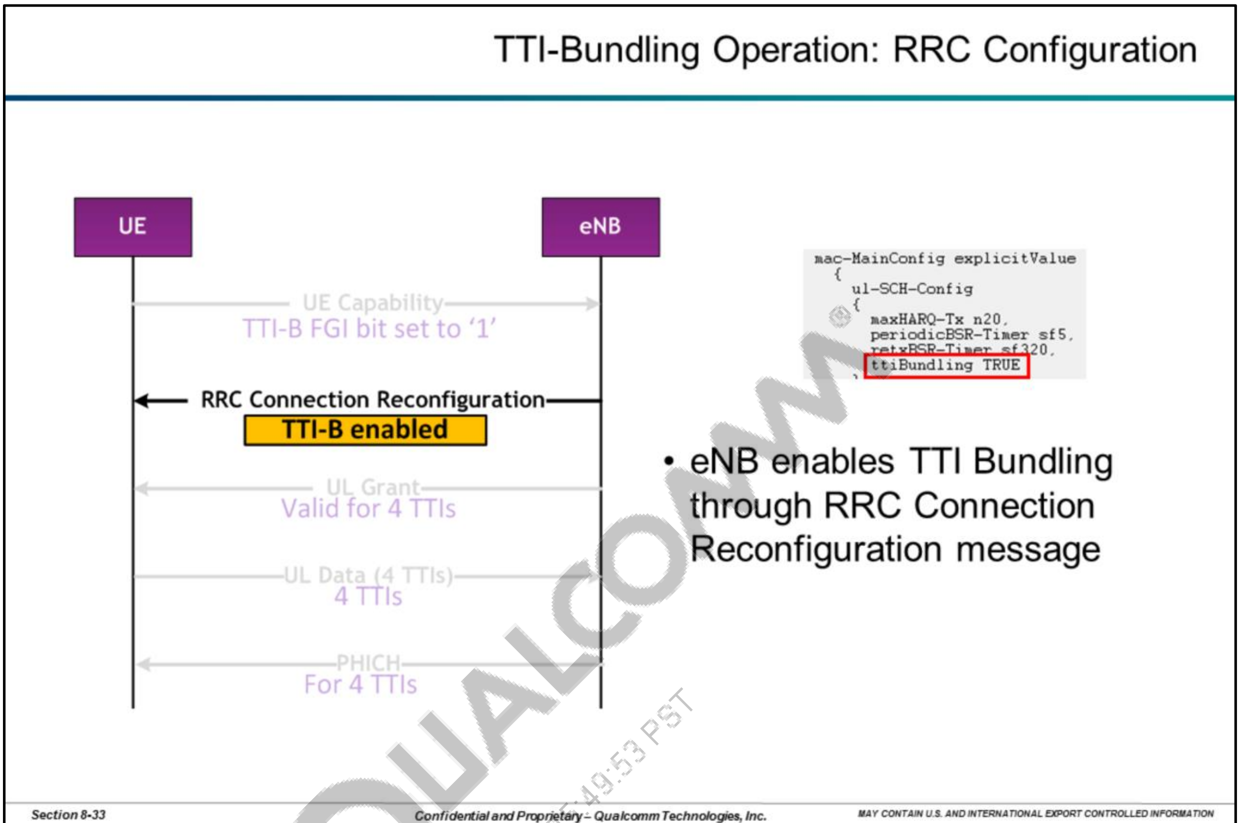
Notes


TTI-Bundling Operation: RRC Configuration
UE
eNB
UE Capability
TTI-B FGI bit set to '1'
RRC Connection Reconfiguration
TTI-B enabled
UL Grant
Valid for 4 TTIs
UL Data (4 TTIs)
4 TTIs
PHICH
For 4 TTIs
mac-MainConfig explicitValue
{
ul-SCH-Config
{
maxHARQ-Tx n20,
periodicBSR-Timer sf5,
retxBSR-Timer sf320,
ttiBundling TRUE
• eNB enables TTI Bundling through RRC Connection Reconfiguration message
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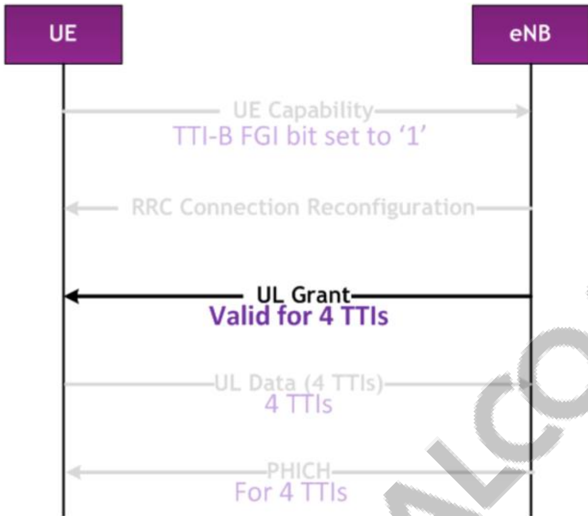
Notes

TTI-Bundling Operation: UL Grants




```
4199 Nov 25  08:12:36.985  [00]  0xB16C  LTE DCI Information Report
Version                 = 2
Number of Records       = 20
DCI Info Records
```

#	SFN	Sub-fn	UL Grant Present	UL Grant Info: RIV Width	RIV Value	Hopping Flag	MCS Index
0	581	2	Yes	11	58	Disabled	10
1	581	6	Yes	11	58	Disabled	10
2	582	0	Yes	11	58	Disabled	10
3	582	4	Yes	11	58	Disabled	10
4	582	8	Yes	11	58	Disabled	10
5	583	2	Yes	11	58	Disabled	10
6	583	6	Yes	11	58	Disabled	10
7	584	0	Yes	11	58	Disabled	10
8	584	4	Yes	11	58	Disabled	10
9	584	8	Yes	11	58	Disabled	10
10	585	2	Yes	11	58	Disabled	10
11	585	6	Yes	11	58	Disabled	10
12	586	0	Yes	11	58	Disabled	10
13	586	4	Yes	11	58	Disabled	10

- UL grants are given, every 4 TTIs (4 subframes)
- One UL grant should be used for 4 TTIs, starting 4 subframes later
- UL grant at 582/0 is used to transmit at 582/4 through 582/7

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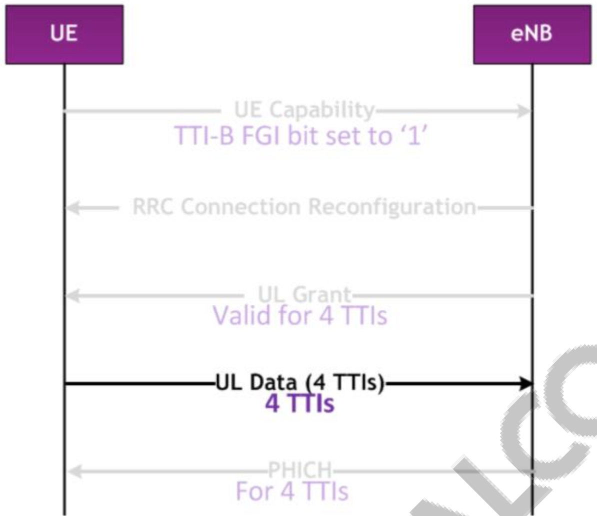
Notes

TTI-Bundling Operation: PUSCH Transmission




```
4199 Nov 25  08:12:36.929  [00]  0xB139  LTE LL1 PUSCH Tx Report
Version                = 5
Serving Cell ID        = 139
Number of Records      = 20
Dispatch SFN SF        = 5833
Records
   -------------------------------------------------------------------------
   |Current |ACK  |CQI  |RI   |Frequency|Re-tx  |Redund|
   |SFN SF  |     |     |     |Hopping  |Index  |Ver   |
   -------------------------------------------------------------------------
   |    5814|  None|  None|  None| Disabled|  Third|     3|
   |    5815|  None|  None|  None| Disabled| Fourth|     1|
   |    5816|  None|  None|  None| Disabled|  First|     0|
   |    5817|  None|  None|  None| Disabled| Second|     2|
   |    5818|  None|  None|  None| Disabled|  Third|     3|
   |    5819|  None|  None|  None| Disabled| Fourth|     1|
   |    5820|  None|  None|  None| Disabled|  First|     0|
   |    5821|  None|  None|  None| Disabled| Second|     2|
   |    5822|  None|  None|  None| Disabled|  Third|     3|
   |    5823|  None|  None|  None| Disabled| Fourth|     1|
   |    5824|  None|  None|  None| Disabled|  First|     0|
   |    5825|  None|  None|  None| Disabled| Second|     2|
   |    5826|  None|  None|  None| Disabled|  Third|     3|
   |    5827|  None|  None|  None| Disabled| Fourth|     1|
   |    5828|  None|  None|  None| Disabled|  First|     0|
   |    5829|  None|  None|  None| Disabled| Second|     2|
   |    5830|  None|  None|  None| Disabled|  Third|     3|
```

- UE uses the UL grants at 582/0 to transmit at 582/4, 582/5, 582/6, and 582/7
- The 4 transmissions have different RV values, but the same HARQ ID

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TTI-Bundling Operation

- UE uses the grant 4 subframes later and transmits for 4 TTIs using the same HARQ ID
- HARQ ID is 2 for subframes 582/4, 582/5, 582/6, and 582/7

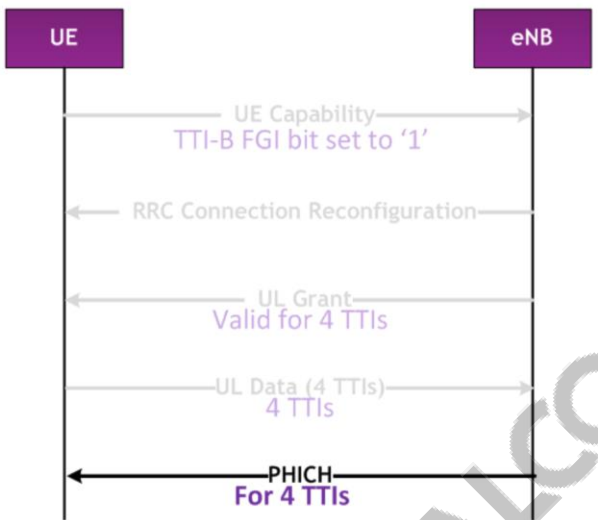
```
Tx Report Records[3] {
   Chan Type                      = PUSCH
   Tx SFN                         = 582
   Tx Sub-fn                      = 4
   Transport Block Size           = 41
   CSF Present Flag               = 0
   UL ACK/NAK Present Flag        = ACK/NAK not present
   ACK/NAK Reporting Mode         = FDD Mode
   Total Tx Power                 = -7 dBm
   Beta PUSCH                     = 242
   Cyclic Shift DMRS              = 0
   Resource Block Start           = 8
   Redundancy Version             = 0
   ACK/NAK Length                 = 0
   Modulation Type                = QPSK
   Number of Resource Blocks      = 2
   Retransmission Index           = 0
   HARQ ID                        = 2
   Freq Hopping Flag              = Disabled
```

```
Tx Report Records[4] {
   Chan Type                      = PUSCH
   Tx SFN                         = 582
   Tx Sub-fn                      = 5
   Transport Block Size           = 41
   CSF Present Flag               = 0
   UL ACK/NAK Present Flag        = ACK/NAK not present
   ACK/NAK Reporting Mode         = FDD Mode
   Total Tx Power                 = -7 dBm
   Beta PUSCH                     = 242
   Cyclic Shift DMRS              = 0
   Resource Block Start           = 8
   Redundancy Version             = 2
   ACK/NAK Length                 = 0
   Modulation Type                = QPSK
   Number of Resource Blocks      = 2
   Retransmission Index           = 1
   HARQ ID                        = 2
   Freq Hopping Flag              = Disabled
```

```
Tx Report Records[3] {
   Chan Type                      = PUSCH
   Tx SFN                         = 582
   Tx Sub-fn                      = 4
   Transport Block Size           = 41
   CSF Present Flag               = 0
   UL ACK/NAK Present Flag        = ACK/NAK not present
   ACK/NAK Reporting Mode         = FDD Mode
   Total Tx Power                 = -7 dBm
   Beta PUSCH                     = 242
   Cyclic Shift DMRS              = 0
   Resource Block Start           = 8
   Redundancy Version             = 0
   ACK/NAK Length                 = 0
   Modulation Type                = QPSK
   Number of Resource Blocks      = 2
   Retransmission Index           = 0
   HARQ ID                        = 2
   Freq Hopping Flag              = Disabled
```

```
Tx Report Records[6] {
   Chan Type                      = PUSCH
   Tx SFN                         = 582
   Tx Sub-fn                      = 7
   Transport Block Size           = 41
   CSF Present Flag               = 0
   UL ACK/NAK Present Flag        = ACK/NAK not present
   ACK/NAK Reporting Mode         = FDD Mode
   Total Tx Power                 = -7 dBm
   Beta PUSCH                     = 242
   Cyclic Shift DMRS              = 0
   Resource Block Start           = 8
   Redundancy Version             = 1
   ACK/NAK Length                 = 0
   Modulation Type                = QPSK
   Number of Resource Blocks      = 2
   Retransmission Index           = 3
   HARQ ID                        = 2
   Freq Hopping Flag              = Disabled
```

TTI-Bundling Operation: ACK



4199 Nov 25 08:12:36.954 [00] 0xB16B LTE PDCCH-PHICH Indication Report
Version = 1
Number of Records = 50
Info Records

#	Num PDCCH Results	PDCCH Timing SFN	PDCCH Timing Sub-fn	PHICH Included	PHICH PHICH Timing SFN	PHICH Timing Sub-fn	PHICH Value	PDCCH I CRC Status
21	0	582	9	No				
22	0	583	0	No				
23	0	583	1	Yes	583	1	ACK	
24	1	583	2	No				Pass
25	0	583	3	No				
26	0	583	4	No				
27	0	583	5	Yes	583	5	ACK	
28	1	583	6	No				Pass
29	0	583	7	No				
30	0	583	8	No				
31	0	583	9	Yes	583	9	ACK	
32	1	584	0	No				Pass
33	0	584	1	No				
34	0	584	2	No				
35	0	584	3	Yes	584	3	ACK	
36	1	584	4	No				Pass

- The 4 UL transmissions, ending at 582/7, are ACK'd 4 subframes later at 583/1
- One PHICH is used to ACK the 4 TTIs
- PHICH is received every 4 TTIs, as the UL grants are also given every 4 TTIs

Notes

Log Analysis: TTI Bundling

Log Analysis Procedure: TTI-Bundling

Open File: 08-03-TTI-Bundling

Notes

TTI-Bundling: Log Walk-Through

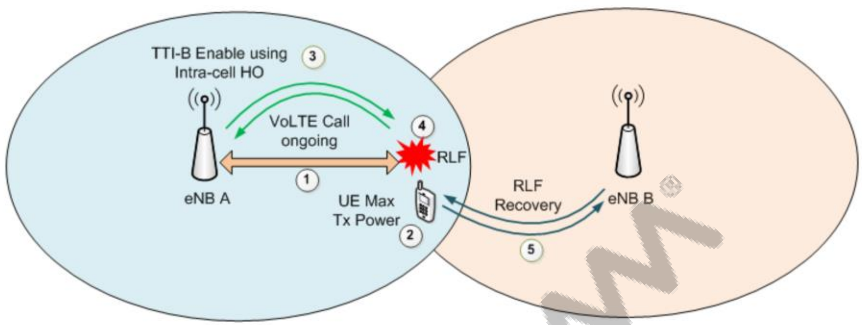
Step	Look for…	Log Packet	Timestamp	Verify…
1	LTE RRC OTA Packet	0xB0C0	08:12:34.649	TTI Bundling is enabled
2	LTE DCI Information Report	0xB16C	08:12:36.985	UL grants are available every 4 subframes Select one grant, say 582/0
3	LTE LL1 PUSCH Tx Report	0xB139	08:12:36.929	UE uses the grant of 582/2 to transmit on 582/4 through 582/7
4	LTE PDCCH-PHICH Indication Report	0xB16B	08:12:36.954	eNB sends PHICH response at 583/1 for the 4 TTIs

TTI-Bundling: Log Walk-Through

The arrival of messages during logging could impact the order in which time stamps are shown.

If needed while analyzing a log file in the browser, use the menu “Edit” + “Find on this Page” (Ctrl+F) to find a specific timestamp.

Overview of RLF issue during TTI Bundling Enabling



1. VoLTE call is in progress on eNB A.
2. UE transmitting at Max power (23 dBm).
3. Due to poor Uplink performance, eNB A triggered TTI bundling through intra-cell handover.
4. Upon intra-cell handover, UE declared RLF due to SIB read failure.
5. UE acquired eNB B after RLF and reestablished on eNB B.

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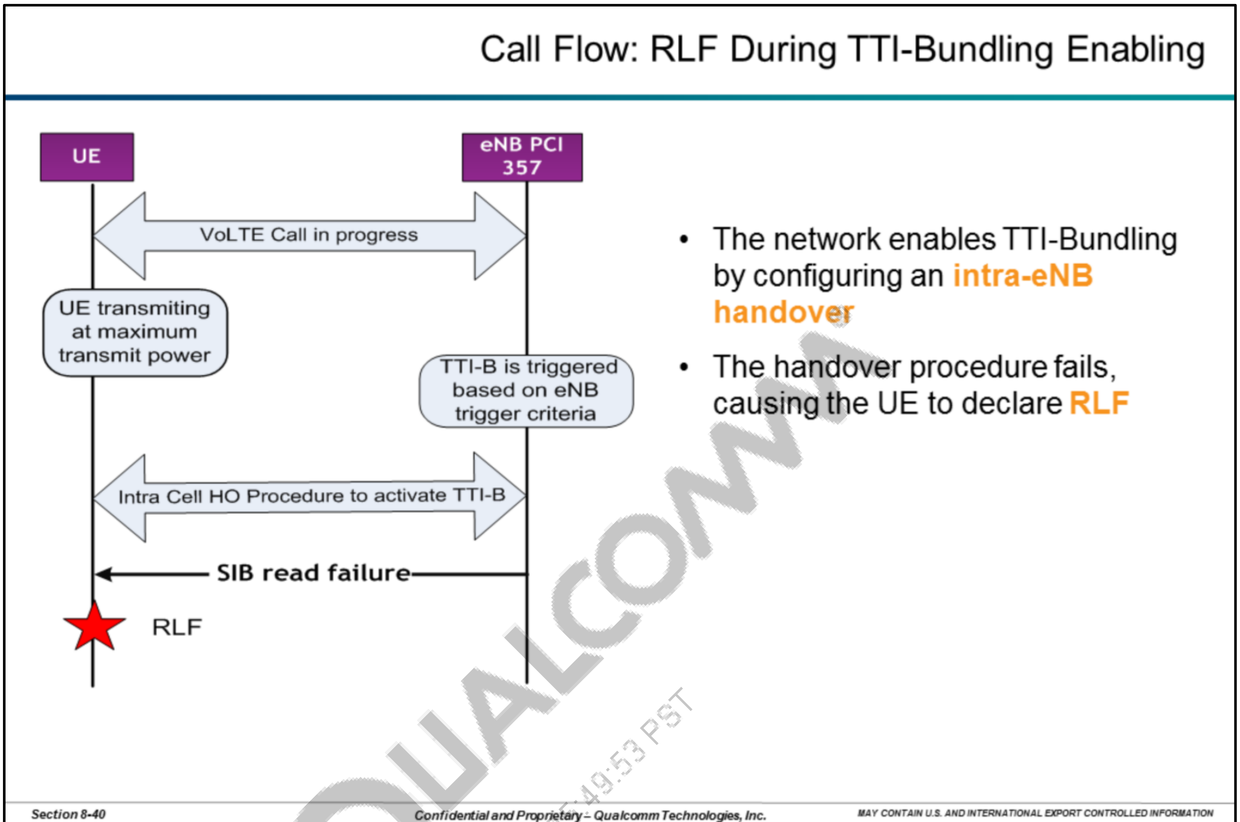
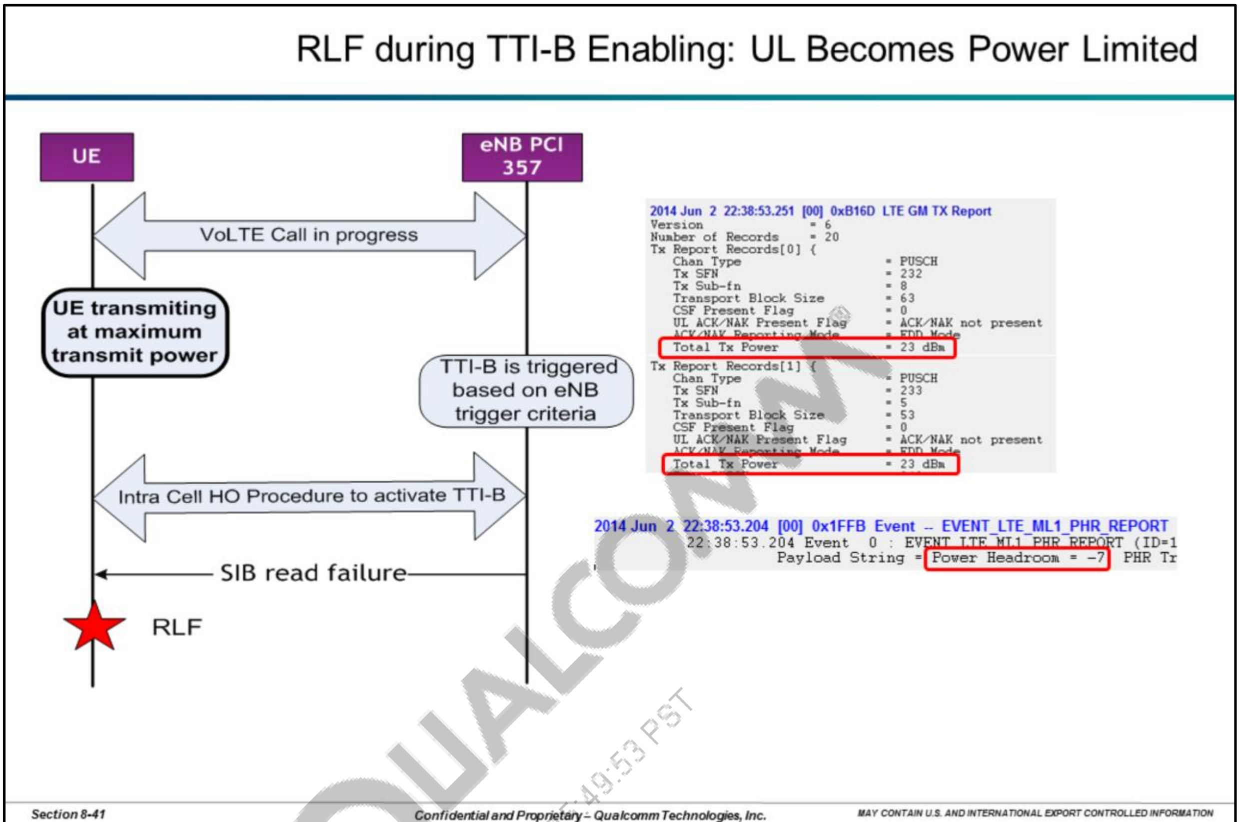
Overview of RLF Issue during TTI Bundling Enabling

- UE is in Mobile to Mobile VoLTE call.
- UE is on PCI 357 and transmitting at max UL Tx power.
- eNB determines that the UE is power limited (Impacts UL performance) and since VoLTE call is on going, eNB enables TTI Bundling.
- eNB triggers TTI Bundling through Intra cell HO procedure.
- UE performs handover to the same PCI (PCI 357).
- As a part of the handover procedure, UE attempts to read the mandatory System information on PCI 357.
- UE fails to decode System Information on PCI 357 and declares SIB Read Failure.
- SIB read failure on Connected mode results in RLF.
- UE attempts to re establish on neighbor PCI (PCI 11).



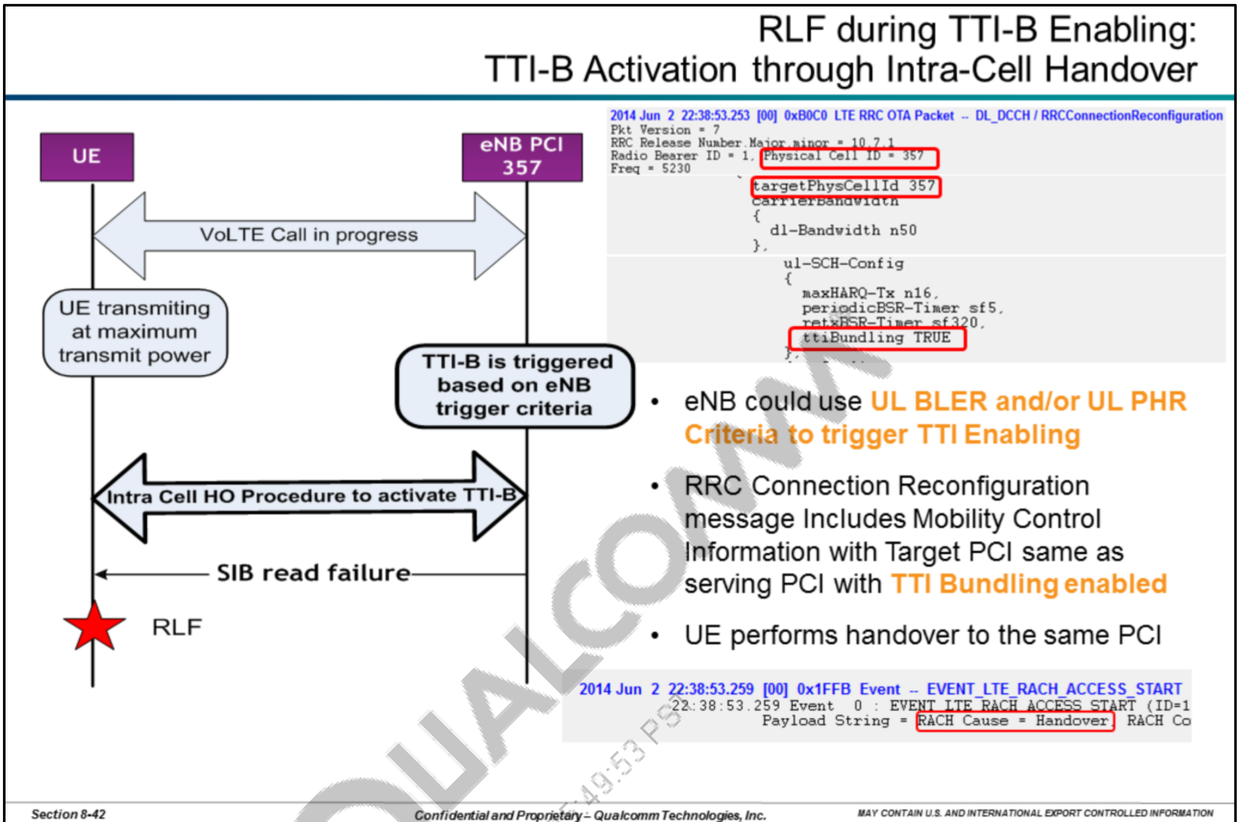
Call Flow: RLF Issue during TTI Bundling Enabling

- UE is on a VoLTE call on PCI 357 and transmitting at max UL Tx power (23 dBm).
- With UE transmitting at maximum UL power, UL performance is still poor.
- eNB triggers TTI-Bundling through Intra cell HO procedure. UE performs handover to the same PCI (PCI 357).
- As a part of handover procedure, UE attempts to read the mandatory SIBs on PCI 357.
- UE fails to decode System Information on PCI 357 and declares SIB Read Failure.
- Mandatory SIB read failure on Connected mode results in RLF.



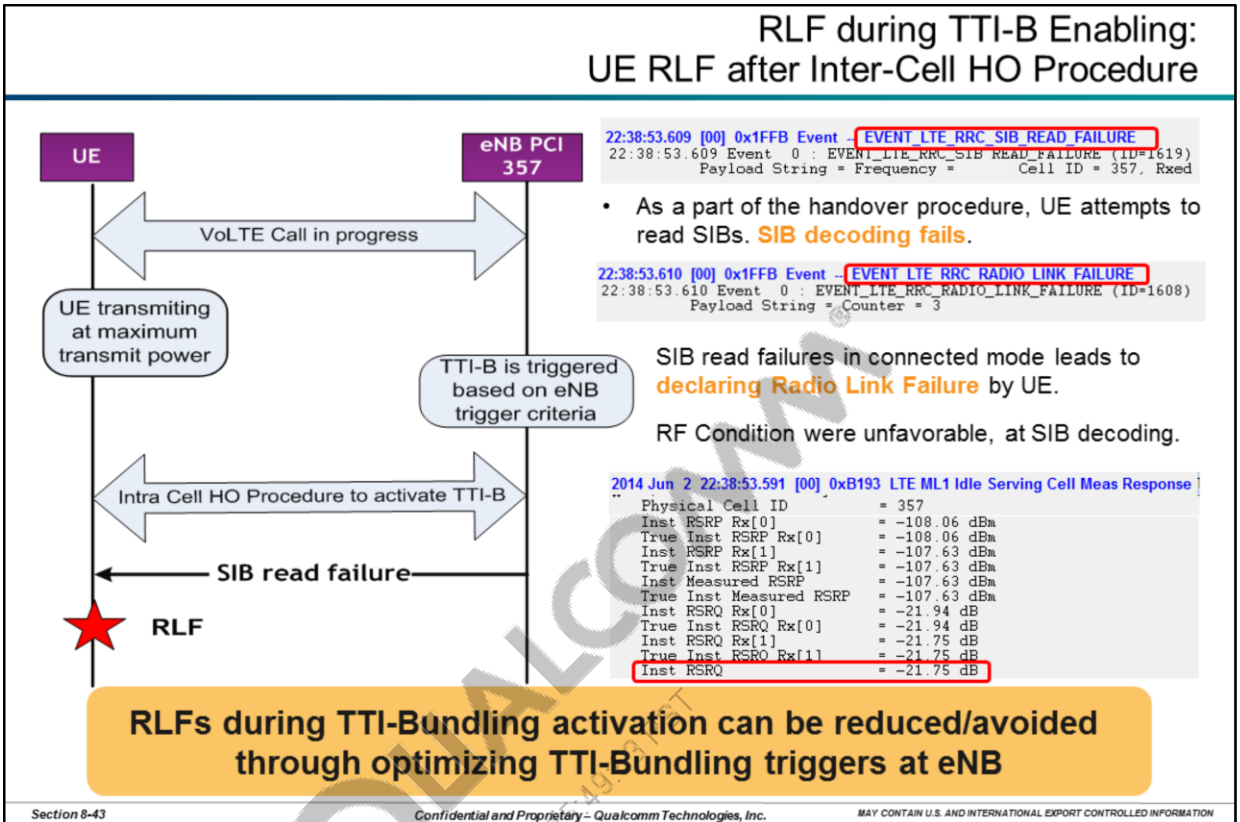
RLF during TTI-B Enabling: UL Performance Degradation Causing TTI-B Activation

- UE is in Mobile to Mobile VoLTE call. UE is on PCI 357 and transmitting at max UL transmit power (23 dBm).
- Negative PHR value reported by UE also indicates that UE is power limited.
- With UE transmitting at maximum UL power, UL performance is still poor.



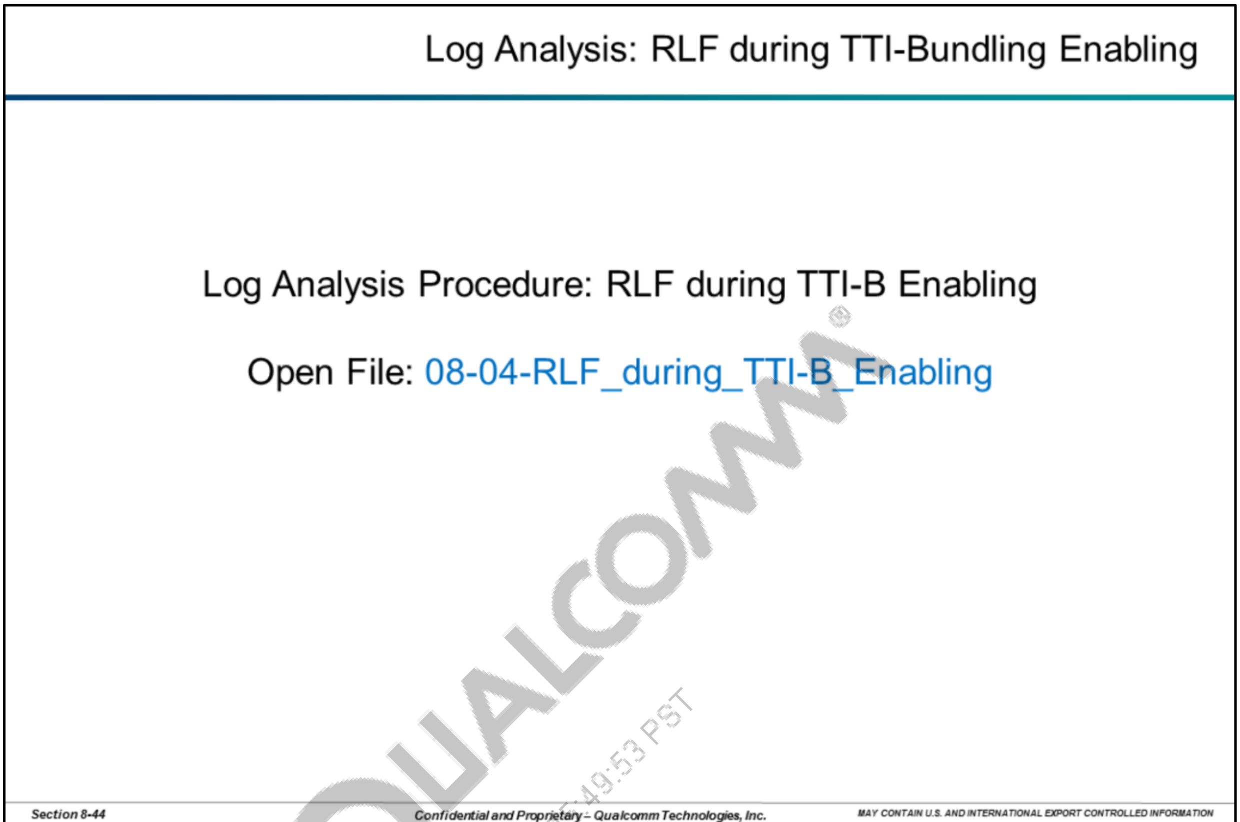
RLF during TTI-B Enabling: TTI-B Activation through Intra-Cell HO Procedure

- In order to improve UL coverage for UE, eNB enables TTI Bundling for improving UL performance for UE.
- eNB activates TTI-Bundling activation through Intra-cell handover procedure.
- UE performs handover to the same PCI (PCI 357).
- UE will transmit each UL packet in 4 TTIs, which will improve UL coverage performance.



RLF during TTI-B Enabling: UE RLF after Inter-Cell HO Procedure

- As part of the handover procedure, UE attempts to read the mandatory System information on PCI 357.
- When UE fails to decode System Information on PCI 357 and declares SIB Read Failure.
- Mandatory SIB read failure on Connected mode results in RLF.
- After RLF Recovery, UE camped on Neighbor PCI and UE attempts to reestablish on neighbor PCI (PCI 11).


Log Analysis: RLF during TTI-Bundling Enabling
Log Analysis Procedure: RLF during TTI-B Enabling
Open File: 08-04-RLF_during_TTI-B_Enabling
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Notes

Log Analysis: RLF Issue during TTI Bundling Enabling

Step	Look for…	Log Packet	Timestamp	Verify…
1	System Information	0xB0C0	22:38:51.841	UE camped on PCI 357
2	EVENT_LTE_ML1_PHR_REPORT	0x1FFB	22:38:53.204	UE sends PHR reports with UL Power headroom with negative value indicating UE is power limited
3	LTE GM TX Report	0xB16D	22:38:53.251	UE is transmitting at PUSCH Max Transmit power (23 dBm)
4	RRC Connection Reconfiguration	0xB0C0	22:38:53.253	On PCI 327, eNB enables TTI Bundling and includes MCI information
5	RRCConnectionReconfigurationComplete	0xB0C0	22:38:53.259	Handover Complete command
6	EVENT_LTE_RACH_ACCESS_START	0x1FFB	22:38:53.259	UE performs handover RACH Procedure
7	EVENT_LTE_RRC_SIB_READ_FAILURE	0x1FFB	22:38:53.609	SIB Read failure declared by UE on PCI 327
8	EVENT_LTE_RRC_RADIO_LINK_FAILURE_STAT	0x1FFB	22:38:53.610	RLF declared by UE
9	RRC Connection Reestablishment Request	0xB0C0	22:38:53.875	RLF Re-establishment on Neighbor PCI 11

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Log Analysis: RLF Issue during TTI Bundling Enabling

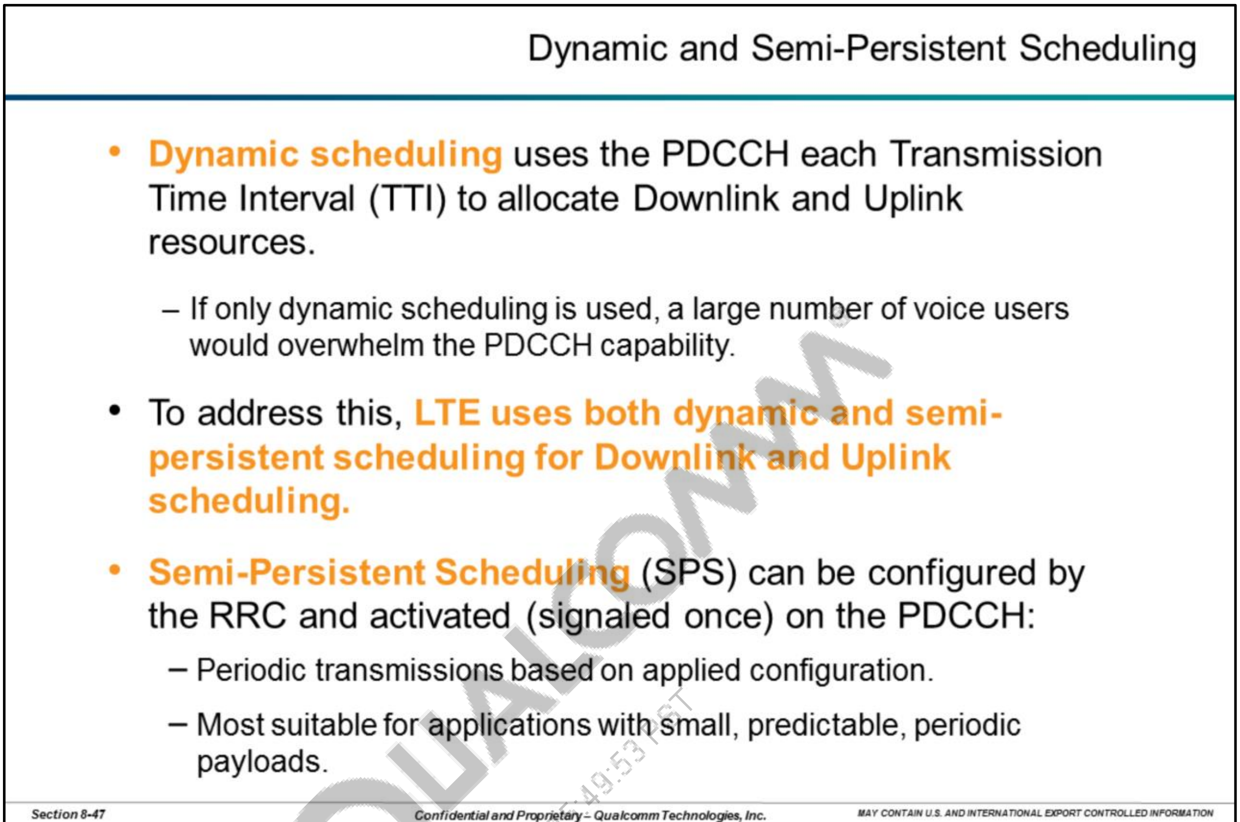
The arrival of messages during logging could impact the order in which time stamps are shown.

If needed while analyzing a log file in the browser, use the menu "Edit" + "Find on this Page" (Ctrl+F) to find a specific timestamp.

Topic Map

- C-DRX
- Robust Header Compression (RoHC)
- TTI-Bundling
- **Semi-Persistent Scheduling (SPS)**

Notes

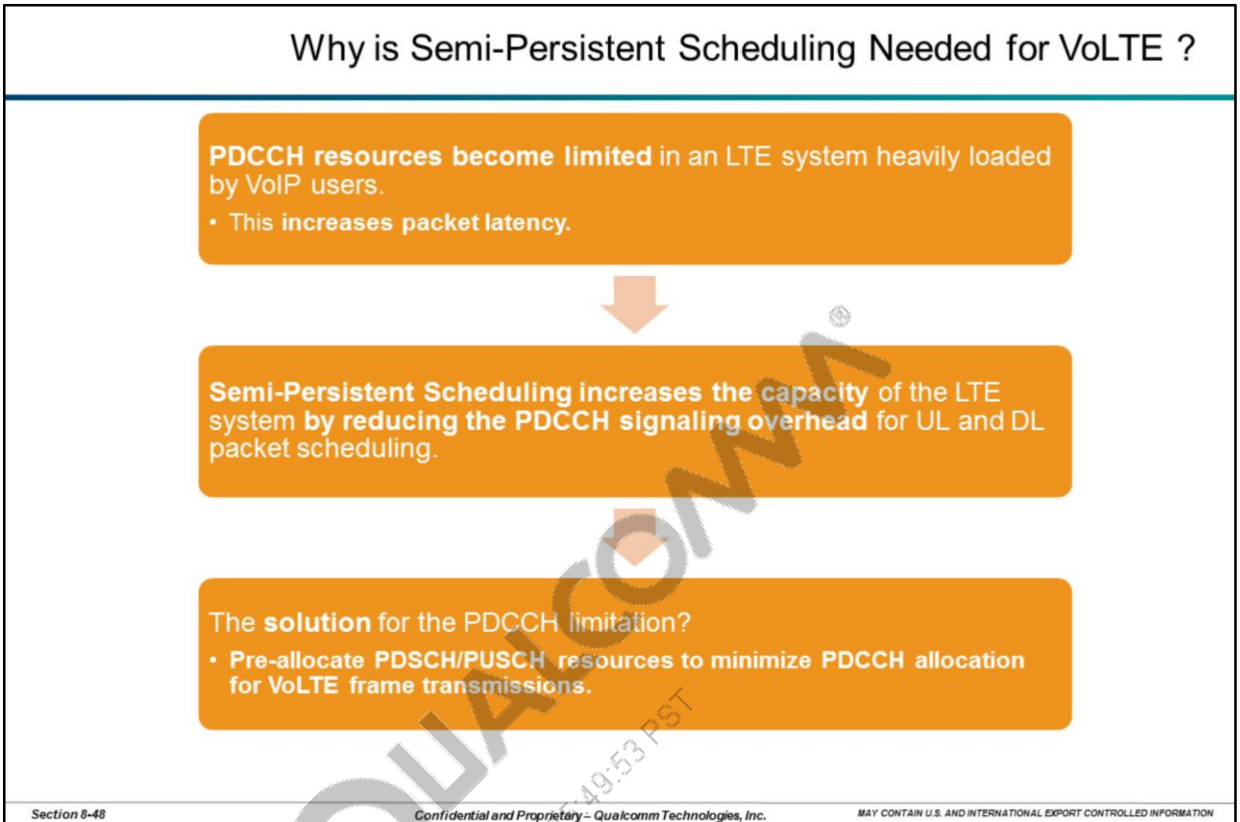


Dynamic and Semi-Persistent Scheduling

The UE may be dynamically scheduled on a per-subframe basis, with the control information signaled on PDCCH. However, the UE may also receive a semi-persistent grant or allocation.

With Semi-Persistent Scheduling (SPS), the scheduling control information is signaled just once via the PDCCH. After that, the UE can transmit and receive periodically following the pattern defined by the Downlink Semi-Persistent Scheduling Interval parameter. The UE will use the same configuration until modified or released.

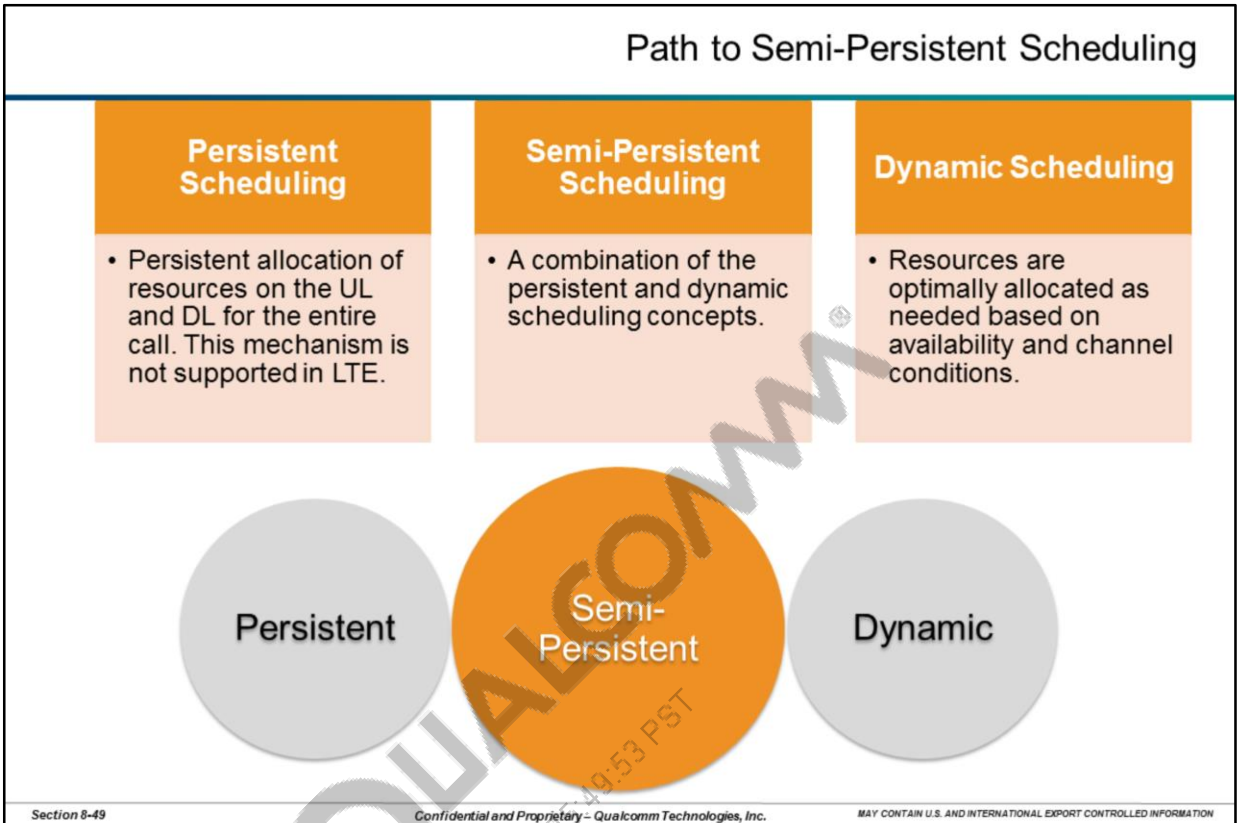
When a dynamic allocation or grant is received that corresponds to a subframe where an SPS scheduled transmission would occur, the dynamic grant takes precedence. Additionally, any retransmissions would be scheduled dynamically via the PDCCH.



Why is Semi-Persistent Scheduling Needed for VoLTE ?

Efficient VoIP support is a fundamental requirement for Evolved UTRA. Because there is no circuit switched domain, voice service will be supported in the packet switched domain only. Therefore, it is necessary for E-UTRA to support a large portion of voice capacity that is currently being handled by traditional circuit switched networks. To achieve this goal, packet scheduling algorithms and related resource allocation methods are destined to play a pivotal role among all the elements of system.

One of the challenges for efficient VoIP support is control signaling overhead for VoIP transmissions. The traditional full dynamic scheduling scheme could become a bottleneck and limit the system capacity. Hence the need for a different type of scheduling that requires less control signaling overhead without losing some of the flexibility of resource allocation in time and frequency domain of the dynamic scheduling.


Path to Semi-Persistent Scheduling
Persistent Scheduling
• Persistent allocation of resources on the UL and DL for the entire call. This mechanism is not supported in LTE.
Semi-Persistent Scheduling
• A combination of the persistent and dynamic scheduling concepts.
Dynamic Scheduling
• Resources are optimally allocated as needed based on availability and channel conditions.
Persistent
Semi-Persistent
Dynamic
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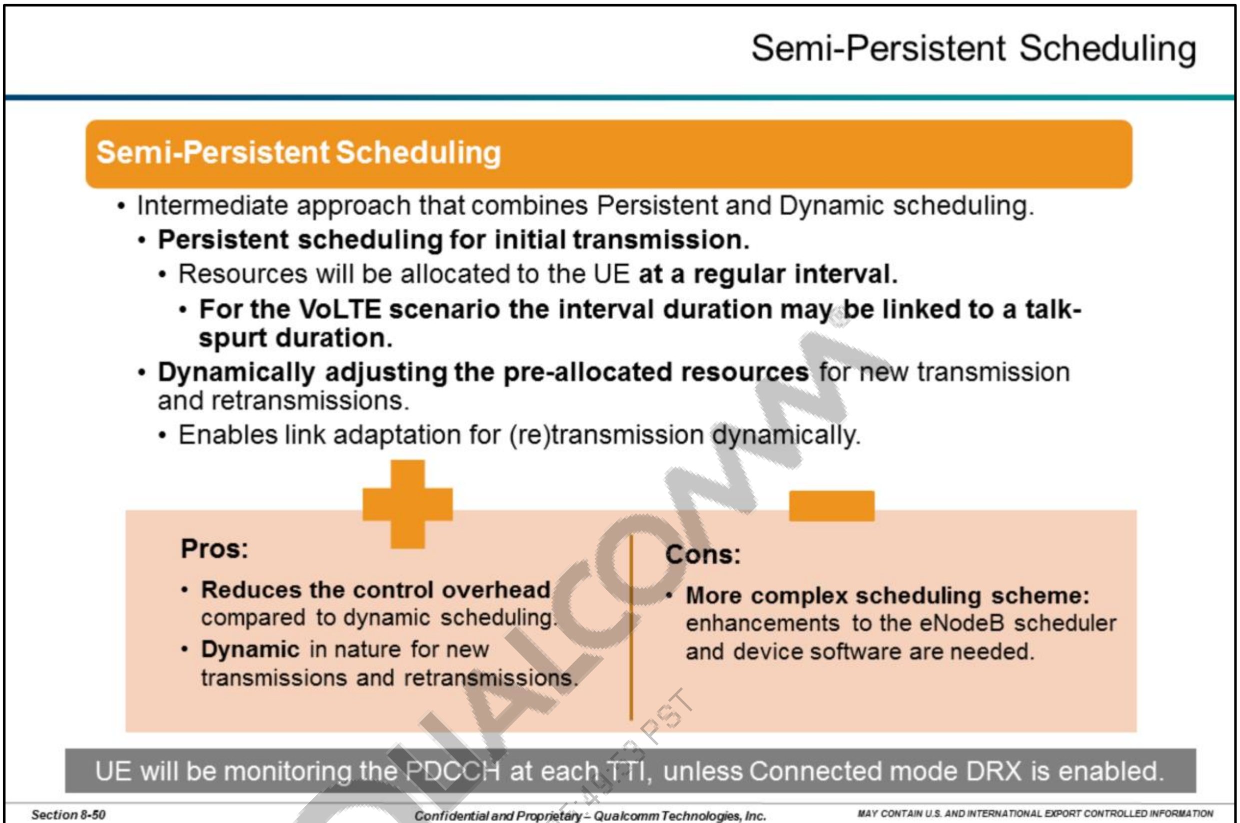
Notes

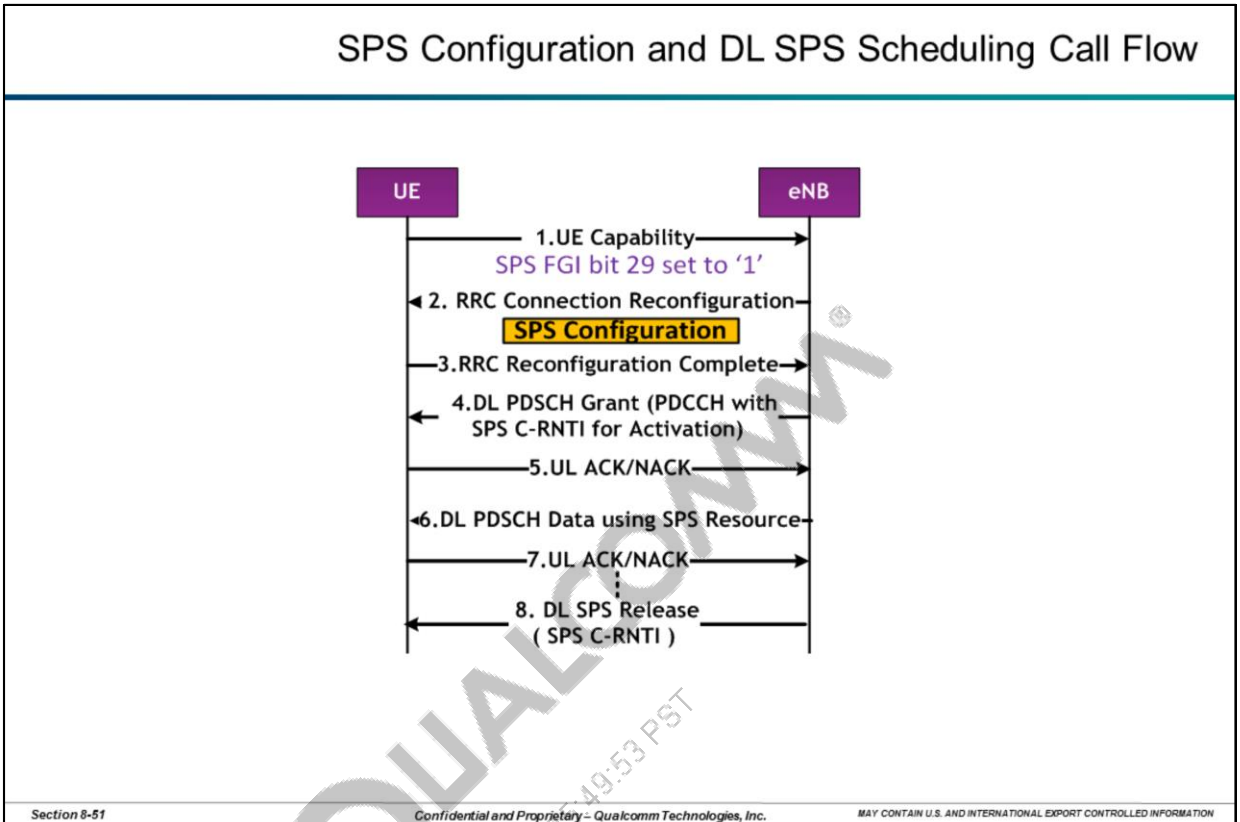


Semi-Persistent Scheduling

The basic principle is to periodically allocate certain transmission resources for a particular user. For semi-persistent resource scheduling, the time pattern is initially configured via the RRC protocol. The Node B can always override semi-persistent scheduling in the TTI by dynamically scheduling the same user via the PDCCH. Because the persistently allocated resources are periodic in time with a fixed bandwidth as well as a constant modulation and coding scheme, they represent regular scheduling of a fixed data amount.

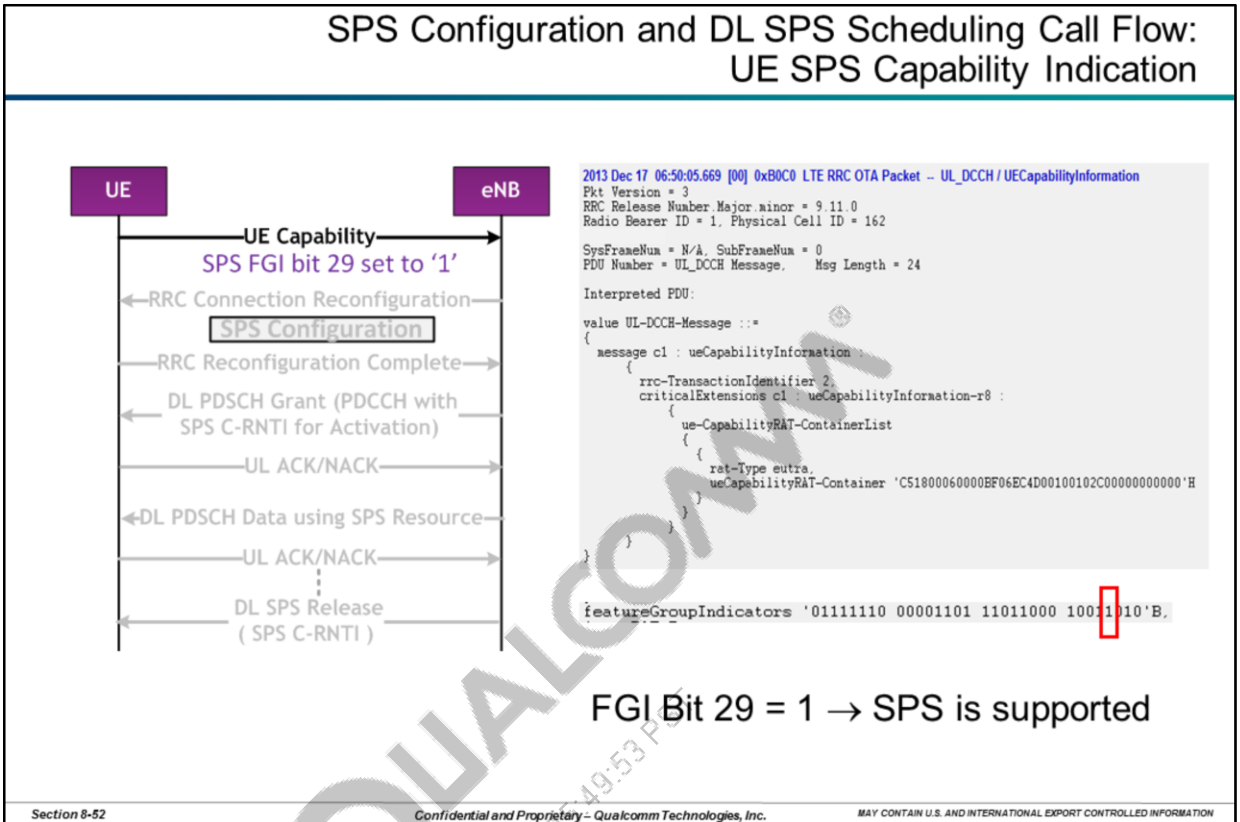
The semi-persistent scheduling method is therefore primarily intended for deterministic data flows (e.g., for Voice over Internet Protocol [VoIP] service). For example, a user with constant size VoIP packets arriving every 20 ms could be persistently scheduled with this time interval on a bandwidth (number of PRBs), and a modulation and coding scheme corresponding to the expected packet size and estimated link quality.

The main advantage of semi-persistent scheduling is that no explicit physical layer signaling on the PDCCH is required for every transmission, which reduces the Downlink control signaling overhead. However, if reception of a persistently scheduled packet fails, any hybrid ARQ retransmissions will need dynamic scheduling.



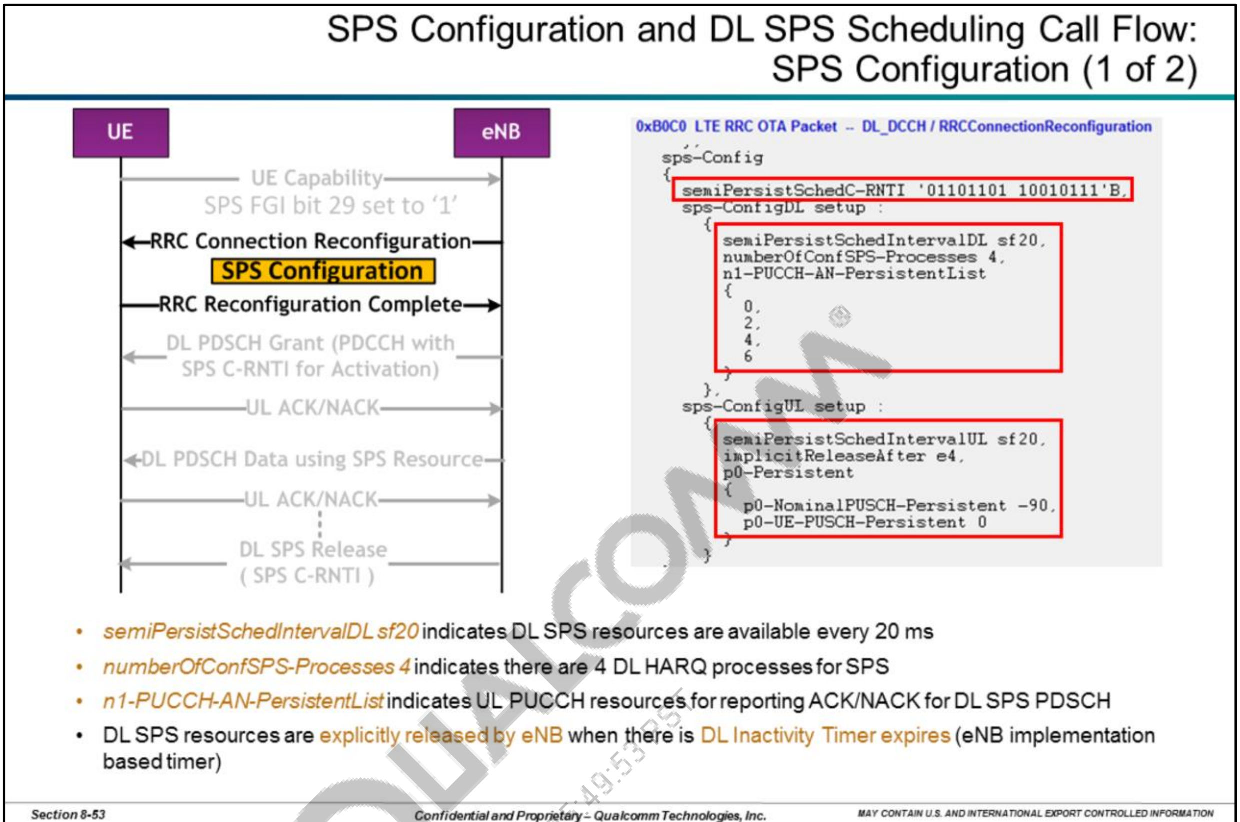
SPS Configuration and DL SPS Scheduling Call Flow

1. During UE Attach Procedure, UE indicates its capability to support SPS feature through FGI bit 29 = 1.
2. When VoLTE call is established, QCI 1 Dedicated Bearer establishment will be trigged by network. QCI 1 Bearer will be used to carry VoLTE Voice Packets. During QCI 1 coupled DRB Bearer (GBR) activation through RRC Reconfiguration Signaling procedure, eNB will configure SPS Parameters and assigns UE specific SPS C-RNTI Value
3. Upon successful UE configuration of DRB and other parameters specified in RRC Connection Reconfiguration message, UE will send RRC Connection Reconfiguration complete message to eNB.
4. Upon successful SPS configuration for UE, in order to activate DL SPS, eNB uses PDCCH to activate DL SPS. PDCCH CRC used to activate SPS will be scrambled with SPS C-RNTI allocated for that UE. PDCCH Payload format for DL SPS Activation is specified by 36.213, Table 9.2-1.
5. Upon UE decoding PDSCH data received on DL SPS Resources, UE will send PUCCH ACK/NACK Resources specified during SPS Configuration Procedure.
6. Subsequently UE will receive DL VoLTE Packets on DL PDSCH SPS Resources. SPS Resources are used only for Initial Transmissions and any Re-Transmission needs dynamic Scheduling Procedure. For receiving DL SPS Scheduled data, there is no need for PDCCH Resources.
7. UE will send UL PUCCH ACK/NACK for DL SPS PDSCH Packets received.
8. When eNB detects that there is no DL VoLTE Packets flow and DL SPS Inactivity Timer (ENB Implementation based Timer) expires, eNB will send DL PDCCH (CRC Scrambled with SPS-C RNTI) to deactivate DL SPS Resources. PDCCH Payload Format to indicate de-activation of DL SPS is specified by 3GPP 36.213, Table 9.2-1 A.



SPS Configuration and DL SPS Scheduling Call Flow: UE SPS Capability Indication

During UE Attach Procedure, UE indicates its capability to support SPS Feature through FGI bit 29 = 1.



SPS Configuration and DL SPS Scheduling Call Flow: SPS Configuration (1 of 3)

When VoLTE call is established, QCI 1 Dedicated Bearer establishment will be trigged by the network. QCI1 Bearer will be used to carry VoLTE voice packets. During QCI 1 coupled DRB Bearer (GBR) activation through RRC Reconfiguration Signaling procedure, eNB will configure SPS Parameters and assigns UE specific SPS C-RNTI value.

After a Semi-Persistent DL assignment is configured, the UE shall consider the assignment recurs in each subframe for which: (10 * SFN + subframe) = [(10 * SFNstart time + subframestart time) + N * semiPersistSchedIntervalDL] modulo 10240, for all N>0 Where SFNstart time and subframestart time are the SFN and subframe, respectively, at the time the configured Downlink assignment were (re)initialized.

In DL HARQ, HARQ ID will be deduced from the equation below:

HARQ Process ID = [floor(CURRENT_TTI/semiPersistSchedIntervalDL)] modulo numberOfConfSPS-Processes

- Current TTI: the TTI at which the UE is receiving the SPS DL assignment
- semiPersistSchedIntervalDl: DL SPS interval
- numberOfConfSPS-Processes: number of configured HARQ processes for SPS See TS36.321 for more details.

For the FDD scenario, when a UE is about to send a HARQ feedback on PUCCH in response to a PDSCH transmission without a corresponding PDCCH detected in subframe n-4 (because DL SPS is activated), the value of the PUCCH resources used to transmit the HARQ-ACK is determined according to n1-PUCCH-AN-PersistentList. The list from Table 9.2-2 in TS 36.213 provides a set of n(1)PUCCH indexes to be used.

SPS Configuration Parameters

Are included in the “RadioResourceConfigDedicated” IE of the RRC Connection Reconfiguration message.

SPS-Config Parameter	Description	Value
SPS C-RNTI	UE ID used to schedule an SPS unicast transmission, activation, reactivation, and retransmission	003D-FFF3
SPS DL Config		
SemiPersistSchedIntervalDL	Semi-persistent scheduling interval in Downlink	10–640 ms
numberOfConfSPS-Processes	The number of configured HARQ processes for Semi-Persistent Scheduling	1-8
SPS UL Config		
SemiPersistSchedIntervalUL	Semi-persistent scheduling interval in Uplink	10–640 ms
ImplicitReleaseAfter	Number of empty transmissions (padding PDUs) on the UL before the UE implicitly releases the UL SPS grant	2, 3, 4, 8

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SPS Configuration Parameters

After a Semi-Persistent DL assignment is configured, the UE shall consider the assignment recurs in each subframe for which:

(10 * SFN + subframe) = [(10 * SFNstart time + subframestart time) + N * *semiPersistSchedIntervalDL] modulo* 10240, for all N>0

Where SFNstart time and subframestart time are the SFN and subframe, respectively, at the time the configured Downlink assignment were (re)initialized.

Other optional parameters can be sent by the eNodeB for UL power control adjustment during SPS UL transmissions:

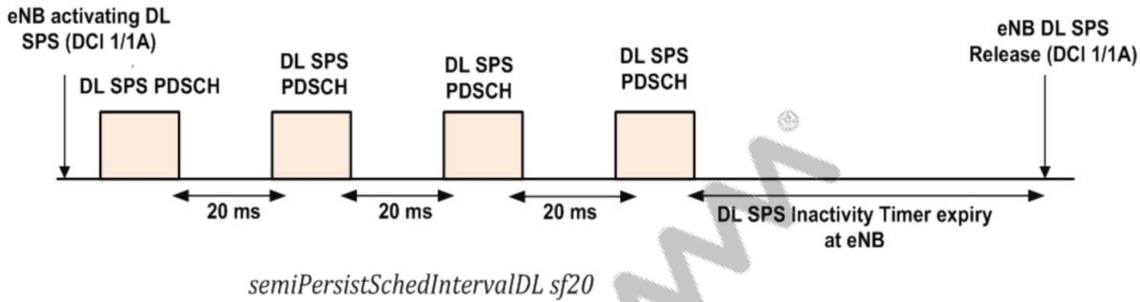
- *p0-NominalPUSCH-Persistent:* unit dBm step 1. This field is applicable SPS only. If choice ‘setup’ is used and *p0-Persistent* is absent, apply the value of *p0-NominalPUSCH* for *p0-NominalPUSCH-Persistent* (see TS 36.213 section 5.1.1.1).
- *p0-UE-PUSCH-Persistent:* unit dB. This field is applicable for SPS only. If choice ‘setup’ is used and *p0-Persistent* is absent, apply the value of p0-UE-PUSCH for *p0-UE-PUSCH-Persistent* (see TS 36.213 section 5.1.1.1).

For the FDD scenario, when a UE is about to send a HARQ feedback on PUCCH in response to a PDSCH transmission without a corresponding PDCCH detected in subframe n-4 (since DL SPS is activated), the value of the PUCCH resources used to transmit the HARQ-ACK is determined according to *n1-PUCCH-AN-PersistentList.* The following list from Table 9.2-2 in TS 36.213 provides a set of *n*(1)PUCCH indexes to be used.

Table 9.2-2: PUCCH Resource Index for Downlink Semi-Persistent Scheduling

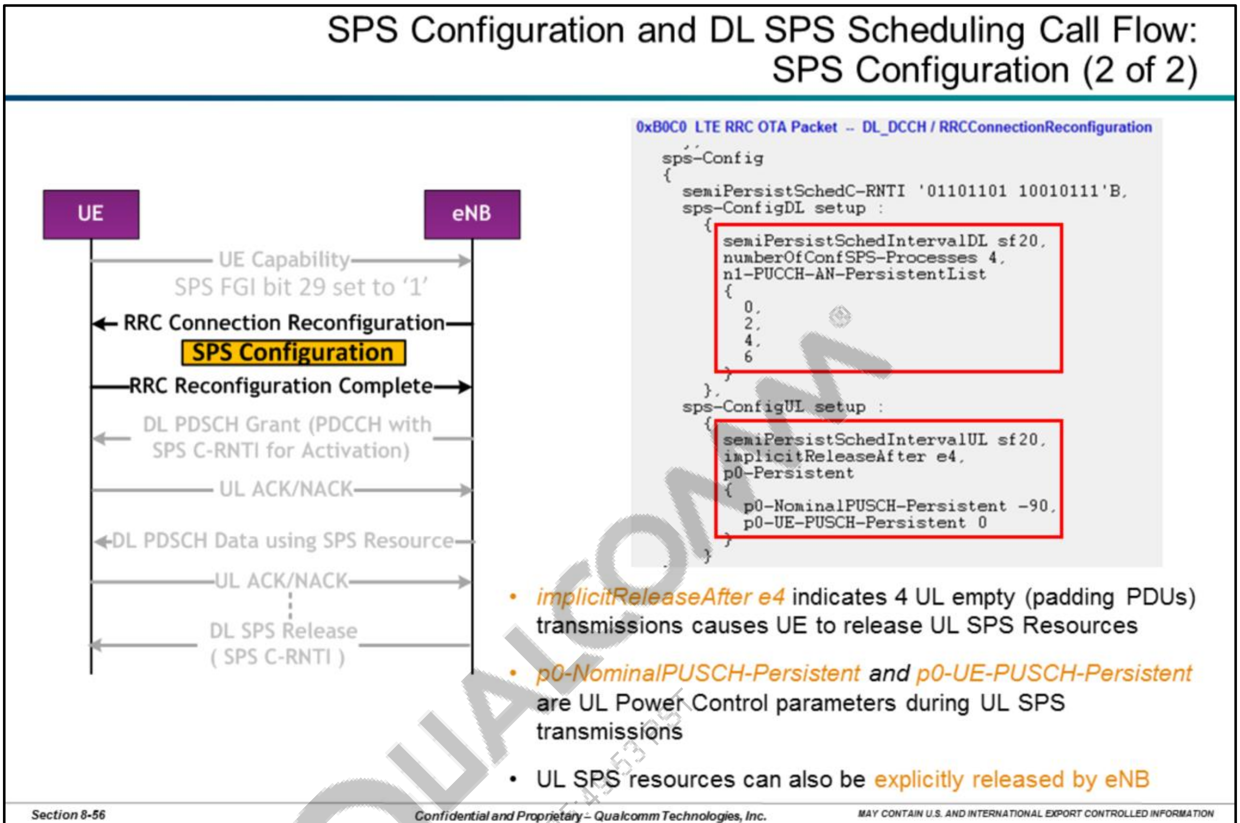
Value of ‘TPC command for PUCCH’	$n^{(1)}_{\mathrm{PUCCH}}$
‘00’	The first PUCCH resource index configured by the higher layers
‘01’	The second PUCCH resource index configured by the higher layers
‘10’	The third PUCCH resource index configured by the higher layers
‘11’	The fourth PUCCH resource index configured by the higher layers

DL SPS Scheduling Mechanism



Typically when eNB implementation based DL SPS Inactivity Timer expires (i.e, when there are no DL Voice Frames), eNB will send DL SPS Resource Release indication through PDCCH DCI 1 or 1A.

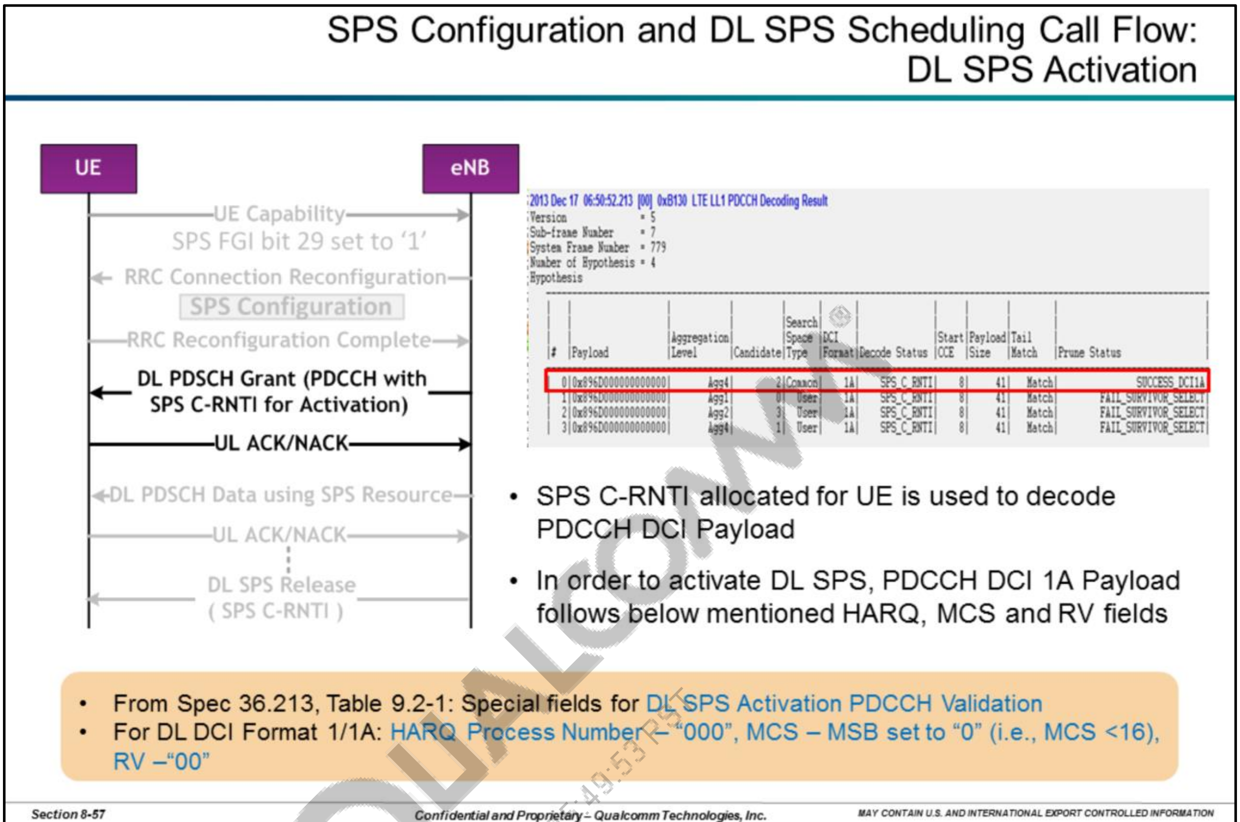
Notes



SPS Configuration and DL SPS Scheduling Call Flow: SPS Configuration (2 of 3)

Other optional parameters can be sent by the eNodeB for UL power control adjustment during SPS UL transmissions:

- *p0-NominalPUSCH-Persistent:* unit dBm step 1. This field is applicable SPS only. If choice 'setup' is used and *p0-Persistent* is absent, apply the value of *p0-NominalPUSCH* for *p0-NominalPUSCH-Persistent* (see TS 36.213 section 5.1.1.1).
- *p0-UE-PUSCH-Persistent:* unit dB. This field is applicable for SPS only. If choice 'setup' is used and *p0-Persistent* is absent, apply the value of p0-UE-PUSCH for *p0-UE-PUSCH-Persistent* (see TS 36.213 section 5.1.1.1).



SPS Configuration and DL SPS Scheduling Call Flow: DL SPS Activation

Upon successful SPS configuration for UE, in order to activate DL SPS, eNB uses PDCCH to activate DL SPS. PDCCH CRC used to activate SPS will be scrambled with SPS C-RNTI allocated for that UE. PDCCH Payload format for DL SPS Activation is specified by 36.213, Table 9.2-1.

From Spec 36.213 (Rel 9)

PDCCH Validation for Semi-persistent Scheduling

A UE shall validate a Semi-Persistent Scheduling assignment PDCCH only if all the following conditions are met:

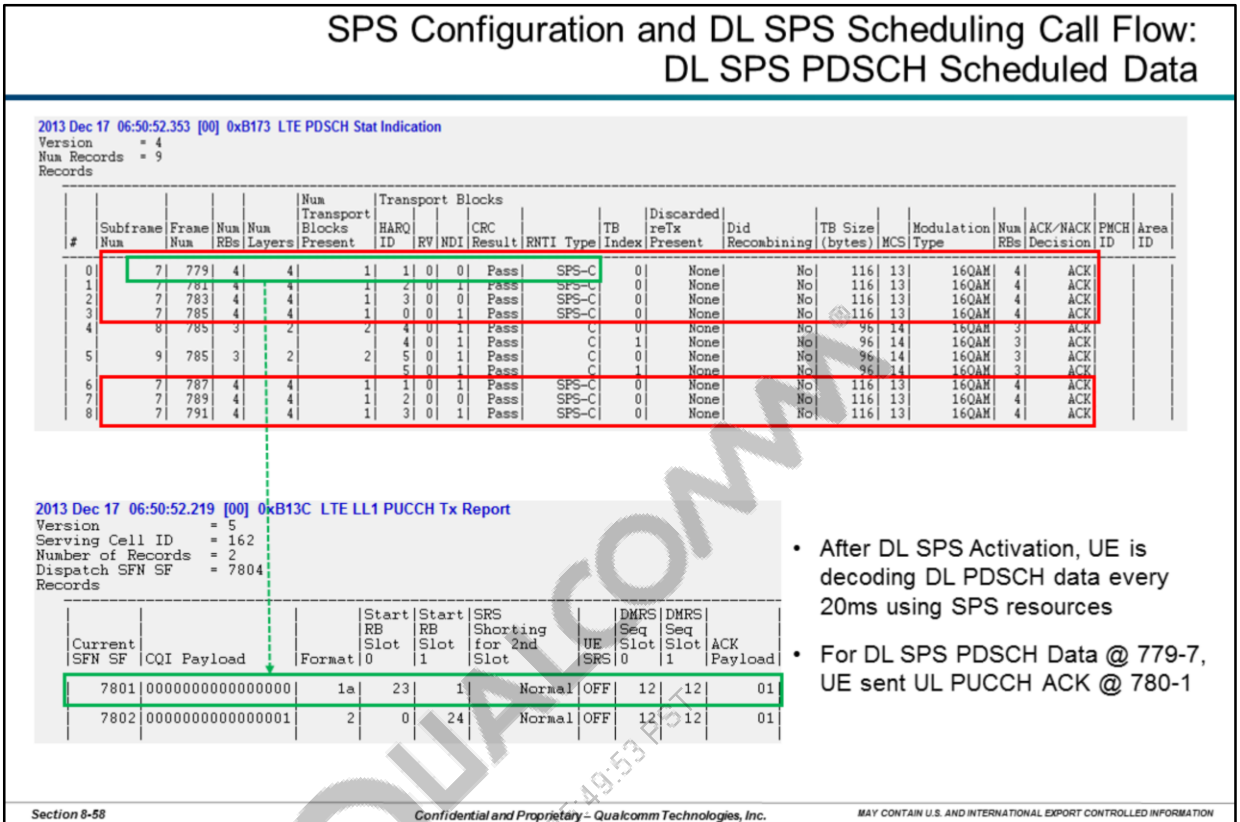
- the CRC parity bits obtained for the PDCCH payload are scrambled with the Semi-Persistent Scheduling C-RNTI.
- the new data indicator field is set to '0'. In case of DCI formats 2, 2A and 2B, the new data indicator field refers to the one for the enabled transport block.

Validation is achieved if all the fields for the respective used DCI format are set according to Table 9.2-1 or Table 9.2-1A.

If validation is achieved, the UE shall consider the received DCI information accordingly as a valid semi-persistent activation or release.

If validation is not achieved, the received DCI format shall be considered by the UE as having been received with a non-matching CRC.

For the case that the DCI format indicates a semi-persistent downlink scheduling activation, the TPC command for PUCCH field shall be used as an index to one of the four PUCCH resource indices configured by higher layers, with the mapping defined in Table 9.2-2.



#	Subframe Num	Frame Num	Num RBs	Num Layers	Num Transport Blocks Present	HARQ ID	RV	NDI	CRC Result	RNTI Type	TB Index	Discarded reTx Present	Did Recombining	TB Size (bytes)	MCS	Modulation Type	Num RBs	ACK/NACK Decision	PMCH ID	Area ID
0	7	779	4	4	1	1	0	0	Pass	SPS-C	0	None	No	116	13	16QAM	4	ACK		
1	7	781	4	4	1	2	0	1	Pass	SPS-C	0	None	No	116	13	16QAM	4	ACK		
2	7	783	4	4	1	3	0	0	Pass	SPS-C	0	None	No	116	13	16QAM	4	ACK		
3	7	785	4	4	1	0	0	1	Pass	SPS-C	0	None	No	116	13	16QAM	4	ACK		
4	8	785	3	2	2	4	0	1	Pass	C	0	None	No	96	14	16QAM	3	ACK		
						4	0	1	Pass	C	1	None	No	96	14	16QAM	3	ACK		
5	9	785	3	2	2	5	0	1	Pass	C	0	None	No	96	14	16QAM	3	ACK		
						5	0	1	Pass	C	1	None	No	96	14	16QAM	3	ACK		
6	7	787	4	4	1	1	0	1	Pass	SPS-C	0	None	No	116	13	16QAM	4	ACK		
7	7	789	4	4	1	2	0	0	Pass	SPS-C	0	None	No	116	13	16QAM	4	ACK		
8	7	791	4	4	1	3	0	1	Pass	SPS-C	0	None	No	116	13	16QAM	4	ACK		

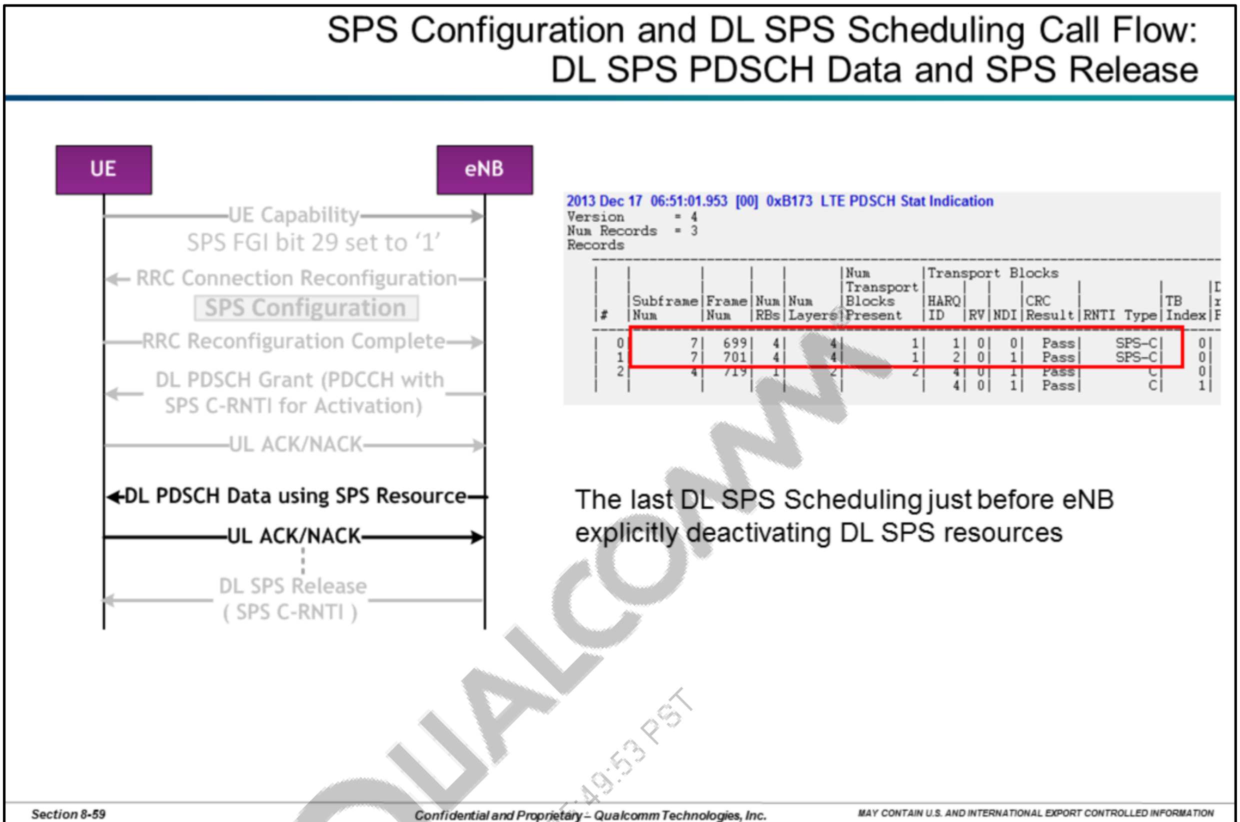
Current SFN SF	CQI Payload	Format	Start RB Slot 0	Start RB Slot 1	SRS Shorting for 2nd Slot	UE SRS	DMRS Seq Slot 0	DMRS Seq Slot 1	ACK Payload
7801	0000000000000000	1a	23	1	Normal	OFF	12	12	01
7802	0000000000000001	2	0	24	Normal	OFF	12	12	01

SPS Configuration and DL SPS Scheduling Call Flow: DL SPS PDSCH Scheduled Data

Upon successful SPS configuration for UE, in order to activate DL SPS, eNB uses PDCCH to activate DL SPS. PDCCH CRC used to activate SPS will be scrambled with SPS C-RNTI allocated for that UE. PDCCH Payload format for DL SPS Activation is specified by 36.213, Table 9.2-1.

Upon UE decoding PDSCH data received on DL SPS resources, UE will send PUCCH ACK/NACK resources specified during SPS configuration procedure.

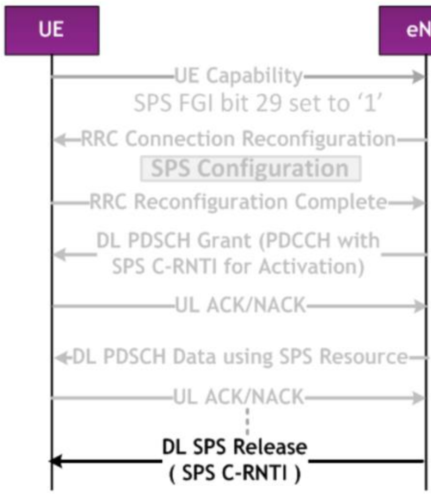
Subsequently the UE will receive DL VoLTE packets on DL PDSCH SPS resources. SPS resources are used only for initial transmissions and any retransmission needs dynamic scheduling procedure. For receiving DL SPS scheduled data, there is no need for PDCCH resources.



SPS Configuration and DL SPS Scheduling Call Flow: DL SPS PDSCH Data and SPS Release

When eNB detects that there is no DL VoLTE packets flow and DL SPS Inactivity Timer (ENB Implementation based Timer) expires, eNB will send DL PDCCH (CRC scrambled with SPS-C RNTI) to deactivate DL SPS resources. PDCCH payload format to indicate deactivation of DL SPS is specified by 3GPP 36.213, Table 9.2-1 A.

SPS Configuration and DL SPS Scheduling Call Flow: DL SPS Release



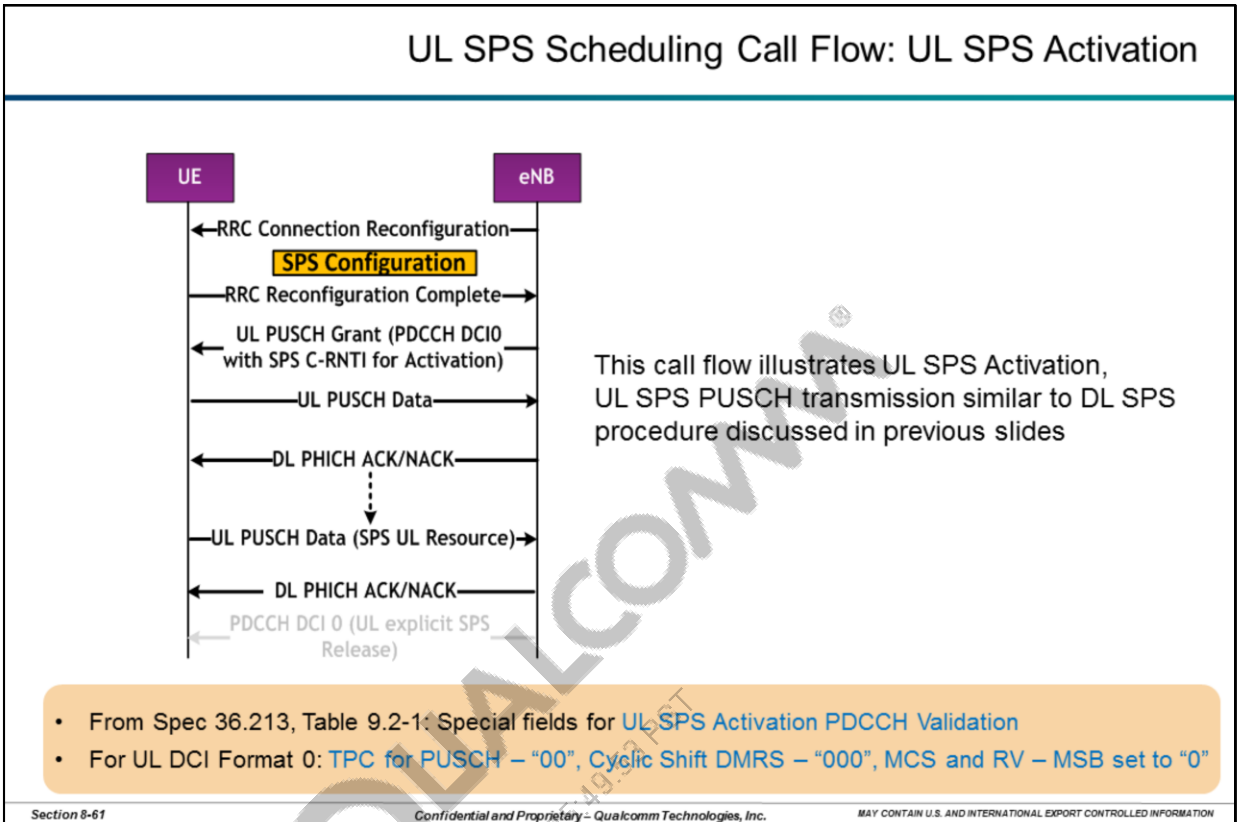
2013 Dec 17 06:51:01.693 [00] 0xB130 LTE LL1 PDCCH Decoding Result
Version = 5
Sub-frame Number = 7
System Frame Number = 703
Number of Hypothesis = 4
Hypothesis

#	Payload	Aggregation Level	Candidate	Search Space Type	DCI Format	Decode Status	Start CCE	Payload Size	Tail Match	Prune Status
0	0xBFFF000000000000	Agg4	2	Common	1A	SPS_C_RNTI	8	41	Match	SUCCESS_DCI1A
1	0xBFFF000000000000	Agg1	0	User	1A	SPS_C_RNTI	8	41	Match	FAIL_SURVIVOR_SELECT
2	0xBFFF000000000000	Agg2	3	User	1A	SPS_C_RNTI	8	41	Match	FAIL_SURVIVOR_SELECT
3	0xBFFF000000000000	Agg4	1	User	1A	SPS_C_RNTI	8	41	Match	FAIL_SURVIVOR_SELECT

In order to de-activate DL SPS resources, eNB sends PDCCH DCI Format 1A Payload with below mentioned HARQ, MCS, RV, and RB fields

- From Spec 36.213, Table 9.2-1A: Special fields for DL SPS Release PDCCH Validation
- For DL DCI Format 1A: HARQ Process Number – "000", MCS – "11111", RV – "00", RB – All 1's

Notes



PDCCH Validation for Semi-persistent Scheduling

From Spec 36.213 (Rel 9)

A UE shall validate a Semi-Persistent Scheduling assignment PDCCH only if all the following conditions are met:

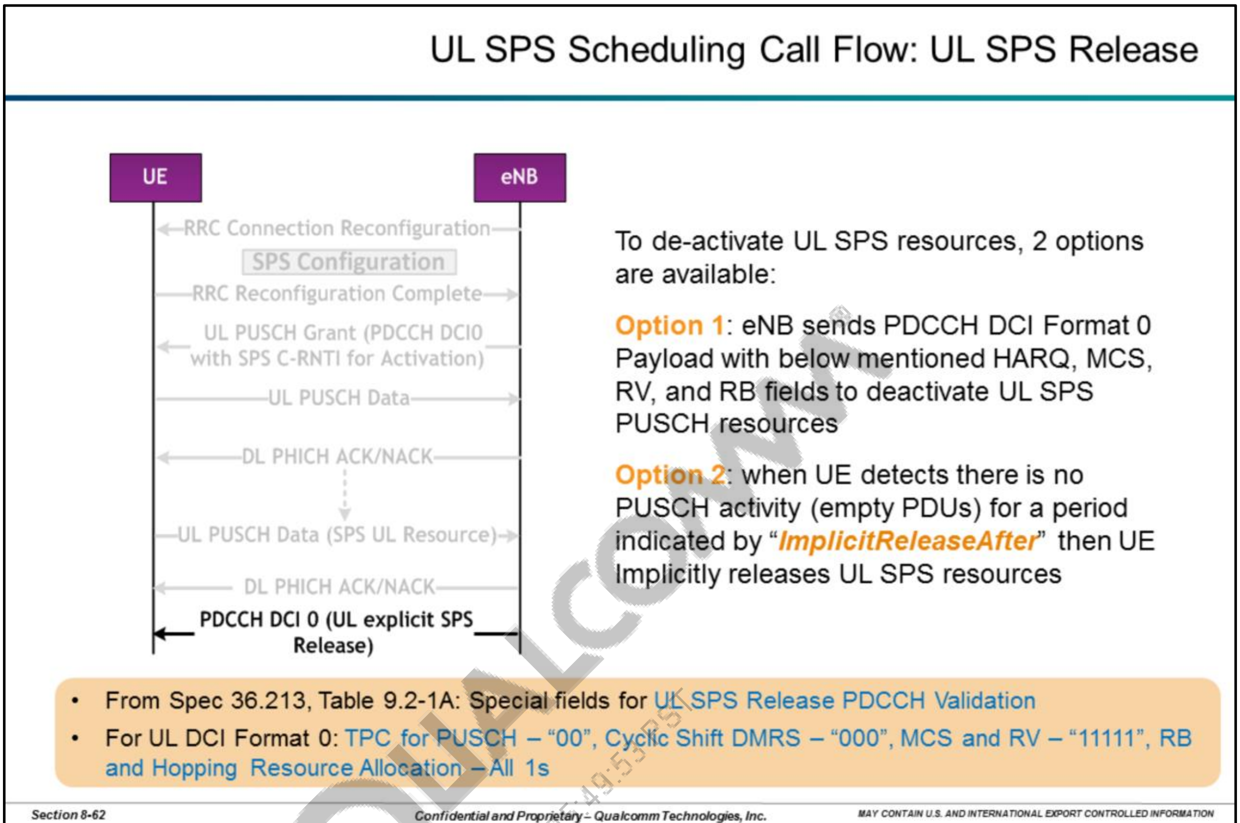
- the CRC parity bits obtained for the PDCCH payload are scrambled with the Semi-Persistent Scheduling C-RNTI.
- the new data indicator field is set to '0'. In case of DCI formats 2, 2A, and 2B, the new data indicator field refers to the one for the enabled transport block.

Validation is achieved if all the fields for the respective used DCI format are set according to Table 9.2-1 or Table 9.2-1A.

If validation is achieved, the UE shall consider the received DCI information accordingly as a valid semi-persistent activation or release.

If validation is not achieved, the received DCI format shall be considered by the UE as having been received with a non-matching CRC.

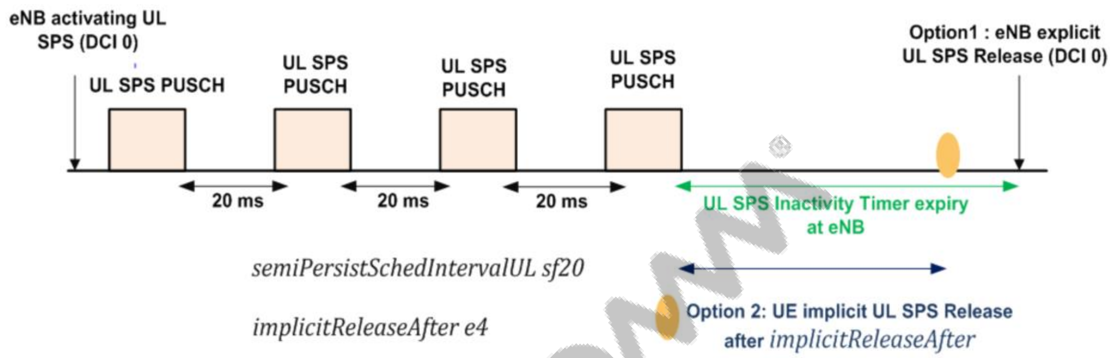
For the case that the DCI format indicates a semi-persistent downlink scheduling activation, the TPC command for PUCCH field shall be used as an index to one of the four PUCCH resource indices configured by higher layers, with the mapping defined in Table 9.2-2.



UL SPS Scheduling Call Flow: UL SPS Release

- UL SPS Resources can either explicitly released by eNB by sending PDCCH to deactivate UL SPS Resources (when UL SPS Inactivity Timer expires at eNB), or
- when UE detects that there is no UL SPS activity for "ImplicitReleaseAfter" specified UL Frames then UE and ENB will both implicitly releases UL SPS Resources.

UL SPS Scheduling Mechanism



- Typically, when eNB implementation based UL SPS Inactivity Timer expires (i.e., when there are no UL Voice Frames), eNB will send explicit UL SPS Resource Release indication through PDCCH DCI 0.
- If UE observes that there are no UL Voice Frames (ex: e4 -> 4 UL Voice Frames), then UE implicitly releases UL SPS resources.

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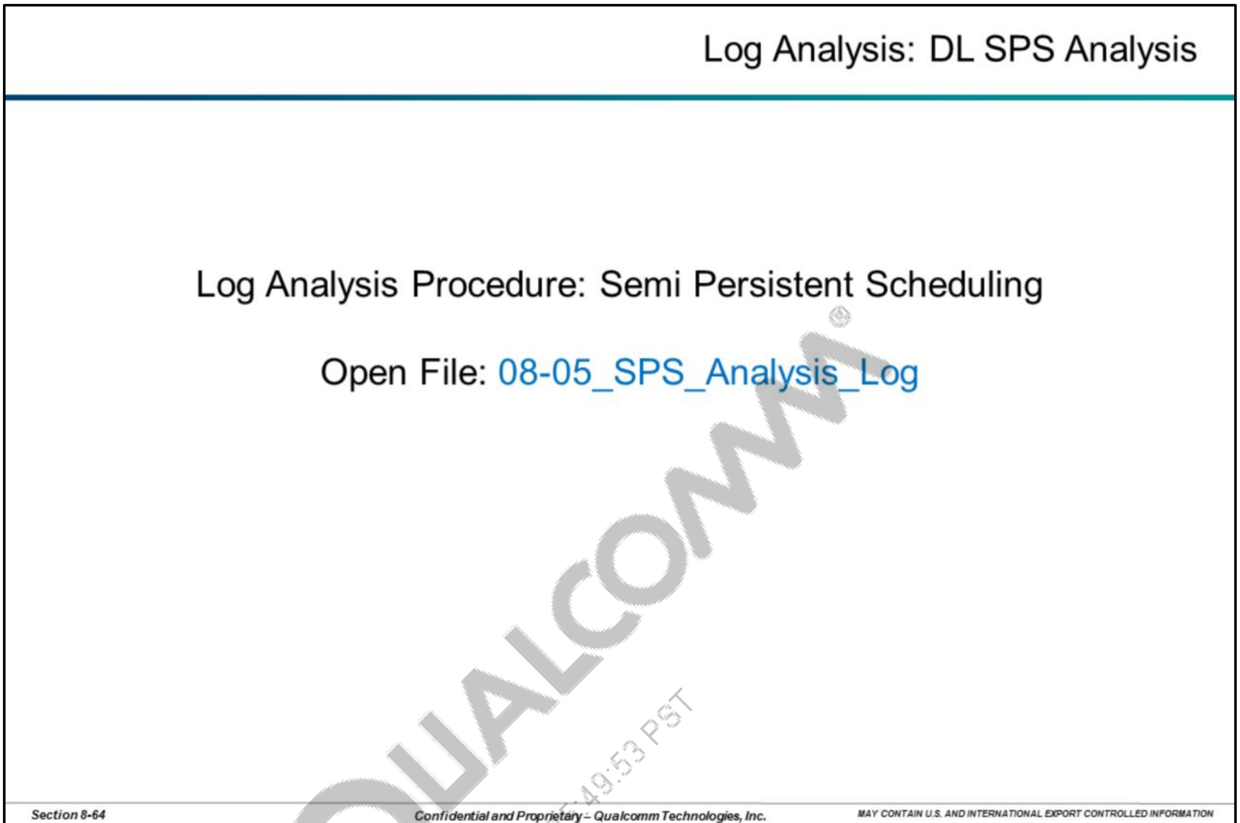
Notes


Log Analysis: DL SPS Analysis
Log Analysis Procedure: Semi Persistent Scheduling
Open File: 08-05_SPS_Analysis_Log
Section 8-64
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Notes

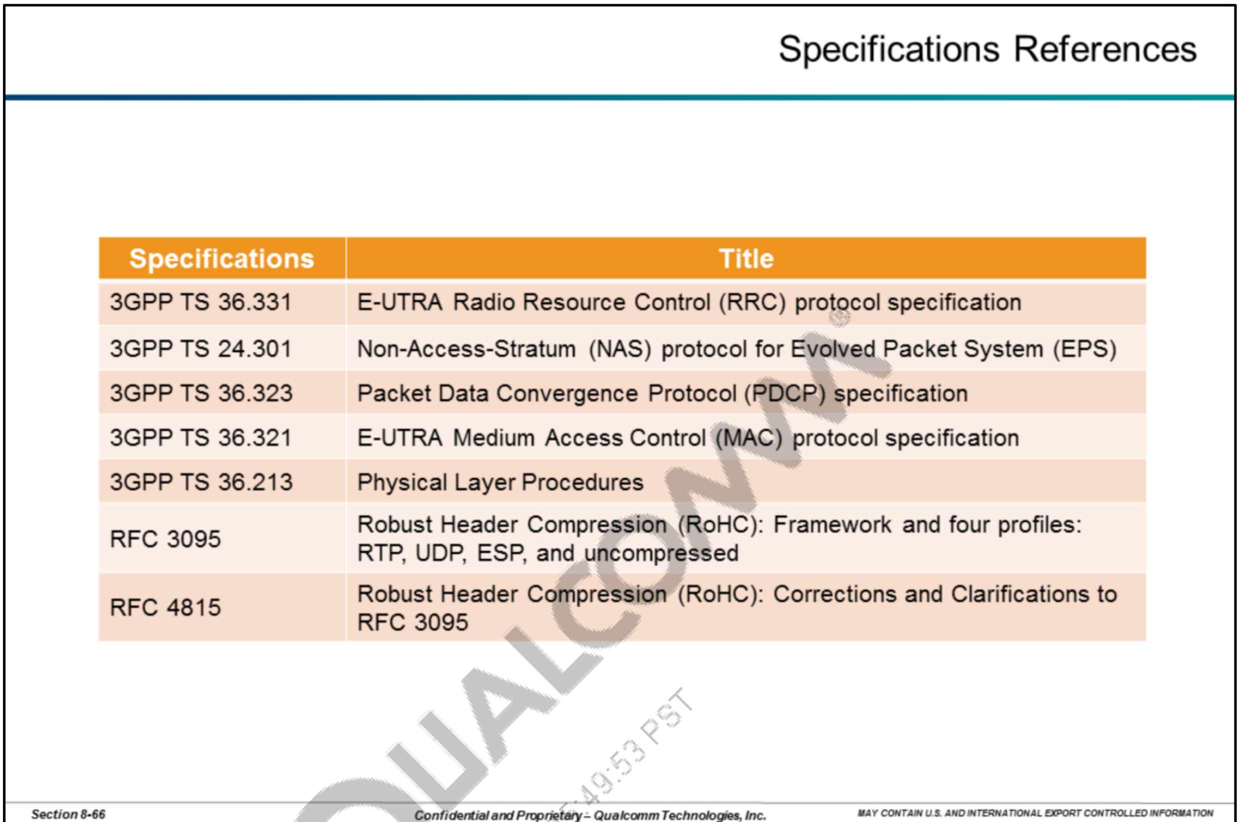
DL SPS Log Analysis: Log Walk-Through

Step	Look for…	Log Packet	Timestamp	Verify…
1	LTE RRC OTA Packet -- DL_DCCH / UE Capability Enquiry	0xB0C0	06:50:05.668	Verify eNB sending UE Capability Enquiry for E-UTRAN
2	LTE RRC OTA Packet -- UL_DCCH / UE Capability Information	0xB0C0	06:50:05:669	Verify UE is sending FGI Bit 29 = 1 to indicate SPS Capability
3	LTE RRC OTA Packet -- DL_DCCH / RRC Connection Reconfiguration	0xB0C0	06:50:05.869	Verify that eNB is configuring SPS Resources for DRB
4	LTE RRC OTA Packet -- UL_DCCH / RRC Connection Reconfiguration Complete	0xB0C0	06:50:05:873	Verify that UE is sending RRC Reconfigure Complete Message after successfully configuring DRB
5	0xB130 LTE LL1 PDCCH Decoding Result	0xB130	06:50:52.213	Verify that UE received SPS Activation Resource and Activation Indication (PDCCH DCI 1A Format)
6	0xB173 LTE PDSCH Stat Indication	0xB173	06:50:52:353	Verify that UE is receiving/decoding PDSCH data at regular intervals of time using DL SPS resources
7	0xB130 LTE LL1 PDCCH Decoding Result	0xB130	06:51:01:693	Verify that UE received PDCCH DCI 0 with SPS Resources Release Indication from eNB
8	0xB173 LTE PDSCH Stat Indication	0xB173	06:51:01:953	Verify that UE does not receive any PDSCH data using DL SPS resources after SPS de-activation

DL SPS Log Analysis: Log Walk-Through

The arrival of messages during logging could impact the order in which time stamps are shown.

If needed while analyzing a log file in the browser, use the menu “Edit” + “Find on this Page” (Ctrl+F) to find a specific timestamp.



Specifications	Title
3GPP TS 36.331	E-UTRA Radio Resource Control (RRC) protocol specification
3GPP TS 24.301	Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS)
3GPP TS 36.323	Packet Data Convergence Protocol (PDCP) specification
3GPP TS 36.321	E-UTRA Medium Access Control (MAC) protocol specification
3GPP TS 36.213	Physical Layer Procedures
RFC 3095	Robust Header Compression (RoHC): Framework and four profiles: RTP, UDP, ESP, and uncompressed
RFC 4815	Robust Header Compression (RoHC): Corrections and Clarifications to RFC 3095

Specifications References

3GPP LTE specifications available at www.3gpp.org

IETF RFCs available at www.ietf.org


9
Intra-LTE Mobility Impacts on VoLTE
www.qualcommwirelessacademy.com
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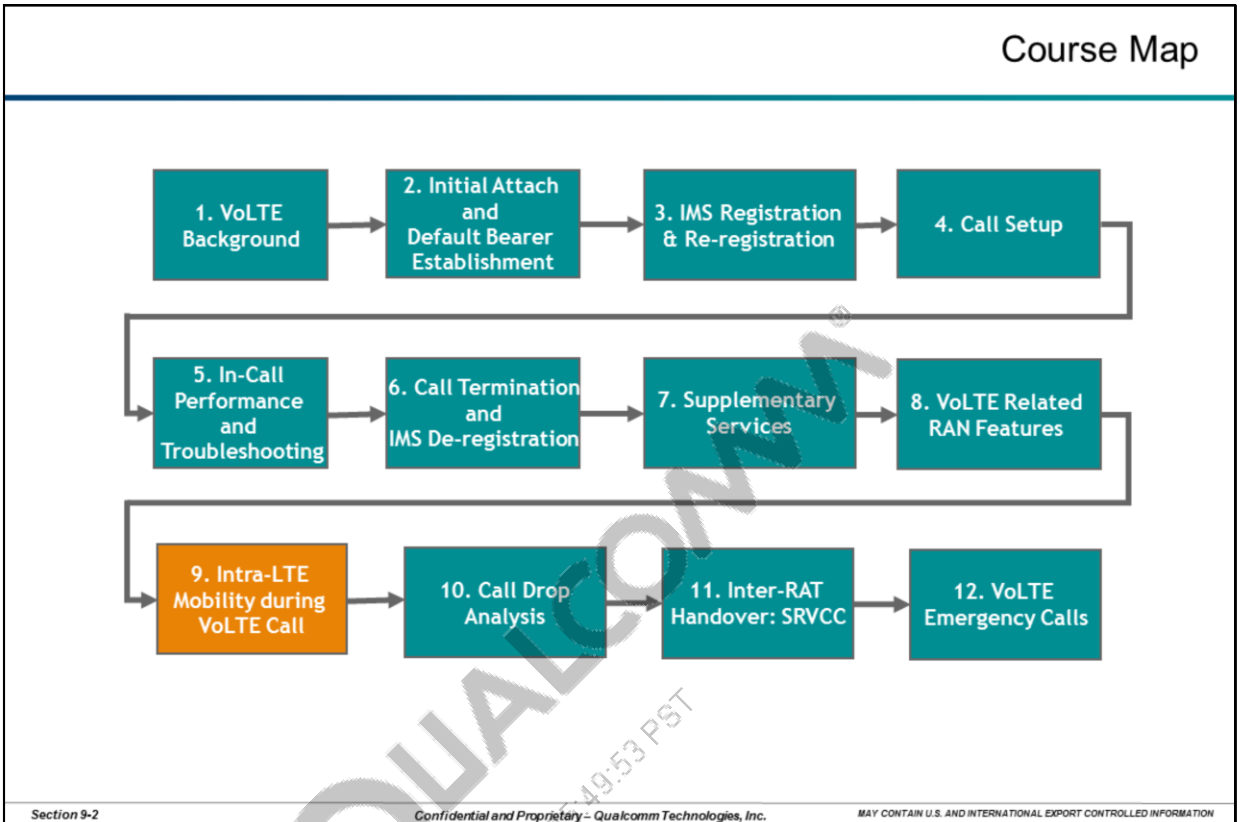
Course Map
1. VoLTE Background
2. Initial Attach and Default Bearer Establishment
3. IMS Registration & Re-registration
4. Call Setup
5. In-Call Performance and Troubleshooting
6. Call Termination and IMS De-registration
7. Supplementary Services
8. VoLTE Related RAN Features
9. Intra-LTE Mobility during VoLTE Call
10. Call Drop Analysis
11. Inter-RAT Handover: SRVCC
12. VoLTE Emergency Calls
Section 9-2
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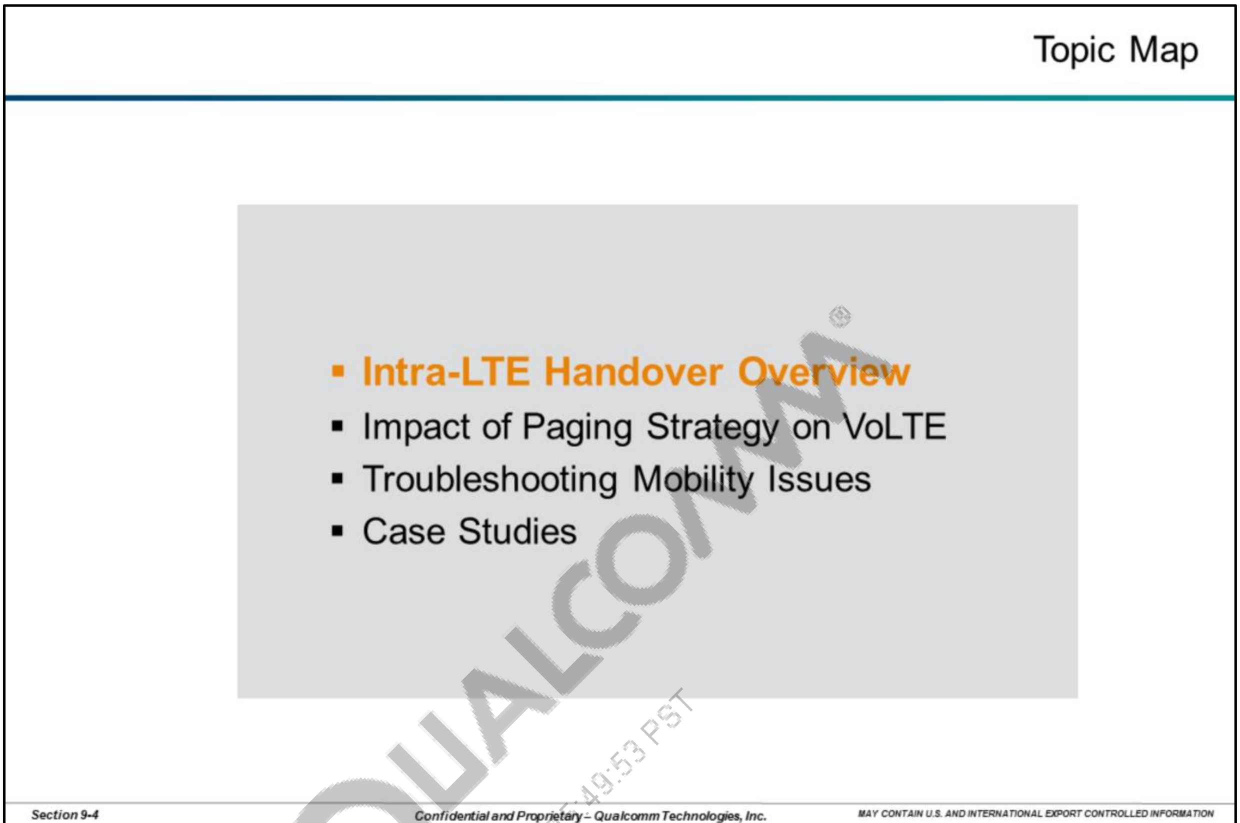
Notes

Objectives

- Review Intra-LTE handover concepts.
- Discuss impacts of paging strategy on VoLTE user experience.
- Outline high-level troubleshooting framework.
- Analyze logs with various VoLTE performance scenarios.

Notes


Topic Map
▪ Intra-LTE Handover Overview
▪ Impact of Paging Strategy on VoLTE
▪ Troubleshooting Mobility Issues
▪ Case Studies
Section 9-4
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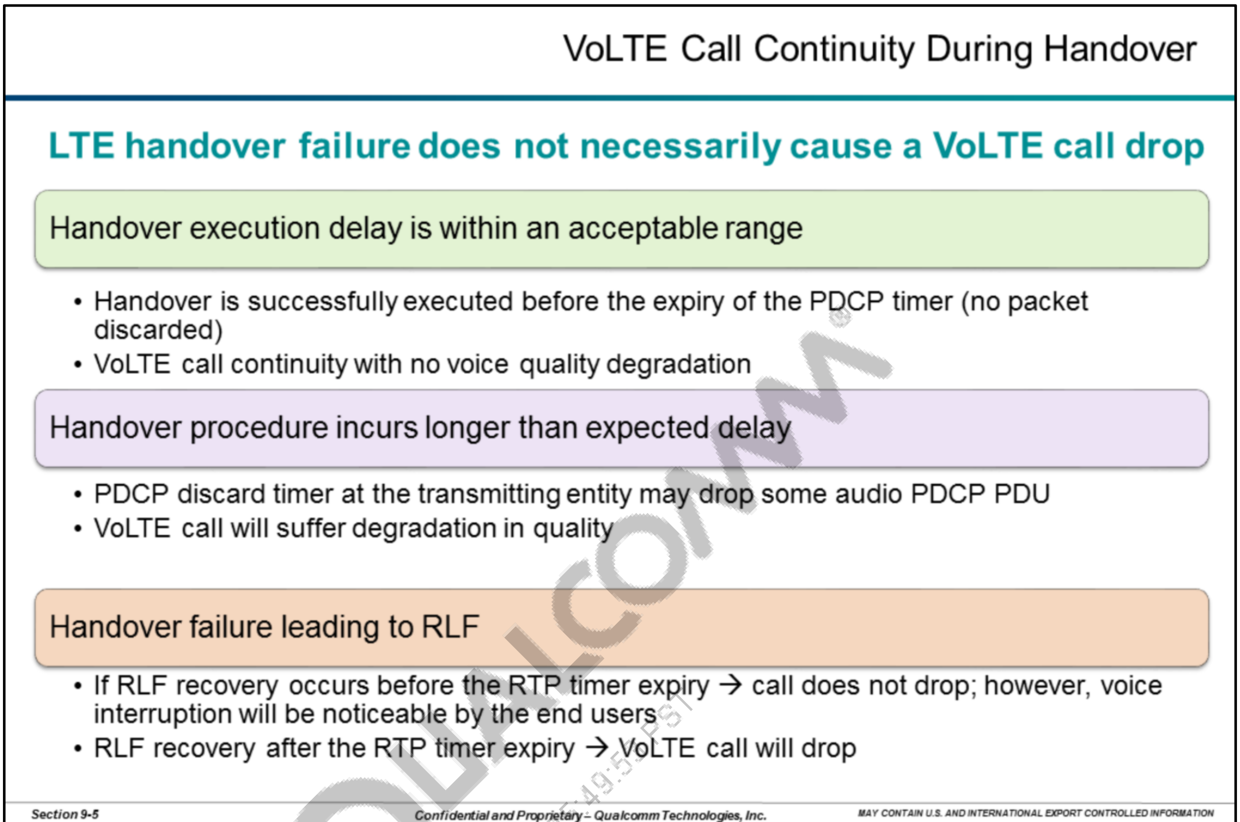
Notes



VoLTE Call Continuity During Handover

Handover execution delay is within an acceptable range:

- VoLTE call continuity with no voice quality degradation is expected

Handover procedure incurs longer than expected delay:

- For example, bad RF conditions may cause handover to take longer than expected (multiple retransmissions are required)
- PDCP discard timer at the transmitting entity may drop some audio PDCP PDU, causing degradation in voice quality
- VoLTE call will suffer degradation in quality

Handover delay was substantially large:

- For example, recovering from RLF by executing re-established procedure
- If UE manages to recover from RLF before the RTP timer expiry, the call won't be dropped; however, voice interruption will be noticeable by the end users
- The VoLTE call will be dropped if the delay exceeds the RTP timer

Benefits of Optimizing Settings

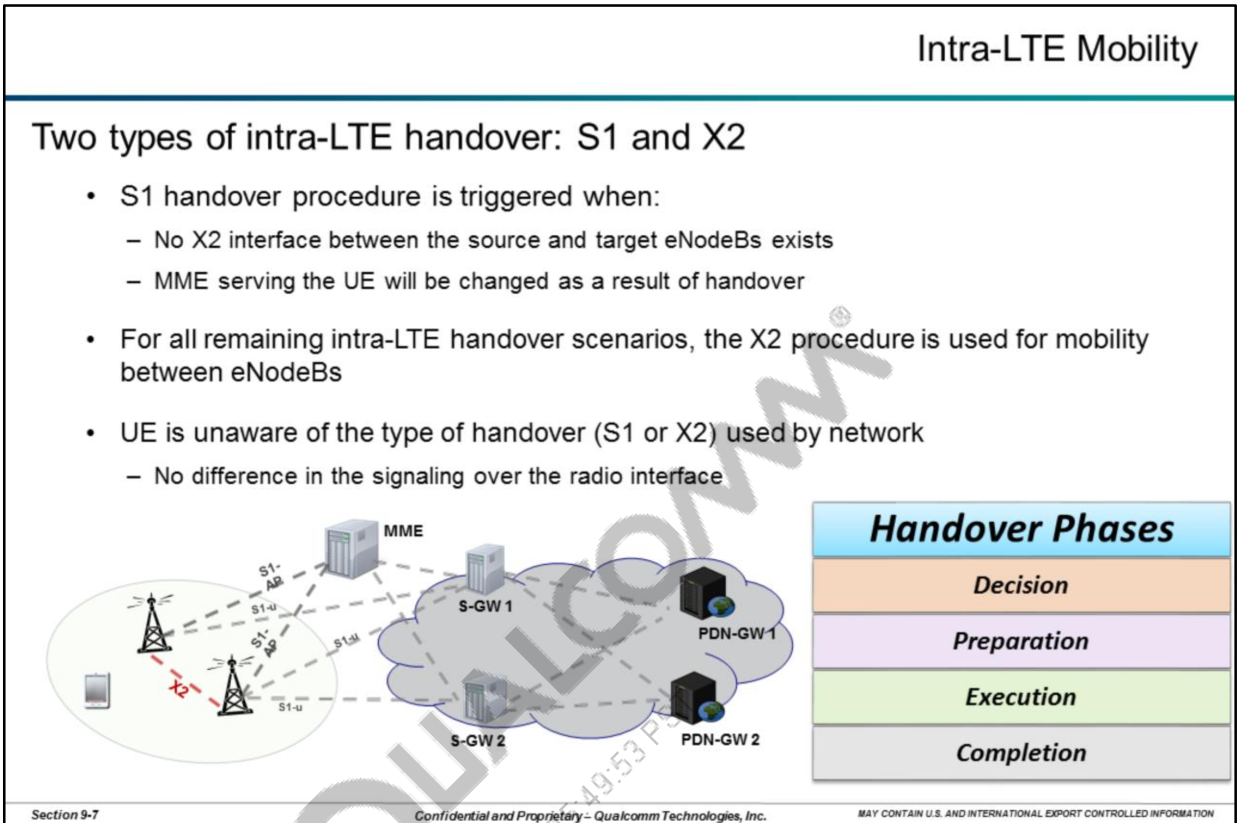
Optimized paging / handover settings are key for VoLTE

- UE is served by the most suitable cell and successfully receive pages
- Good call set up performance

Sub-optimal settings and/or architecture directly impact performance and user experience

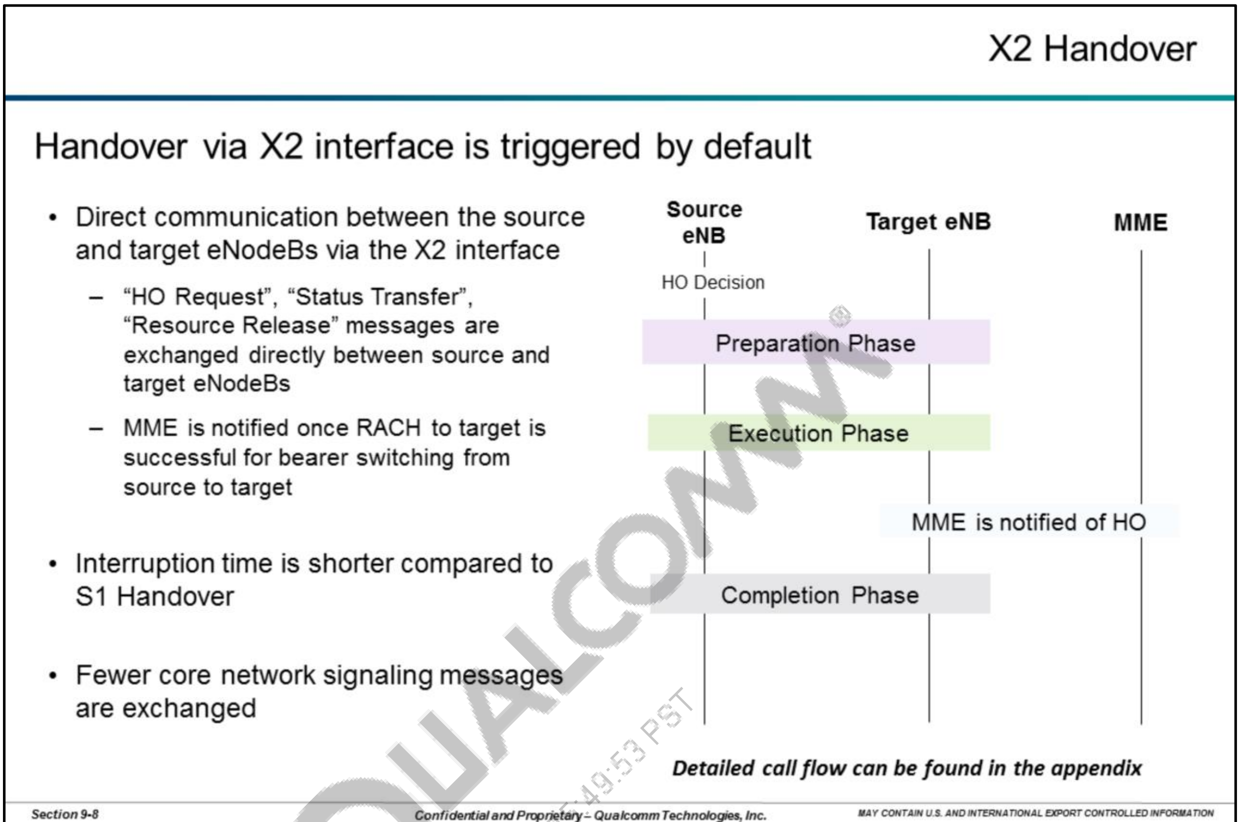
- S1 vs. X2 handover architectures → Impact on call quality
- Poor Idle mode paging strategy → missed pages during MT call set up
- Sub-optimal handover during call set up → call set up delay and/or bearer set up issues
- Sub-optimal handover during call → RTP packet drops, poor call quality and, in extreme cases, VoLTE call drop
- RoHC context mismatch after HO during call → can result in VoLTE call drop

Notes



Handover Phases:

1. **Decision:** E-UTRAN decides to execute a handover based on measurement reports received by the UE.
2. **Preparation:** The serving eNB notifies the target eNB that a handover is requested. It includes a list of the bearers that will be transferred and if Downlink data forwarding is proposed. The target eNB acknowledges the Handover Request and responds with a list of the bearers that are admitted along with DL and UL GTP tunnel endpoints to enable data forwarding.
3. **Execution:** Once the resources have been set up on the target side, the UE is notified and detaches from the source eNB. Downlink packets that are received by the source from the S-GW are forwarded to the target eNB. PDCP status and hyper frame number information are exchanged to enable lossless handover, if required. At this point, the MME is notified of the changes in order to define direct Uplink and Downlink paths for the User Plane with the S-GW.
4. **Completion:** Resources in the source eNB are released following successful completion of the handover.



X2 Handover

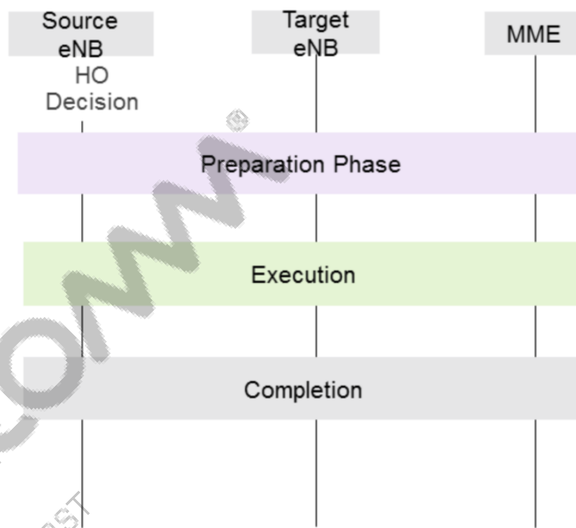
During a handover procedure, multiple timers are running to monitor the handover progress and terminate the process in case of failure.

- TA window and Contention Resolution timer
  - To monitor the RACH procedure triggered due to handover
  - Expiry of any of these timers will cause the RACH attempt to fail and a new RACH attempt will be triggered, eventually increasing the delay incurred during the handover procedure
- T304 timer at the RRC layer
  - Triggered upon the reception of the HO Command (reception RRCConnectionReconfiguration that contains the MobilityControlInfo IE)
  - The timer is stopped upon a successful handover procedure (successful transmission of the RRCConnectionReconfigurationComplete message)
  - Expiry of this timer will cause the handover procedure to fail and eventually the UE will declare Radio Link Failure, which in turn will trigger the Re-establishment procedure
- PDCP discard timer
  - This timer is running at the PDCP layer that is storing the RTP audio packet during the handover procedure
  - If the handover procedure took longer than expected, this might cause expiry of this timer, subsequently causing the some RTP packet to be dropped

S1 Handover

Intervention of MME is required during the Handover procedure

- HO messages between eNodeBs are exchanged indirectly through MME
  - MME request for resource at target eNB on behalf of source eNB
  - MME creates indirect data tunnel between source and target eNB
  - MME triggers the command for handover to target eNB
  - MME transfers the source eNB SN status to target eNB
- MME involvement causes longer interruption time compared to X2 Handover
- More core network signaling is involved

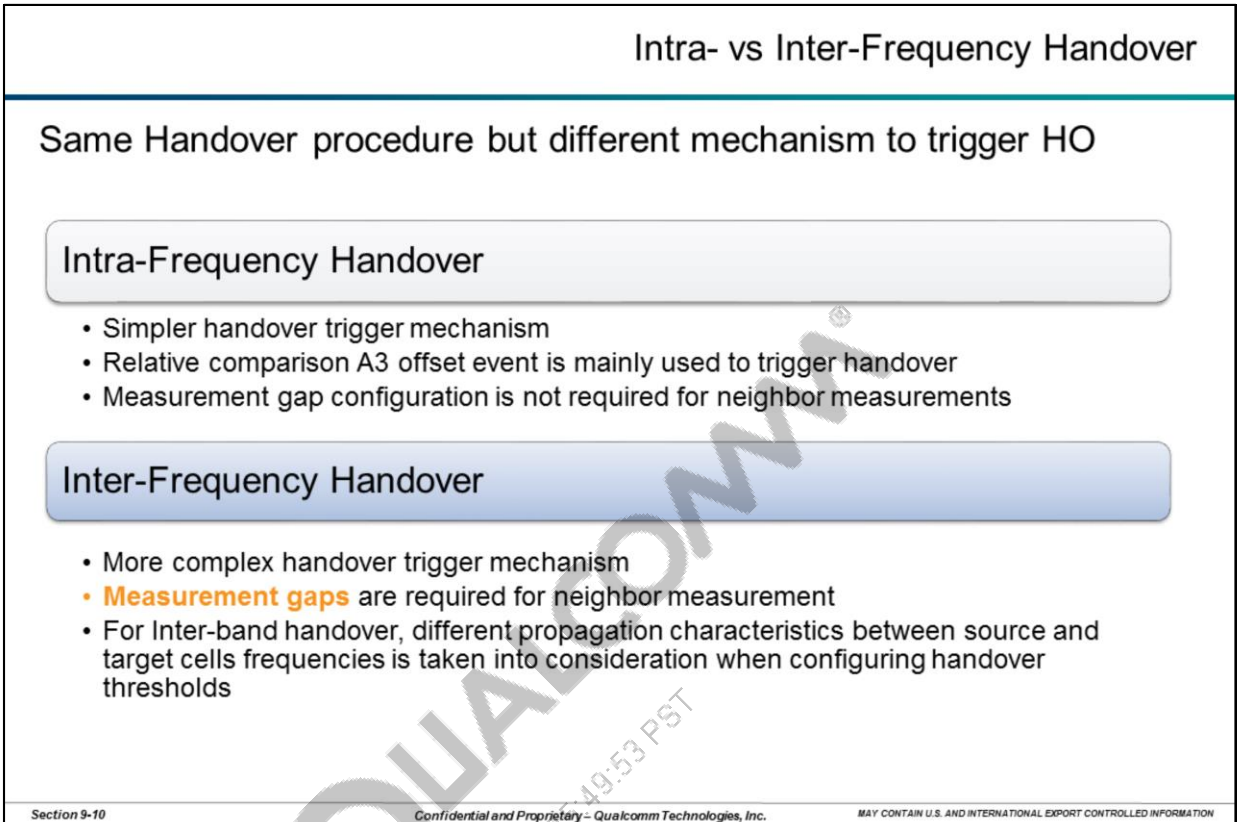


Detailed call flow can be found in the appendix

S1 Handover

- **Preparation** - Serving eNB notifies MME of handover requirement. MME initiates preparation of target eNB resources.
- **Execution** - MME orders UE to handover (through source eNB). UE initiates random access procedures to target eNB. SN Status is transferred from the source eNB to the target eNB through the MME.
- **Completion** - Target eNB notifies MME of handover completion. MME request source eNB resources to be released.

Handover Type	HO delay (ms)	Data interruption delay (ms)
Inter-eNB X2 Based	40 ~ 70	60 ~ 90
Inter-eNB S1 Based	90 ~ 140	105 ~ 160



Intra-Frequency HO

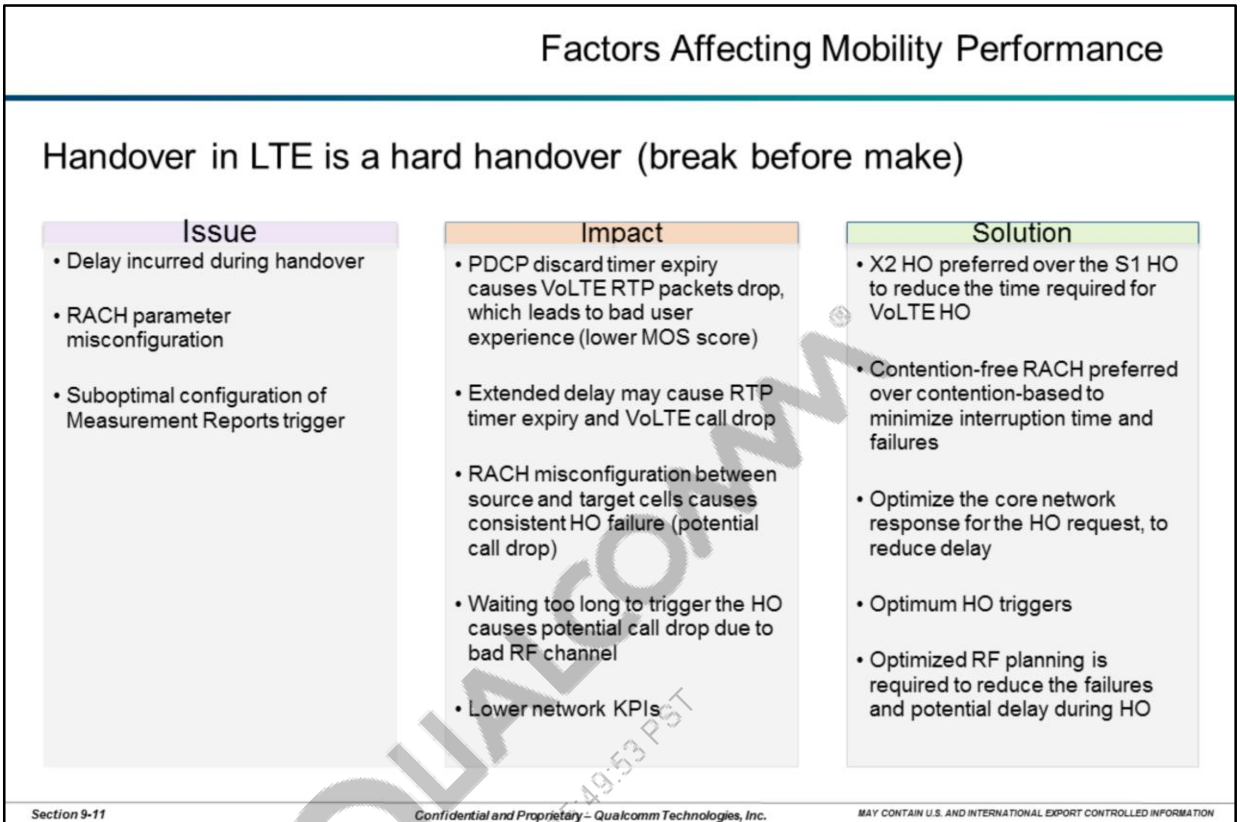
Simpler mechanism to trigger handover (stronger signal strength indicates better serving cell).

- Cells are using the same frequency and have the same propagation characteristics.
  - Relative comparison between the signal strength of the serving cell and neighbor cell is usually used (e.g., A3-event).
  - "Frequency Offsets" is not required to accommodate for the path loss different .
- No tune away is required when the UE is performing measurement since the cells have the same propagation characteristics → no measurement gaps configuration .

Inter-Frequency HO

More complex mechanism to trigger HO (stronger signal strength might not indicate better serving cell).

- UE cannot be served by the source cell and perform measurement on the neighbor cell simultaneously, hence the need to enable/disable measurement gaps based on serving cell signal strength.
- Enabling/disabling the measurement gaps are typically based on measurement reports triggered based on A1/A2 events.
- For inter-band handover, there are different propagation characteristics between source and target cells:
  - Relative comparison between source and target cells can be implemented only if propagation loss is considered by applying proper offset for the event thresholds.
  - Absolute threshold comparison also can be implemented (e.g., A5-event thresholds) after careful consideration of the propagation loss for each frequency.



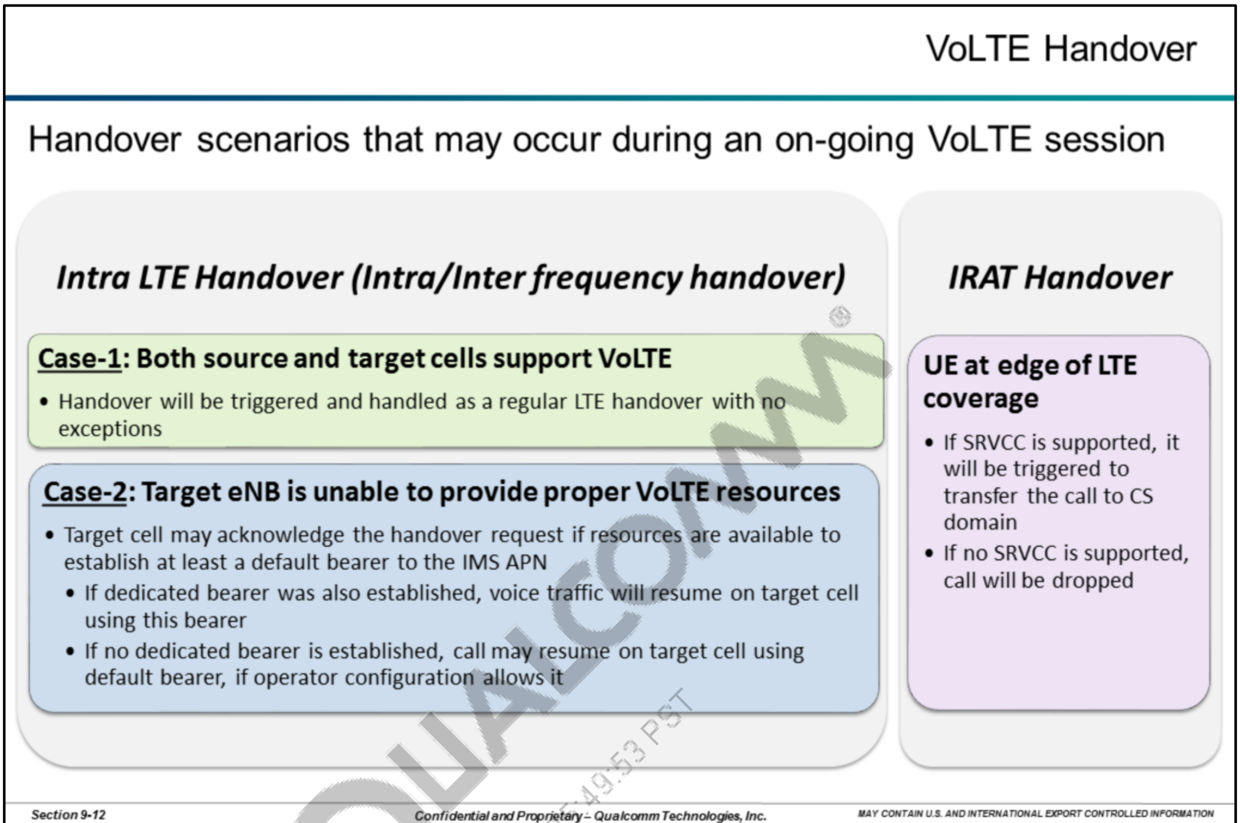
Factors Affecting Mobility Performance

Handover in LTE is a hard handover (break before make). It is important to minimize the delay incurred during handover as much as possible.

- Contention-free RACH preferred over contention-based to minimize interruption time and failures
- X2 HO preferred over S1 HO to reduce the time required for handover
- Suboptimum core network configuration can incur extra delay to process HO request
  - Core network response for the HO request should be optimized to reduce the delay incurred
- Optimized RF planning is required to reduce the failures and potential delay during HO
- Larger delay can impact the performance of the application layer
  - e.g., higher interruption → lower MOS score for VoLTE

Proper HO parameters configuration

- Proper Measurement Report/thresholds configuration to trigger HO command
  - Waiting too long to trigger HO can cause potential failure of HO procedure
  - Too early can cause excessive handovers
- Proper RACH configuration of the eNBs (source and target) to avoid potential RACH failure during handover


VoLTE Handover
Handover scenarios that may occur during an on-going VoLTE session
Intra LTE Handover (Intra/Inter frequency handover)
Case-1: Both source and target cells support VoLTE
• Handover will be triggered and handled as a regular LTE handover with no exceptions
Case-2: Target eNB is unable to provide proper VoLTE resources
• Target cell may acknowledge the handover request if resources are available to establish at least a default bearer to the IMS APN
• If dedicated bearer was also established, voice traffic will resume on target cell using this bearer
• If no dedicated bearer is established, call may resume on target cell using default bearer, if operator configuration allows it
IRAT Handover
UE at edge of LTE coverage
• If SRVCC is supported, it will be triggered to transfer the call to CS domain
• If no SRVCC is supported, call will be dropped
Section 9-12
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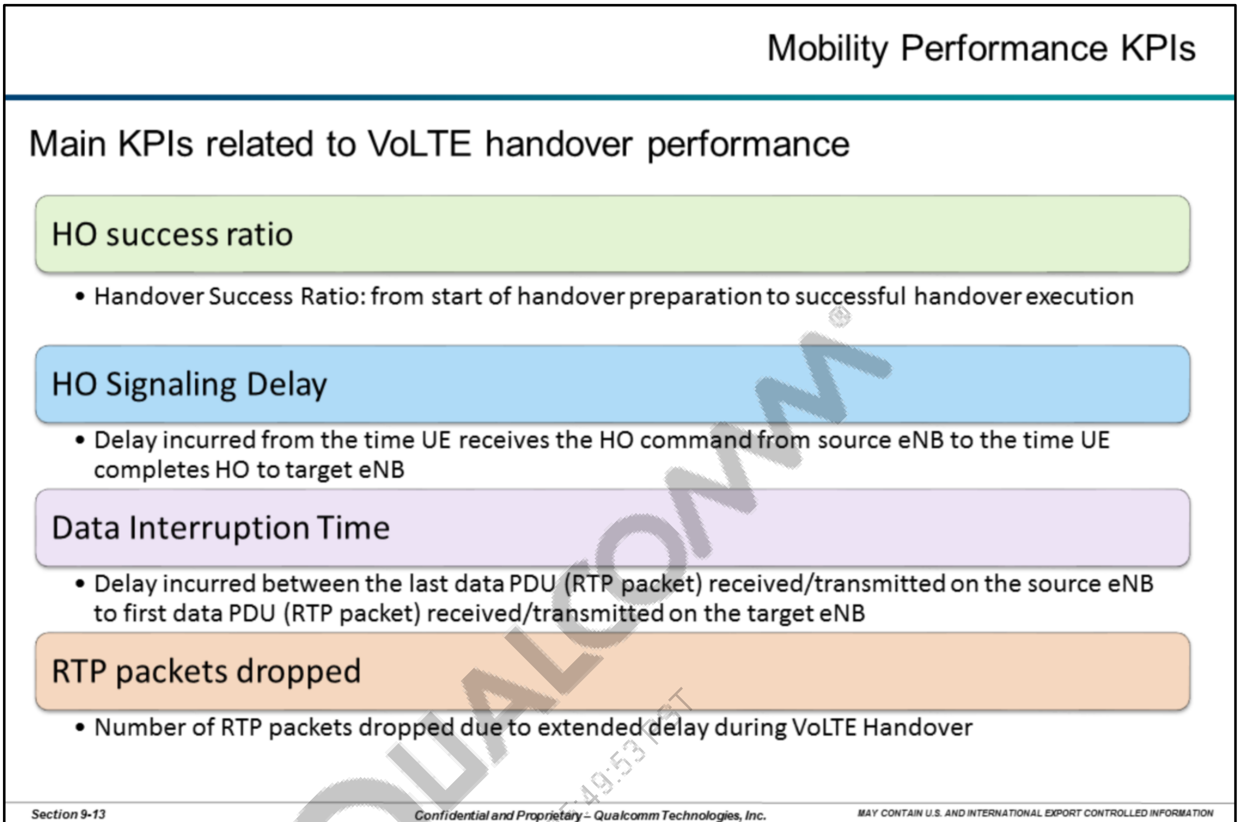
Notes

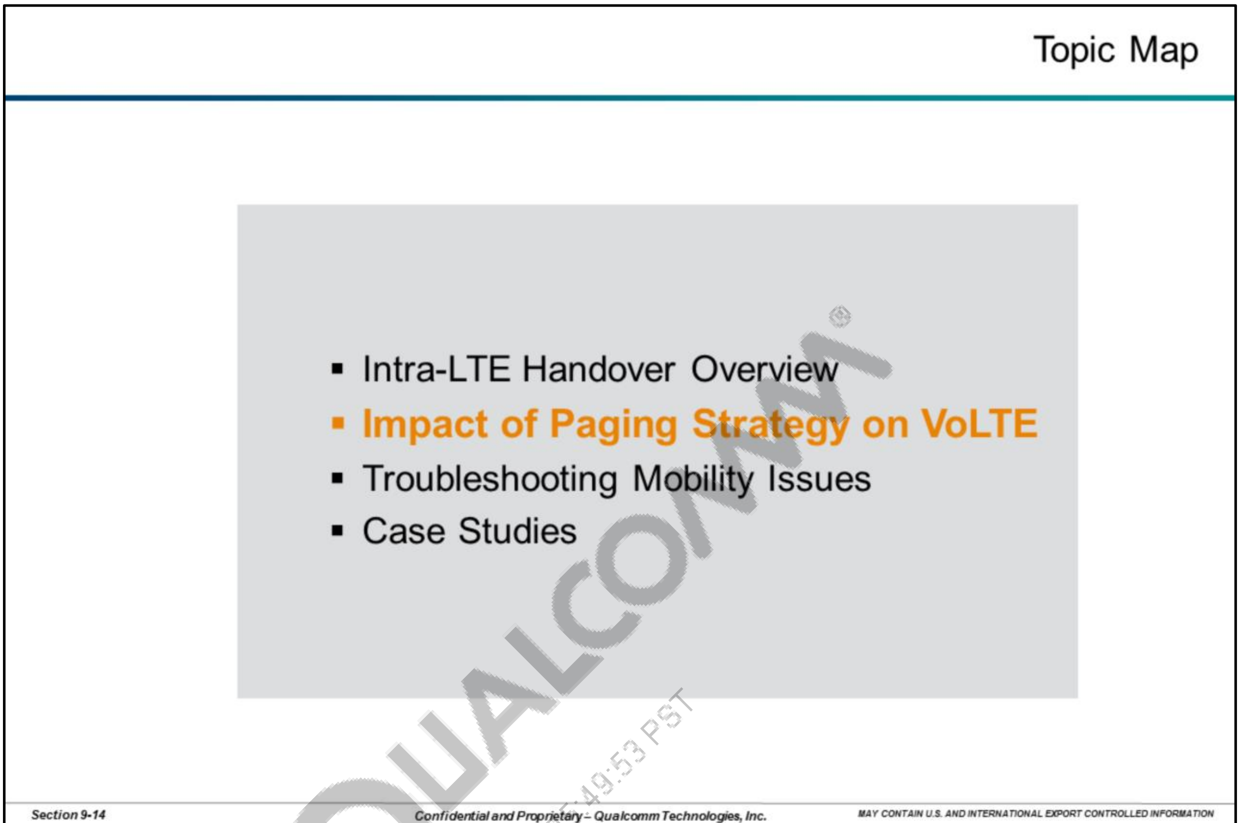


KPI collected from UE side

- **HO trigger success ratio.** The success ratio of UE receiving a handover command from the source eNB upon the transmission of the measurement report(s).
- **HO RACH Msg2/MSG1 success rate**. Ratio of Msg2 received by UE to Msg1 that is triggered due to HO procedure.
- **HO RACH Msg4/MSG3 success rate**. Ratio of Msg4 received by UE to Msg3 triggered due to HO.
- **HO Signaling Delay**. Delay incurred from the time UE receives the HO command from source eNB to the time UE transmit the RRCConnectionReconfigurationComplete to target eNB.
- **Data Interruption Time.** Delay incurred between the last data PDU (RTP packet) received/ transmitted on the source eNB to first data PDU (RTP packet) received/transmitted on the target eNB.
- **RTP packets dropped.** RTP packets dropped due to extended delay during HO.

KPI collected from Network side

- **HO success rate.** Total HO Success rate from the start of HO preparation until the successful HO execution.
- **HO Preparation success ratio.** The success ratio for the handover preparation phase, when the source eNB requests resources from target eNB and receives ACK response to start the HO attempt.
- **HO execution success ratio.** The success ratio for the handover execution phase, when the source eNB receives information that the UE successfully is connected to the target cell.
- **HO Preparation Failure ratio per Cause.** The ratio of a specific intra eNB handover preparation failure cause related to the total number of intra eNB HO preparations.


Topic Map
▪ Intra-LTE Handover Overview
▪ Impact of Paging Strategy on VoLTE
▪ Troubleshooting Mobility Issues
▪ Case Studies
Section 9-14
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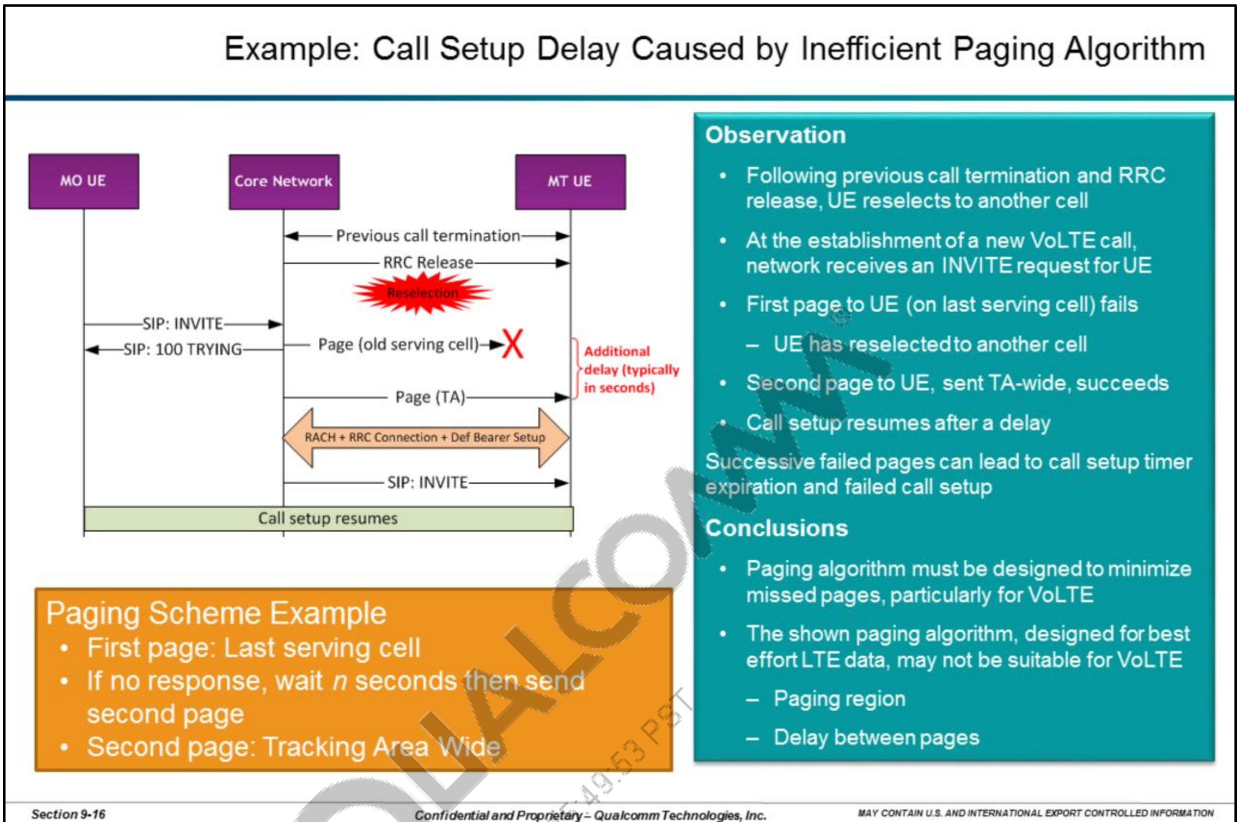
Notes

Paging Algorithm for VoLTE Call Setup

- First page success is critical for VoLTE call set up performance
- Paging algorithm for VoLTE should be designed to minimize missed pages, while keeping signaling to a minimum
- Considerations for Paging algorithm
  - Deployment density (urban, rural, venues, etc.)
  - Possibility of idle reselection, following the last VoLTE call
  - Call set up timeout timer
    - Delay between successive pages could be set to a lower value for VoLTE calls than best effort data traffic

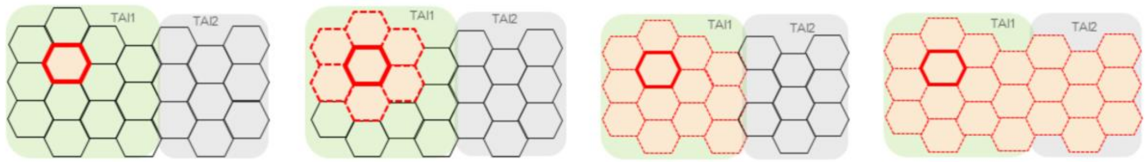
Notes



Call Setup Delay Caused by Inefficient Paging Algorithm

For paging performance analysis, a combination of network logs together with MO/MT UE logs for the same test case should be analyzed.

Options for First Page



Last Serving Cell	Last Serving Cell plus Neighbors	Tracking Area-Wide	Tracking Area List
Pros Minimal signaling **Cons** High probability of a missed page, particularly in mobility scenarios and dense coverage	**Pros** Moderate signaling **Cons** High probability of a missed page, particularly in dense environments	**Pros** High chance of success on first page **Cons** More signaling than previous approaches	**Pros** Guaranteed success on first page **Cons** Excessive signaling

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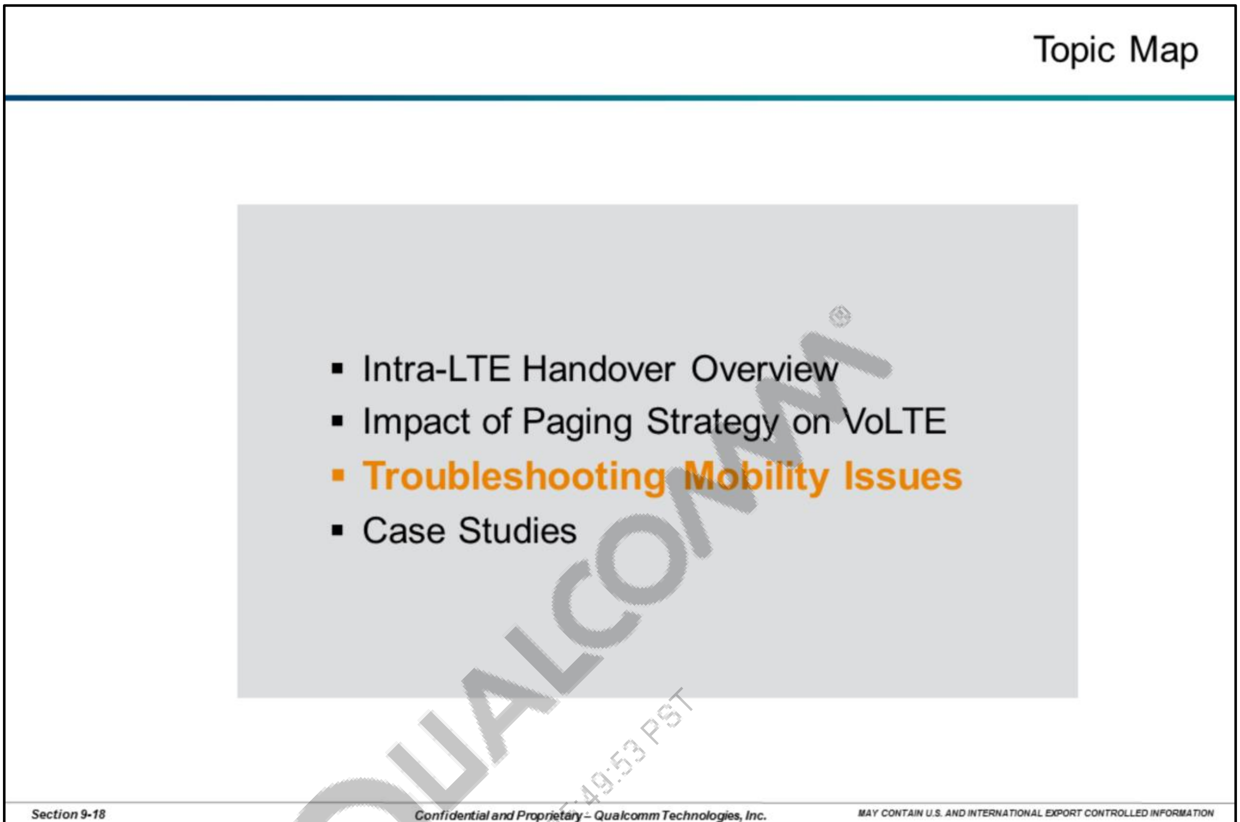
Notes


Topic Map
Intra-LTE Handover Overview
Impact of Paging Strategy on VoLTE
Troubleshooting Mobility Issues
Case Studies
Section 9-18
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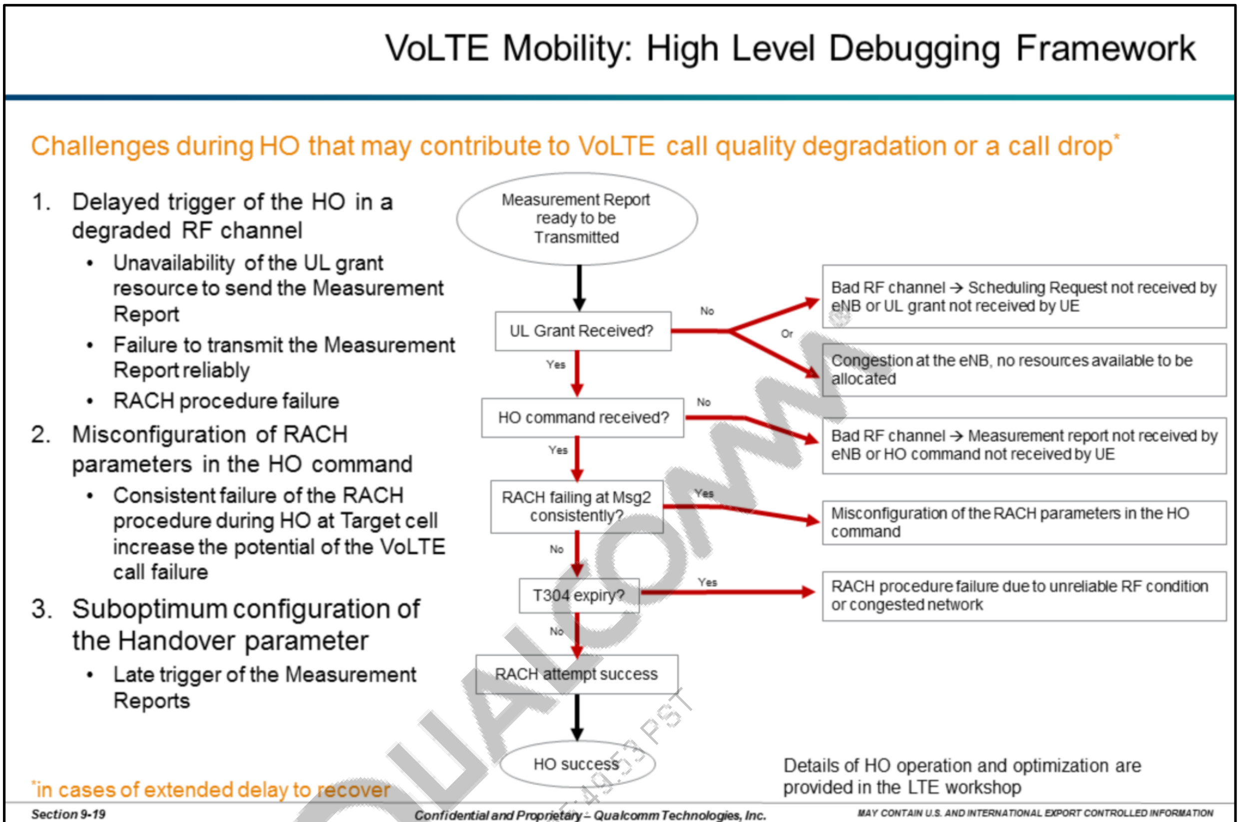
Notes



VoLTE Mobility: High Level Debugging Framework

1. Measurement Reports

Unavailability of UL grant to transmit the measurement report, RF channel degrade and call drops suboptimum configuration of MeasReport trigger, where the report will be triggered when RF condition are severely degraded causing unreliable transmission of the report.

2. RACH procedure

RACH procedure fails if RF condition changes drastically after the HO command was received by the UE causing unreliable transmission of the any of the RACH Messages (Msg1, Msg2, Msg3, Msg4). Adjustment of the event Threshold values is needed to trigger the HO earlier.

Misconfiguration of the RACH parameters between source and target cells will cause RACH failure during VoLTE handover. For instance the parameters conveyed HO command to the UE by the source cell of the target cell are different from the actually values used by the target cell. Symptoms of RACH consistently failing during HO on the target cell, however RACH is successful after the RLF.

Topic Map

- Intra-LTE Handover Overview
- Impact of Paging Strategy on VoLTE
- Troubleshooting Mobility Issues
- **Case Studies**

Notes

Summary: Debugging Scenarios

- Case Study-1 (Intra-LTE, Intra-frequency Handover during Call Setup – Good Case)
  - Intra-LTE handover happened during call set up and UM bearer was set up at the target cell.
    - Represents a good case as to how the entire process should actually take place.
- Case Study-2 (Handover during Call Setup: No UM Bearer Setup at Target Cell)
  - Multiple intra-LTE handover happened during call setup. However, UM bearer was NOT setup after receipt of SIP ACK at the target cell.
    - The call continued on default bearer.
- Case Study-3 (Impact of Handover on Call Setup Latency)
  - Compare two call setups: with handover and without handover during call setup.
  - Compare incremental impact on call setup latency.
- Case Study-4 (RoHC Context Reset during Inter-eNB handover– Good Case)
  - Example of RoHC context reset during HO and re-initiation of context at target cell.
- Case Study-5 (Intra-Frequency Handover during VoLTE call in session – Good Case)
  - Example showing no RTP packet loss and low delay due to successful, ideal case handover.
- Case Study-6 (RTP Packet Loss due to Failed Inter-Frequency Handover and RLF)
  - Inter-frequency handover failure resulting in RTP packet loss.

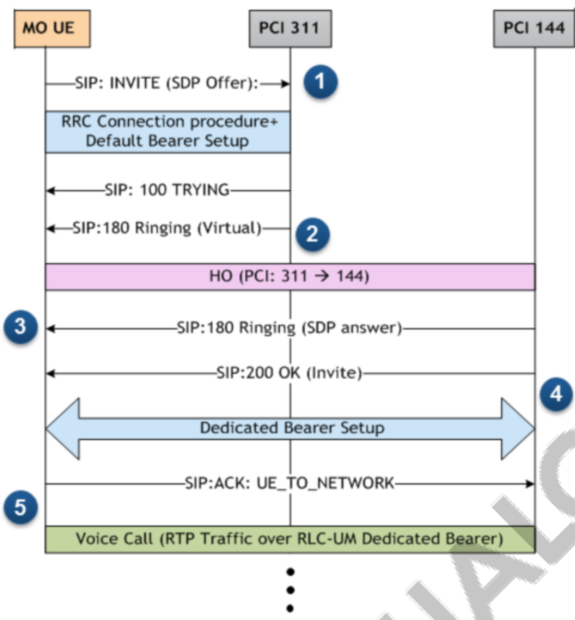
Notes

Summary: Debugging Scenarios

- **Case Study-1 (Intra-LTE, Intra-frequency Handover during Call Setup – Good Case)**
- Case Study-2 (Handover during Call Setup: No UM Bearer Setup at Target Cell)
- Case Study-3 (Impact of Handover on Call Setup Latency)
- Case Study-4 (RoHC Context Reset during Inter-eNB HO – Good Case)
- Case Study-5 (Intra-Frequency Handover during VoLTE call in session – Good Case)
- Case Study-6 (RTP Packet Loss due to Failed Inter-Frequency Handover and RLF)

Notes

Summary: Handover during VoLTE Call Setup



Observation

1. MO UE initiates a Voice Call on PCI 311.
2. During call setup procedure, post virtual ringing (180) MO UE undergoes handover from PCI 311 → PCI 144.
3. Ringing (180) from network to UE is received on new PCI.
4. Reception of SIP:200 OK triggers RRC Reconfiguration from PCI 144 with dedicated UM bearer establishment. This trigger is operator specific, not mandated by the 3GPP standards.
5. UE then sends SIP:ACK to network, which is followed to bi-directional RTP traffic over the dedicated bearer.

Conclusion

- Handover does not affect the voice call setup procedure.
- The IMS messages are received on the appropriate cells.
- The new cell sets up a dedicated bearer for the RTP traffic.

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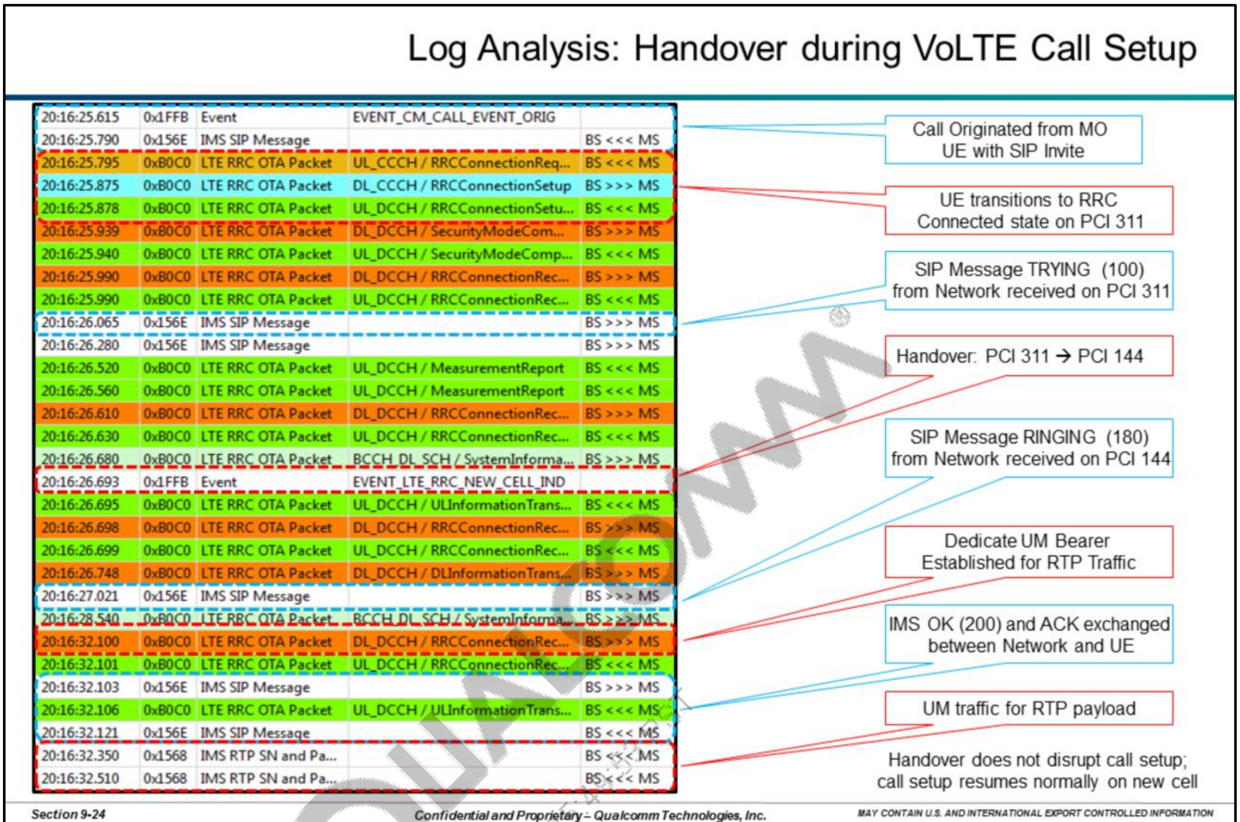
Notes



Log Analysis: Handover during VoLTE Call Setup

20:16:25.615	0x1FFB	Event	EVENT_CM_CALL_EVENT_ORIG	
20:16:25.790	0x156E	IMS SIP Message		BS <<< MS
20:16:25.795	0xB0C0	LTE RRC OTA Packet	UL_CCCH / RRCConnectionReq...	BS <<< MS
20:16:25.875	0xB0C0	LTE RRC OTA Packet	DL_CCCH / RRCConnectionSetup	BS >>> MS
20:16:25.878	0xB0C0	LTE RRC OTA Packet	UL_DCCH / RRCConnectionSetu...	BS <<< MS
20:16:25.939	0xB0C0	LTE RRC OTA Packet	DL_DCCH / SecurityModeCom...	BS >>> MS
20:16:25.940	0xB0C0	LTE RRC OTA Packet	UL_DCCH / SecurityModeComp...	BS <<< MS
20:16:25.990	0xB0C0	LTE RRC OTA Packet	DL_DCCH / RRCConnectionRec...	BS >>> MS
20:16:25.990	0xB0C0	LTE RRC OTA Packet	UL_DCCH / RRCConnectionRec...	BS <<< MS
20:16:26.065	0x156E	IMS SIP Message		BS >>> MS
20:16:26.280	0x156E	IMS SIP Message		BS >>> MS
20:16:26.520	0xB0C0	LTE RRC OTA Packet	UL_DCCH / MeasurementReport	BS <<< MS
20:16:26.560	0xB0C0	LTE RRC OTA Packet	UL_DCCH / MeasurementReport	BS <<< MS
20:16:26.610	0xB0C0	LTE RRC OTA Packet	DL_DCCH / RRCConnectionRec...	BS >>> MS
20:16:26.630	0xB0C0	LTE RRC OTA Packet	UL_DCCH / RRCConnectionRec...	BS <<< MS
20:16:26.680	0xB0C0	LTE RRC OTA Packet	BCCH_DL_SCH / SystemInforma...	BS >>> MS
20:16:26.693	0x1FFB	Event	EVENT_LTE_RRC_NEW_CELL_IND	
20:16:26.695	0xB0C0	LTE RRC OTA Packet	UL_DCCH / ULInformationTrans...	BS <<< MS
20:16:26.698	0xB0C0	LTE RRC OTA Packet	DL_DCCH / RRCConnectionRec...	BS >>> MS
20:16:26.699	0xB0C0	LTE RRC OTA Packet	UL_DCCH / RRCConnectionRec...	BS <<< MS
20:16:26.748	0xB0C0	LTE RRC OTA Packet	DL_DCCH / DLInformationTrans...	BS >>> MS
20:16:27.021	0x156E	IMS SIP Message		BS >>> MS
20:16:28.540	0xB0C0	LTE RRC OTA Packet	BCCH_DL_SCH / SystemInforma...	BS >>> MS
20:16:32.100	0xB0C0	LTE RRC OTA Packet	DL_DCCH / RRCConnectionRec...	BS >>> MS
20:16:32.101	0xB0C0	LTE RRC OTA Packet	UL_DCCH / RRCConnectionRec...	BS <<< MS
20:16:32.103	0x156E	IMS SIP Message		BS >>> MS
20:16:32.106	0xB0C0	LTE RRC OTA Packet	UL_DCCH / ULInformationTrans...	BS <<< MS
20:16:32.121	0x156E	IMS SIP Message		BS <<< MS
20:16:32.350	0x1568	IMS RTP SN and Pa...		BS <<< MS
20:16:32.510	0x1568	IMS RTP SN and Pa...		BS <<< MS

Notes

Analysis – Handover during VoLTE Call Setup

Log Analysis Procedure:

Open File: 09-01-Handover_During_Call_Setup

Notes

Handover during VoLTE Call Setup: Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	IMS SIP Message	0x156E	20:16:25:790	IMS_SIP_INVITE from UE to Network (Sent on PCI 311)
2	LTE RRC OTA Packet	0xB0C0	20:16:25:878	Transition to RRC Connected state on PCI 311
4	IMS SIP Message	0x156E	20:16:26:065	IMS_SIP_INVITE (TRYING:100) from Network to UE (Sent on PCI 311)
5	LTE RRC OTA Packet	0xB0C0	20:16:26:610	RRC Reconfiguration on PCI 311 (Verify handover command to PCI 144 under mobilityControlInfo)
6	LTE RRC OTA Packet	0xB0C0	20:16:26:699	RRC Reconfiguration on PCI 144 (Verify successful handover to PCI 144)
7	IMS SIP Message	0x156E	20:16:27:021	RINGING (180) received on new cell; indicates handover did not affect call setup procedure
8	IMS SIP Message	0x156E	20:16:32:103	SIP OK(200) received by MO UE; triggers dedicated bearer setup
9	LTE RRC OTA Packet	0xB0C0	20:16:32:100	RRC Reconfig (Verify dedicated bearer setup)
10	IMS SIP Message	0x156E	20:16:32:121	IMS-SIP-ACK sent by MO UE
11	IMS RTP SN and Payload	0x1568	20:16:32:350 Onwards	IMS RTP Payload (bi-directional)
12	LTE RLC DL/UL UM All PDU	0xB082	20:18:32:413 Onwards	Verify IMS traffic is carried on UM bearers

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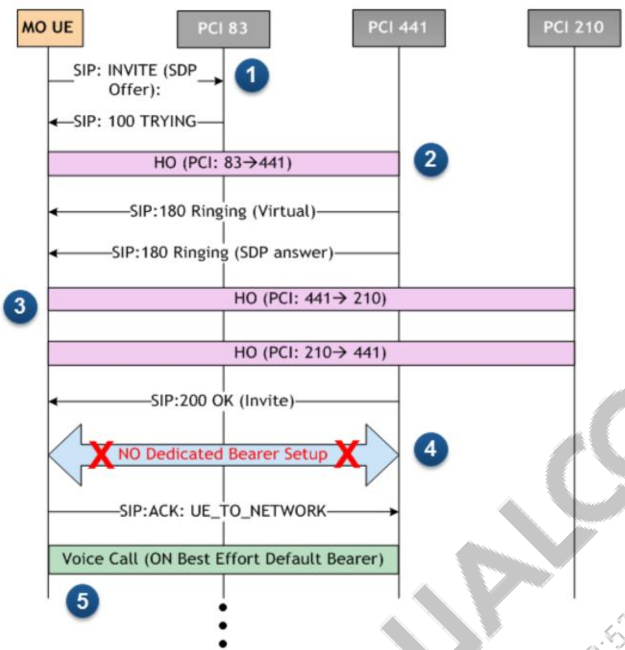
Notes

Summary: Debugging Scenarios

- Case Study-1 (Intra-LTE, Intra-frequency Handover during Call Setup – Good Case)
- **Case Study-2 (Handover during Call Setup: No UM Bearer Setup at Target Cell)**
- Case Study-3 (Impact of Handover on Call Setup Latency)
- Case Study-4 (RoHC Context Reset during Inter-eNB HO – Good Case)
- Case Study-5 (Intra-Frequency Handover during VoLTE call in session – Good Case)
- Case Study-6 (RTP Packet Loss due to Failed Inter-Frequency Handover and RLF)

Notes

Summary: Handover during Call Setup (with Default Bearer)



Observation

1. MO UE initiates a Voice Call on PCI 83.
2. While establishing default bearer MO UE undergoes handover from PCI 83 to 441.
3. Post Ringing (180) MO UE undergoes two handovers 441→210→441.
4. Dedicated bearer is typically established when SIP:200 OK is received. In this case, PCI 441 does not send a RRC re-configuration with UM Bearer establishment information. Hence, TFT was not triggered.
5. Without dedicated bearer for voice traffic, voice (RTP) traffic is carried on Default Bearers (AM: Best Effort).

Conclusion

- PCI 441 did not establish a dedicate bearer, possibly due to network/eNodeB related reasons. Poor RF conditions or frequent handover are not likely responsible for this.
- However, lack of dedicated bearer setup on the appropriate cell does not result in call drop, as per operator/UE configurations.
- Call is established normally on the default bearer in RLC-AM mode.
- The main drawback of an IMS call on default bearer could be high inter-arrival delays compared to IMS calls on dedicated bearers.

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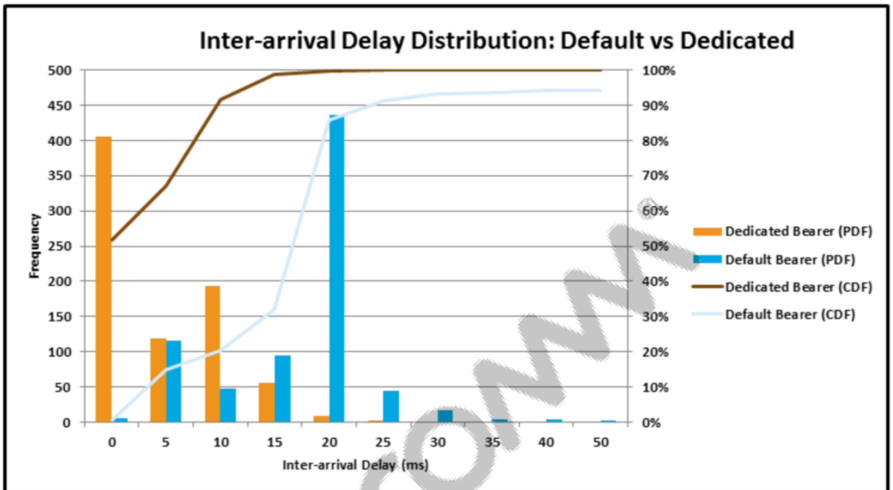
Notes

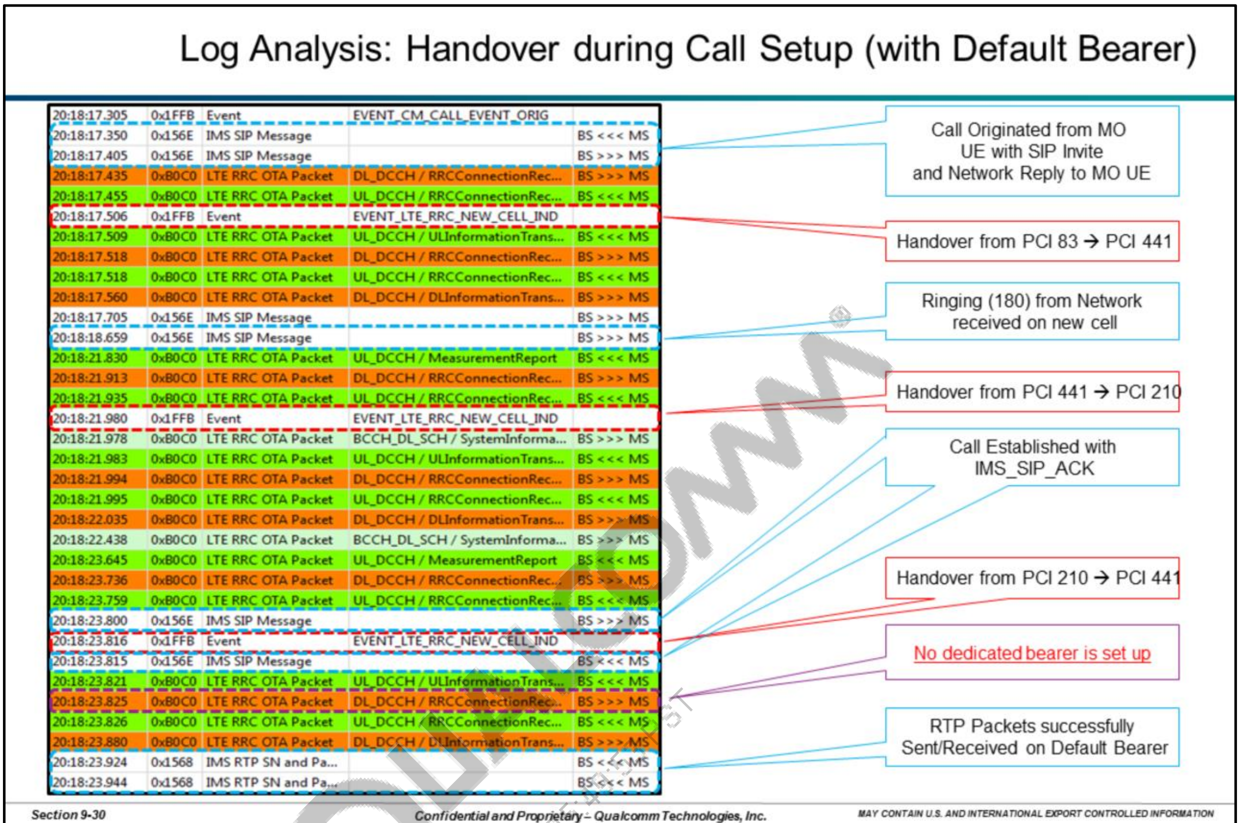
Inter-Arrival Time Comparison



Conclusions

- The mean inter-arrival delay for dedicated bearer traffic is less than 5 ms.
- For default bearer, the mean is greater than 15 ms.
- Extremely high variance could be seen in Inter-arrival times when RTP traffic goes on default bearer, which may impact call performance.

Notes



20:18:17.305	0x1FFB	Event	EVENT_CM_CALL_EVENT_ORIG	
20:18:17.350	0x156E	IMS SIP Message		BS <<< MS
20:18:17.405	0x156E	IMS SIP Message		BS >>> MS
20:18:17.435	0xB0C0	LTE RRC OTA Packet	DL_DCCH / RRCConnectionRec...	BS >>> MS
20:18:17.455	0xB0C0	LTE RRC OTA Packet	UL_DCCH / RRCConnectionRec...	BS <<< MS
20:18:17.506	0x1FFB	Event	EVENT_LTE_RRC_NEW_CELL_IND	
20:18:17.509	0xB0C0	LTE RRC OTA Packet	UL_DCCH / ULInformationTrans...	BS <<< MS
20:18:17.518	0xB0C0	LTE RRC OTA Packet	DL_DCCH / RRCConnectionRec...	BS >>> MS
20:18:17.518	0xB0C0	LTE RRC OTA Packet	UL_DCCH / RRCConnectionRec...	BS <<< MS
20:18:17.560	0xB0C0	LTE RRC OTA Packet	DL_DCCH / DLInformationTrans...	BS >>> MS
20:18:17.705	0x156E	IMS SIP Message		BS >>> MS
20:18:18.659	0x156E	IMS SIP Message		BS >>> MS
20:18:21.830	0xB0C0	LTE RRC OTA Packet	UL_DCCH / MeasurementReport	BS <<< MS
20:18:21.913	0xB0C0	LTE RRC OTA Packet	DL_DCCH / RRCConnectionRec...	BS >>> MS
20:18:21.935	0xB0C0	LTE RRC OTA Packet	UL_DCCH / RRCConnectionRec...	BS <<< MS
20:18:21.980	0x1FFB	Event	EVENT_LTE_RRC_NEW_CELL_IND	
20:18:21.978	0xB0C0	LTE RRC OTA Packet	BCCH_DL_SCH / SystemInforma...	BS >>> MS
20:18:21.983	0xB0C0	LTE RRC OTA Packet	UL_DCCH / ULInformationTrans...	BS <<< MS
20:18:21.994	0xB0C0	LTE RRC OTA Packet	DL_DCCH / RRCConnectionRec...	BS >>> MS
20:18:21.995	0xB0C0	LTE RRC OTA Packet	UL_DCCH / RRCConnectionRec...	BS <<< MS
20:18:22.035	0xB0C0	LTE RRC OTA Packet	DL_DCCH / DLInformationTrans...	BS >>> MS
20:18:22.438	0xB0C0	LTE RRC OTA Packet	BCCH_DL_SCH / SystemInforma...	BS >>> MS
20:18:23.645	0xB0C0	LTE RRC OTA Packet	UL_DCCH / MeasurementReport	BS <<< MS
20:18:23.736	0xB0C0	LTE RRC OTA Packet	DL_DCCH / RRCConnectionRec...	BS >>> MS
20:18:23.759	0xB0C0	LTE RRC OTA Packet	UL_DCCH / RRCConnectionRec...	BS <<< MS
20:18:23.800	0x156E	IMS SIP Message		BS >>> MS
20:18:23.816	0x1FFB	Event	EVENT_LTE_RRC_NEW_CELL_IND	
20:18:23.815	0x156E	IMS SIP Message		BS <<< MS
20:18:23.821	0xB0C0	LTE RRC OTA Packet	UL_DCCH / ULInformationTrans...	BS <<< MS
20:18:23.825	0xB0C0	LTE RRC OTA Packet	DL_DCCH / RRCConnectionRec...	BS >>> MS
20:18:23.826	0xB0C0	LTE RRC OTA Packet	UL_DCCH / RRCConnectionRec...	BS <<< MS
20:18:23.880	0xB0C0	LTE RRC OTA Packet	DL_DCCH / DLInformationTrans...	BS >>> MS
20:18:23.924	0x1568	IMS RTP SN and Pa...		BS <<< MS
20:18:23.944	0x1568	IMS RTP SN and Pa...		BS <<< MS

Notes

Analysis – Handover during Call Setup (Default Bearer)

Log Analysis Procedure:

Open File: 09-02-HO_Call_Setup_No_UM_Bearer_at_Target

Notes

Handover during Call Setup (Default Bearer): Walk-Through

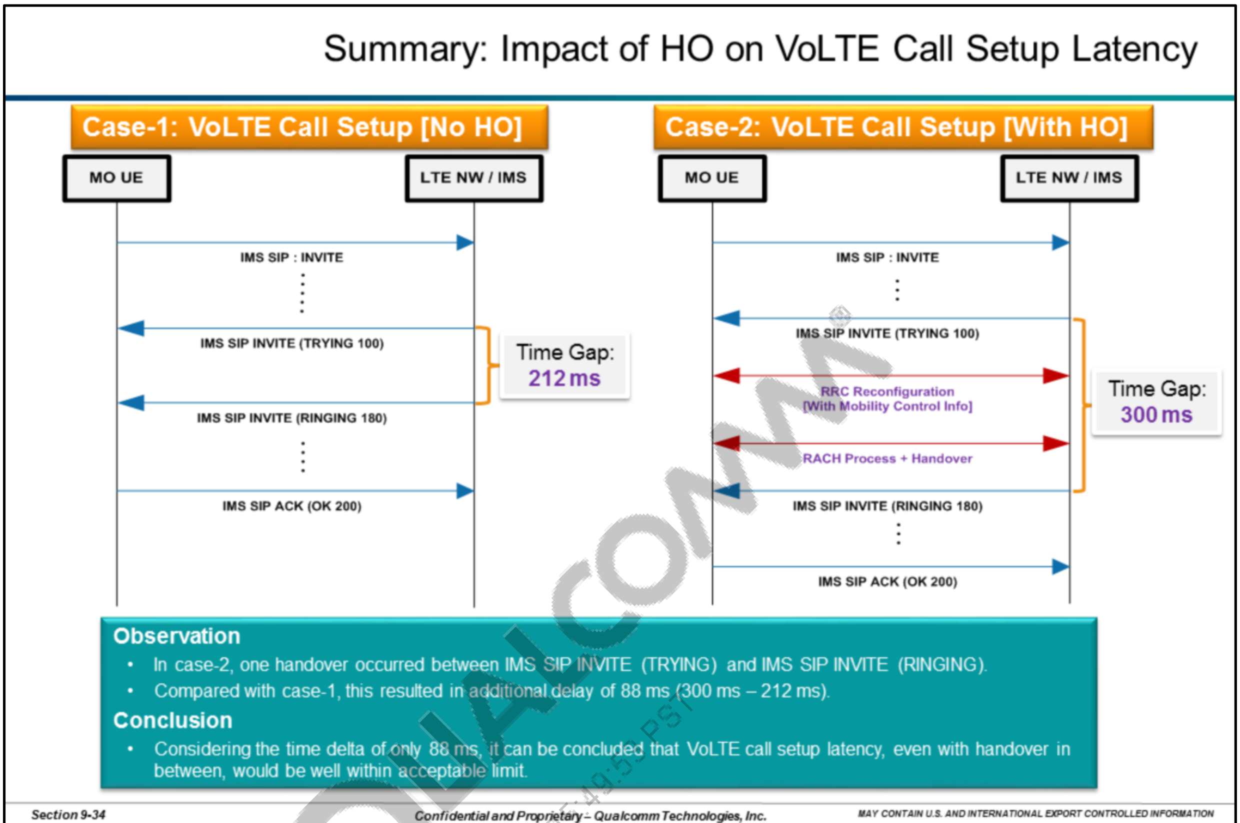
Step	Look for	Log Packet	Time Stamp	Verify
1	IMS SIP Message	0x156E	20:18:17:350	IMS_SIP_INVITE from UE to Network (Sent on PCI 83)
2	LTE RRC OTA Packet	0xB0C0	20:18:17:435	RRC Reconfiguration with handover info to PCI 441
3	IMS SIP Message	0x156E	20:18:17:705	IMS_SIP_INVITE (RINGING) sent to new PCI 441
4	LTE RRC OTA Packet	0xB0C0	20:18:21:913	RRC Reconfiguration with handover info to PCI 210
5	LTE RRC OTA Packet	0xB0C0	20:18:23:736	RRC Reconfiguration with handover info to PCI 441
6	IMS SIP Message	0x156E	20:18:23:800	IMS_SIP_INVITE (OK) from Network to UE (Sent on PCI 441)
7	IMS SIP Message	0x156E	20:18:23:815	IMS_SIP_ACK from UE to Network (Call Established)
8	LTE RRC OTA Packet	0xB0C0	20:18:23:825	RRC Reconfiguration on PCI 441 (Verify lack of dedicated bearer)
9	IMS RTP SN and Payload	0x1568	20:18:23:924 Onwards	IMS RTP Payload (bi-directional)
10	LTE RLC DL/UL AM All PDU	0xB082	20:18:24:001 Onwards	Verify IMS traffic is carried on AM bearers instead of UM bearer

Notes

Summary: Debugging Scenarios

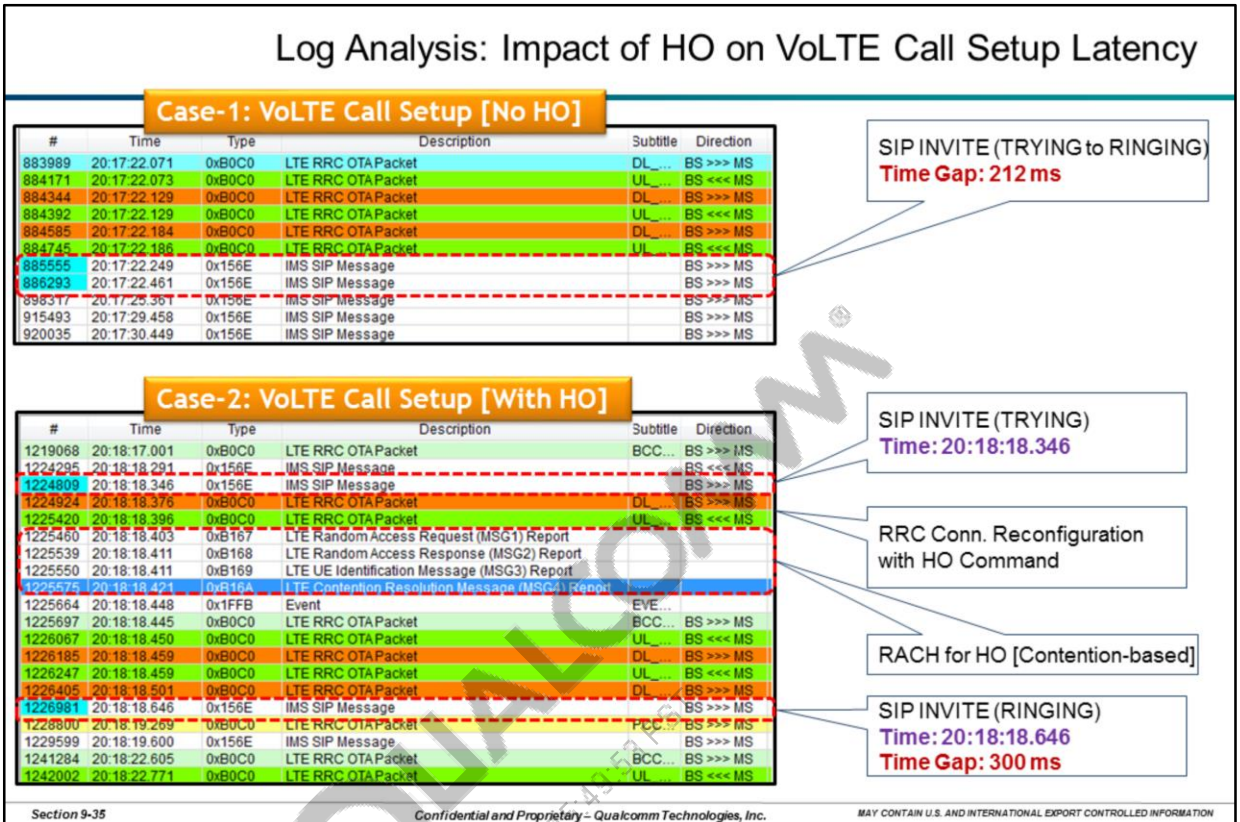
- Case Study-1 (Intra-LTE, Intra-frequency Handover during Call Setup - Good Case)
- Case Study-2 (Handover during Call Setup: No UM Bearer Setup at Target Cell)
- **Case Study-3 (Impact of Handover on Call Setup Latency)**
- Case Study-4 (RoHC Context Reset during Inter-eNB HO - Good Case)
- Case Study-5 (Intra-Frequency Handover during VoLTE call in session - Good Case)
- Case Study-6 (RTP Packet Loss due to Failed Inter-Frequency Handover and RLF)

Notes



Summary: Impact of HO on VoLTE Call Setup Latency

Additional 88 ms delay was added due to X2 based handover during call setup. In order to further reduce the time gap, one may attempt to optimize the handover process by opting for contention-free RACH instead of the contention-based ones observed in the current log file.



Log Analysis: Impact of HO on VoLTE Call Setup Latency

Contention-based RACH for handover was used in this example.

Analysis – Impact of HO on VoLTE Call Setup Latency

Log Analysis Procedure:

Open File: 09-03-HO_Impact_on_Call_Setup_Latency

Notes

Impact of HO on VoLTE Call Setup Latency: Log Walk-Through

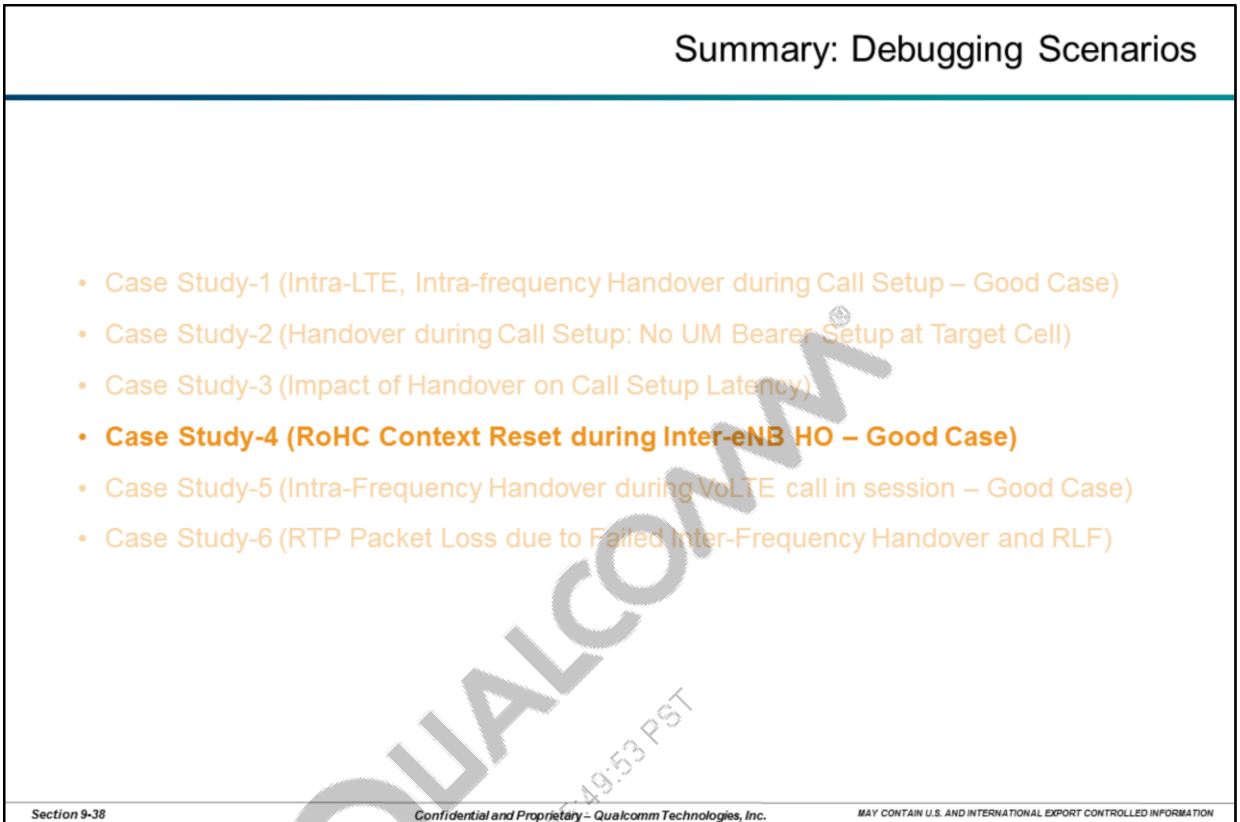
Case-1: VoLTE Call Setup [No HO]

Step	Look for	Log Packet	Time Stamp	Verify
1	IMS SIP Message	0x156E	**20:17:22.249**	IMS SIP INVITE (TRYING 100) [IMS → UE]
2	IMS SIP Message	0x156E	**20:17:22.461**	IMS SIP INVITE (RINGING 180) [IMS → UE]
Time Gap between TRYING and RINGING: **212 ms**				

Case-2: VoLTE Call Setup [With HO]

Step	Look for	Log Packet	Time Stamp	Verify
1	IMS SIP Message	0x156E	**20:18:18.346**	IMS SIP INVITE (TRYING 100) [IMS → UE]
2	LTE RRC OTA packet	0xB0C0	20:18:18.376	RRC Connection Reconfiguration with Mobility Control Info [Handover Command]
3	LTE RACH: MSG1-4 Report	0xB167 - 0xB16A	20:18:18.403 to 20:18:18.421	Message1-4 exchanged between UE and network
4	LTE RRC OTA Packet	0xB0C0	20:18:18.445	System Information Type-1
5	IMS SIP Message	0x156E	**20:18:18.646**	IMS SIP INVITE (RINGING 180) [IMS → UE]
Time Gap between TRYING and RINGING: **300 ms** [Additional **88 ms** added by X2 based HO]				

Notes


Summary: Debugging Scenarios
• Case Study-1 (Intra-LTE, Intra-frequency Handover during Call Setup – Good Case)
• Case Study-2 (Handover during Call Setup: No UM Bearer Setup at Target Cell)
• Case Study-3 (Impact of Handover on Call Setup Latency)
• Case Study-4 (RoHC Context Reset during Inter-eNB HO – Good Case)
• Case Study-5 (Intra-Frequency Handover during VoLTE call in session – Good Case)
• Case Study-6 (RTP Packet Loss due to Failed Inter-Frequency Handover and RLF)
Section 9-38
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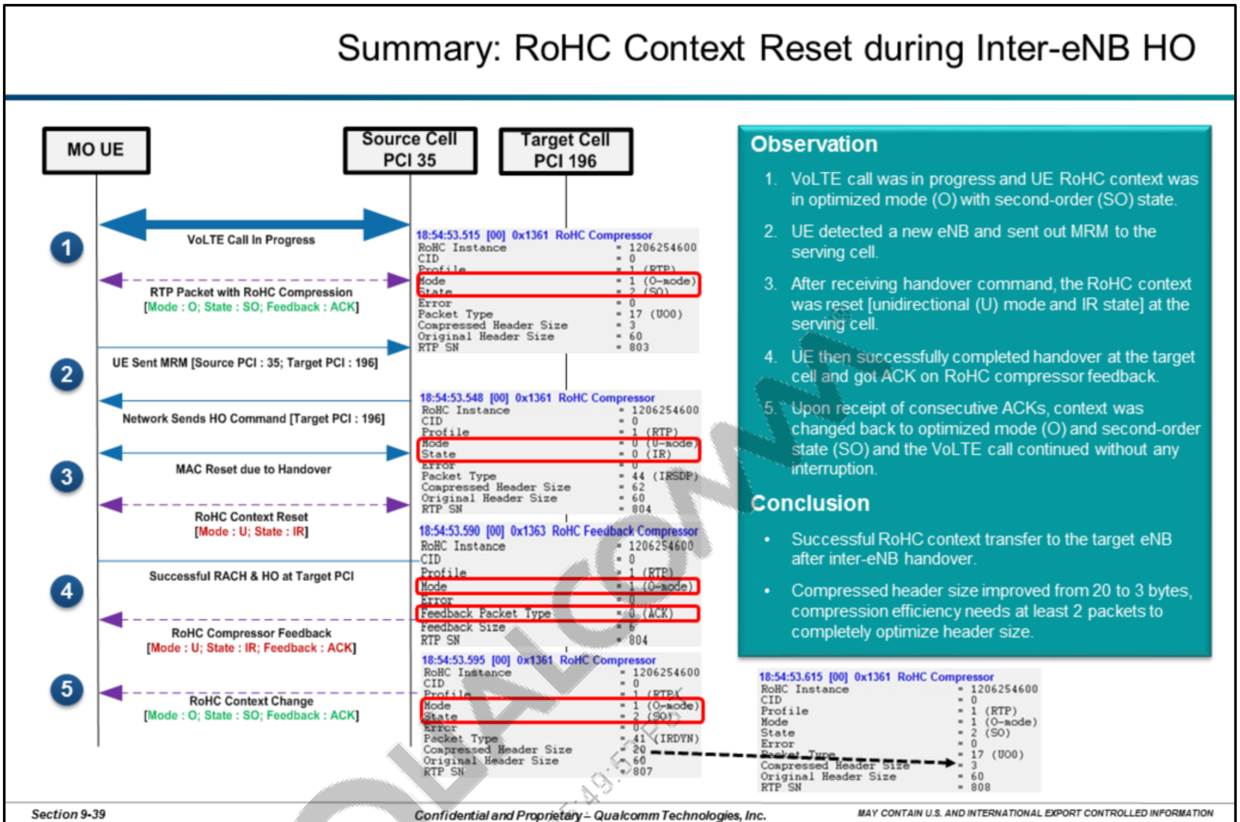
Notes

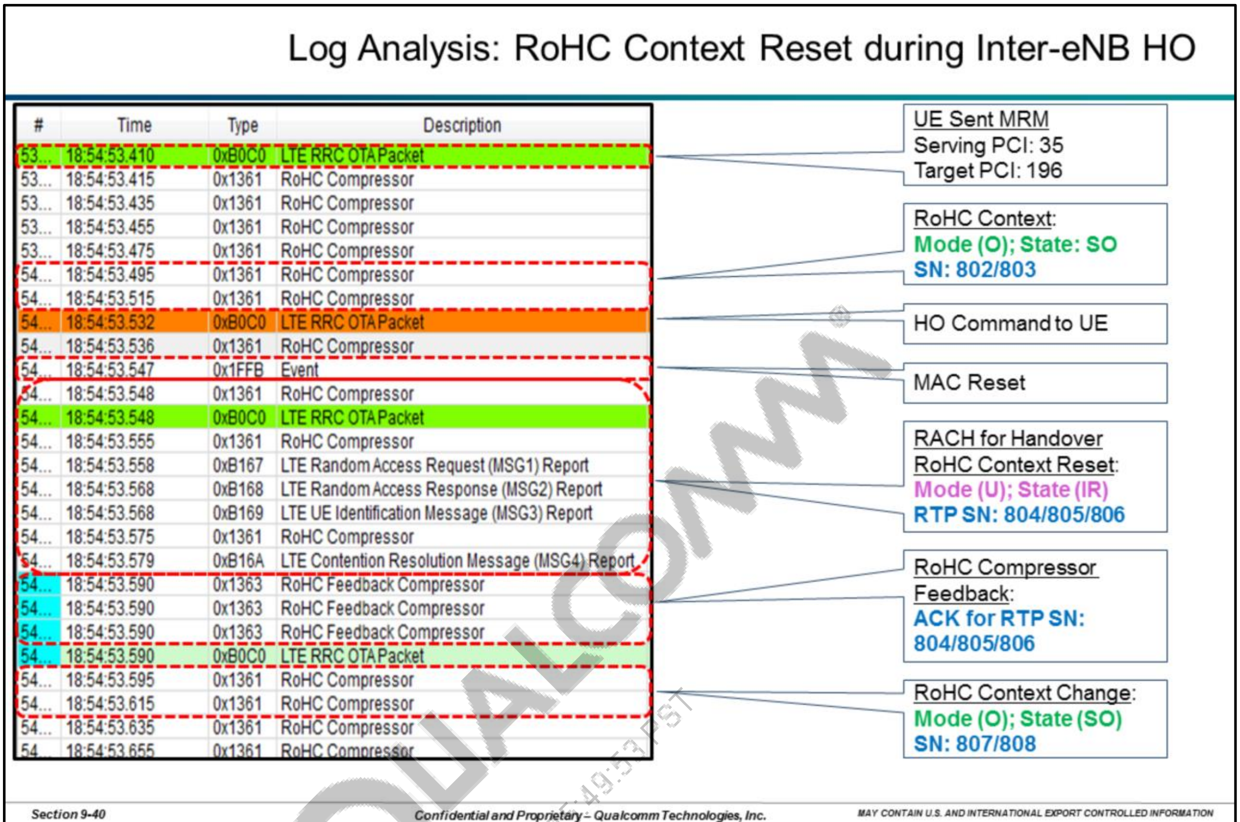


Summary: RoHC Context Reset during Inter-eNB HO

This is not a failure scenario, but represents how, during a normal, inter-eNB handover process, the RoHC context reset and resumption will happen without impacting the ongoing VoLTE call.

The table shows RTP SNs and their header compression status.

RTP SN	RoHC Compressor Mode	RoHC Compressor State	RoHC Feedback Compressor Type	Compressed Header Size
803	O-mode	SO	ACK	3 bytes
804	O-mode	SO	NACK	3 bytes
804	U-mode	IR	ACK	62 bytes
805	U-mode	IR	ACK	64 bytes
806	U-mode	IR	ACK	64 bytes
807	O-mode	SO	ACK	20 bytes
808	O-mode	SO	ACK	3 bytes



Log Analysis: RoHC Context Reset during Inter-eNB HO

VoLTE call was ongoing with RoHC context mode set to Optimized (O) and in second-order state. UE sent out measurement report message (MRM) indicating presence of new inter-eNB sector with PCI 196 (serving PCI: 35). UE produced RoHC contexts up to SN 803 in optimized mode and received ACK as compressor feedback.

At this stage, the eNB sent out the handover command and tge UE executed successful handover using contention-based RACH procedure. During this stage, RoHC context was reset and SN 804/805/806 were sent in IR state and in unidirectional (U) model.

After successful handover completion, ACK was received as RoHC compressor feedback for SN 804/805/806.

Based on ACK received, UE modified RoHC context to optimized (O) mode and second order (SO) state again for subsequent SN 807/808.

Subsequently, the VoLTE call continued at the target cell with RoHC context mode (O) and state (SO).

Analysis – RoHC Context Reset during Inter-eNB HO

Log Analysis Procedure:

Open File: 09-04-RoHC_Reset_at_HO

Notes

RoHC Context Reset during Inter-eNB HO: Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	LTE RRC OTA Packet	0xB0C0	18:54:53.410	Measurement Report (Serving PCI: 35; Target PCI: 196)
2	RoHC Compressor	0x1361	18:54:53.515	RoHC Context: Mode(O); State (SO); SN:803
3	LTE RRC OTA Packet	0xB0C0	18:54:53.532	HO Command to Target PCI 196
4	Event	0x1FFB	18:54:53.547	MAC Reset due to handover
5	RoHC Compressor	0x1361	18:54:53.548	RoHC Context Reset: Mode(U); State(IR); SN:804
6	RoHC Compressor	0x1361	18:54:53.555	RoHC Context Reset: Mode(U); State(IR); SN:805
7	RoHC Compressor	0x1361	18:54:53.575	RoHC Context Reset: Mode(U); State(IR); SN:806
8	LTE Contention Resolution Message	0xB16A	18:54:53.579	Contention Resolution: Pass
9	RoHC Feedback Compressor	0x1363	18:54:53.590	Feedback ACK for SN: 804/805/806
10	RoHC Compressor	0x1361	18:54:53.595	RoHC Context: Mode(O); State(SO); SN:807
11	RoHC Compressor	0x1361	18:54:53.615	RoHC Context: Mode(O); State(SO); SN:808

Notes

Summary: Debugging Scenarios

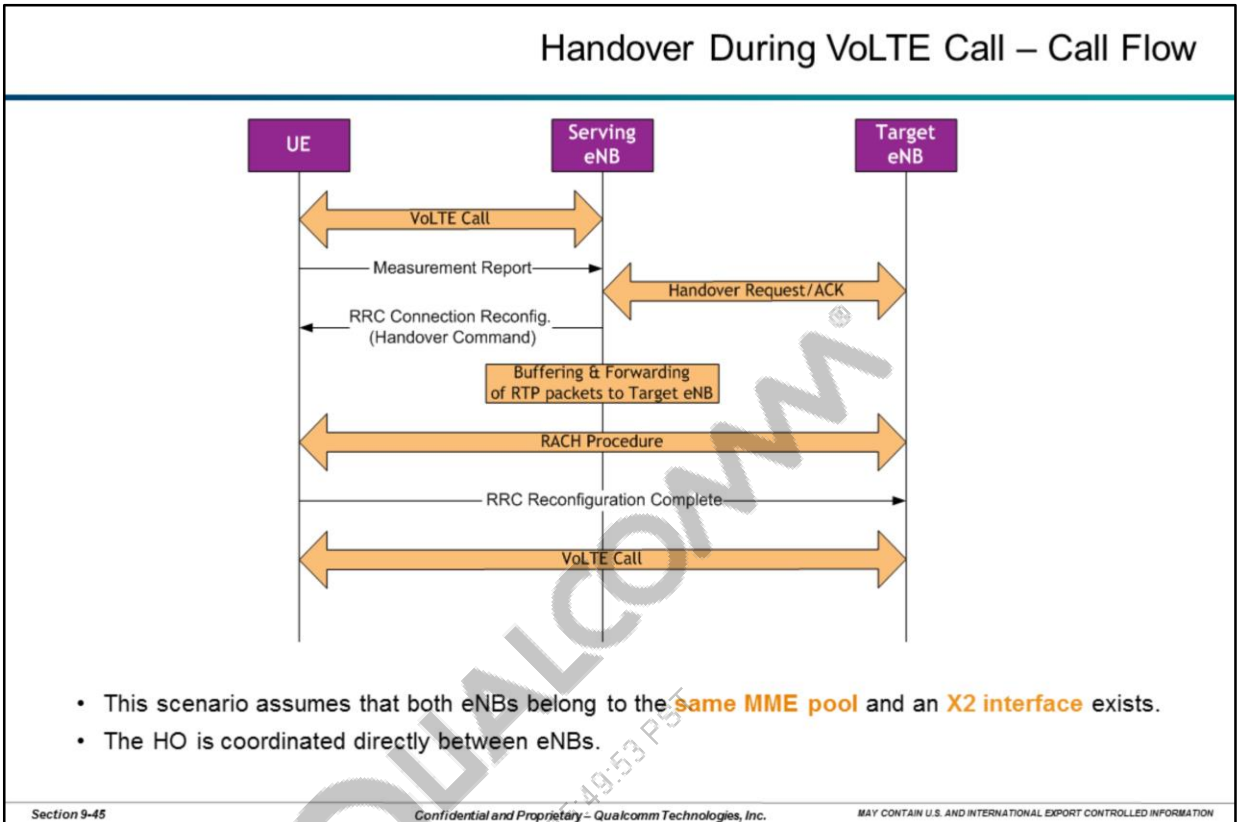
- Case Study-1 (Intra-LTE, Intra-frequency Handover during Call Setup – Good Case)
- Case Study-2 (Handover during Call Setup: No UM Bearer Setup at Target Cell)
- Case Study-3 (Impact of Handover on Call Setup Latency)
- Case Study-4 (RoHC Context Reset during Inter-eNB HO – Good Case)
- **Case Study-5 (Intra-Frequency Handover during VoLTE call in session – Good Case)**
- Case Study-6 (RTP Packet Loss due to Failed Inter-Frequency Handover and RLF)

Notes

Overview – Handover During VoLTE Call

- UE in a VoLTE call, with RTP traffic in one or both directions.
- UE sends out a measurement report.
- UE receives an RRC Connection Reconfiguration with Mobility Control Information (handover command).
- The UE initiates the RACH process to target eNodeB to complete the handover.
- The source eNodeB buffers the RTP packets and forwards them to the target eNodeB.
- The delay between the **last RTP packet before handover and the first RTP packet after handover** is measured to obtain the **RTP interruption delay**.
- Longer RTP interruption delay can lead to discarded (dropped) RTP packets.

Notes

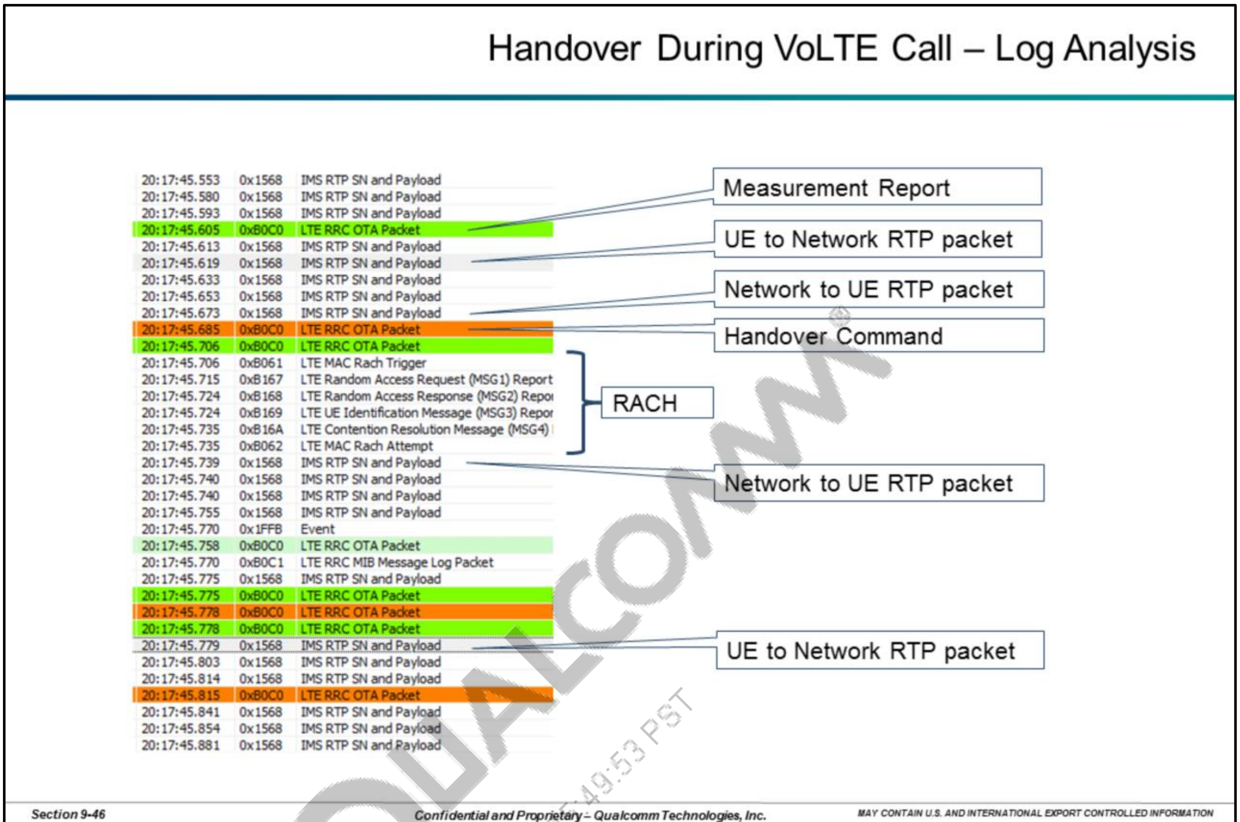


VoLTE Call During Handover

A simplified handover process is outlined in the above call flow. For the detailed process, refer to LTE CALL PROCESSING OVERVIEW (80-W2598-1).

- VoLTE call active with the Source eNB.
- A measurement report is triggered and sent by the UE to the serving eNB.
- The source eNB makes the handover decision and sends a Handover Command (included in RRC Connection Reconfiguration message) to the UE, after coordinating with the Target eNB.
- Source eNB also buffers the UE data and forwards it to Target eNB.
- The UE performs RACH procedure with the Target eNB for time synchronization.
- Once connection to Target eNB is established, the UE confirms the handover by sending an “RRC Connection Reconfiguration Complete” to the Target eNB.
- Voice call resumes with the Target eNB.

In the absence of X2 interface, S1 handover takes place where S-GW buffers the packets. Latency in S1 handover is typically longer than that in X2 handover.


Handover During VoLTE Call – Log Analysis
20:17:45.553 0x1568 IMS RTP SN and Payload
20:17:45.580 0x1568 IMS RTP SN and Payload
20:17:45.593 0x1568 IMS RTP SN and Payload
20:17:45.605 0xB0C0 LTE RRC OTA Packet
20:17:45.613 0x1568 IMS RTP SN and Payload
20:17:45.619 0x1568 IMS RTP SN and Payload
20:17:45.633 0x1568 IMS RTP SN and Payload
20:17:45.653 0x1568 IMS RTP SN and Payload
20:17:45.673 0x1568 IMS RTP SN and Payload
20:17:45.685 0xB0C0 LTE RRC OTA Packet
20:17:45.706 0xB0C0 LTE RRC OTA Packet
20:17:45.706 0xB061 LTE MAC Rach Trigger
20:17:45.715 0xB167 LTE Random Access Request (MSG1) Report
20:17:45.724 0xB168 LTE Random Access Response (MSG2) Repor
20:17:45.724 0xB169 LTE UE Identification Message (MSG3) Repor
20:17:45.735 0xB16A LTE Contention Resolution Message (MSG4)
20:17:45.735 0xB062 LTE MAC Rach Attempt
20:17:45.739 0x1568 IMS RTP SN and Payload
20:17:45.740 0x1568 IMS RTP SN and Payload
20:17:45.740 0x1568 IMS RTP SN and Payload
20:17:45.755 0x1568 IMS RTP SN and Payload
20:17:45.770 0x1FFB Event
20:17:45.758 0xB0C0 LTE RRC OTA Packet
20:17:45.770 0xB0C1 LTE RRC MIB Message Log Packet
20:17:45.775 0x1568 IMS RTP SN and Payload
20:17:45.775 0xB0C0 LTE RRC OTA Packet
20:17:45.778 0xB0C0 LTE RRC OTA Packet
20:17:45.778 0xB0C0 LTE RRC OTA Packet
20:17:45.779 0x1568 IMS RTP SN and Payload
20:17:45.803 0x1568 IMS RTP SN and Payload
20:17:45.814 0x1568 IMS RTP SN and Payload
20:17:45.815 0xB0C0 LTE RRC OTA Packet
20:17:45.841 0x1568 IMS RTP SN and Payload
20:17:45.854 0x1568 IMS RTP SN and Payload
20:17:45.881 0x1568 IMS RTP SN and Payload
Measurement Report
UE to Network RTP packet
Network to UE RTP packet
Handover Command
RACH
Network to UE RTP packet
UE to Network RTP packet
Section 9-46
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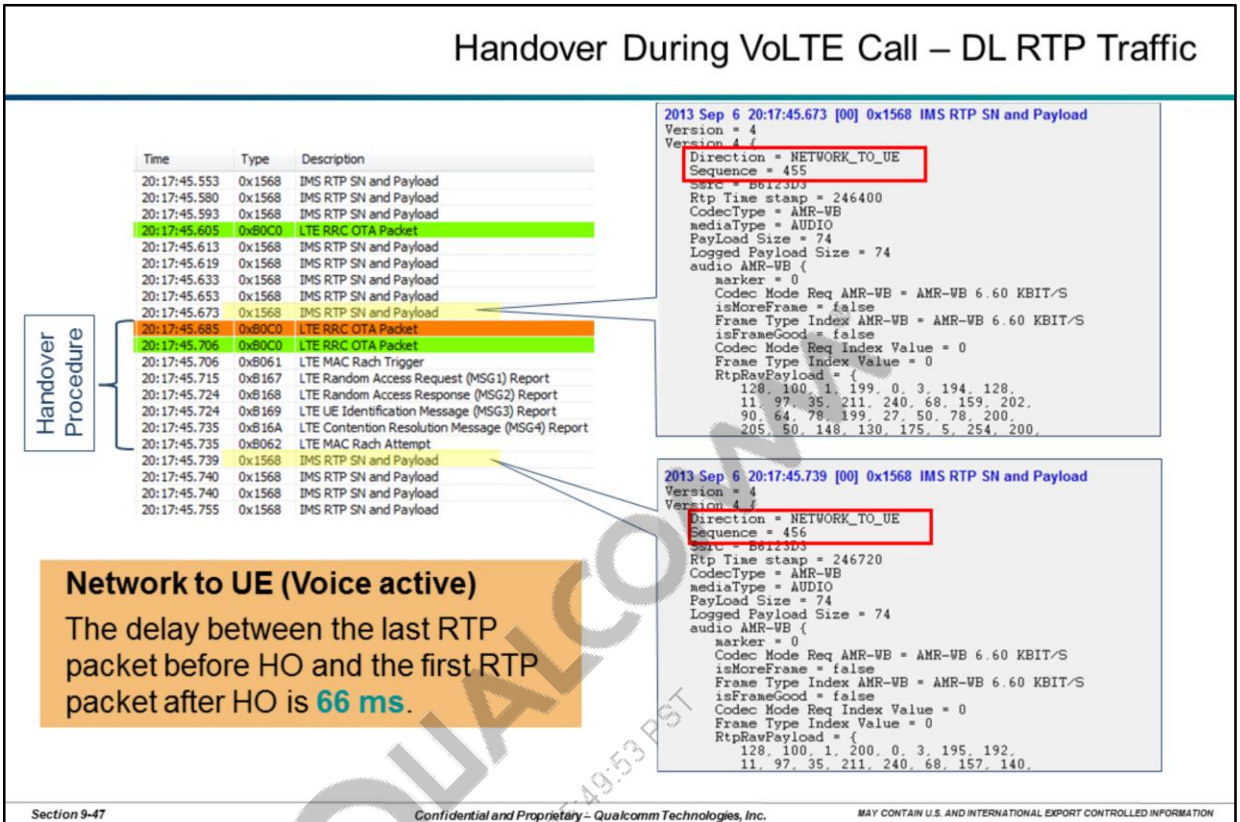
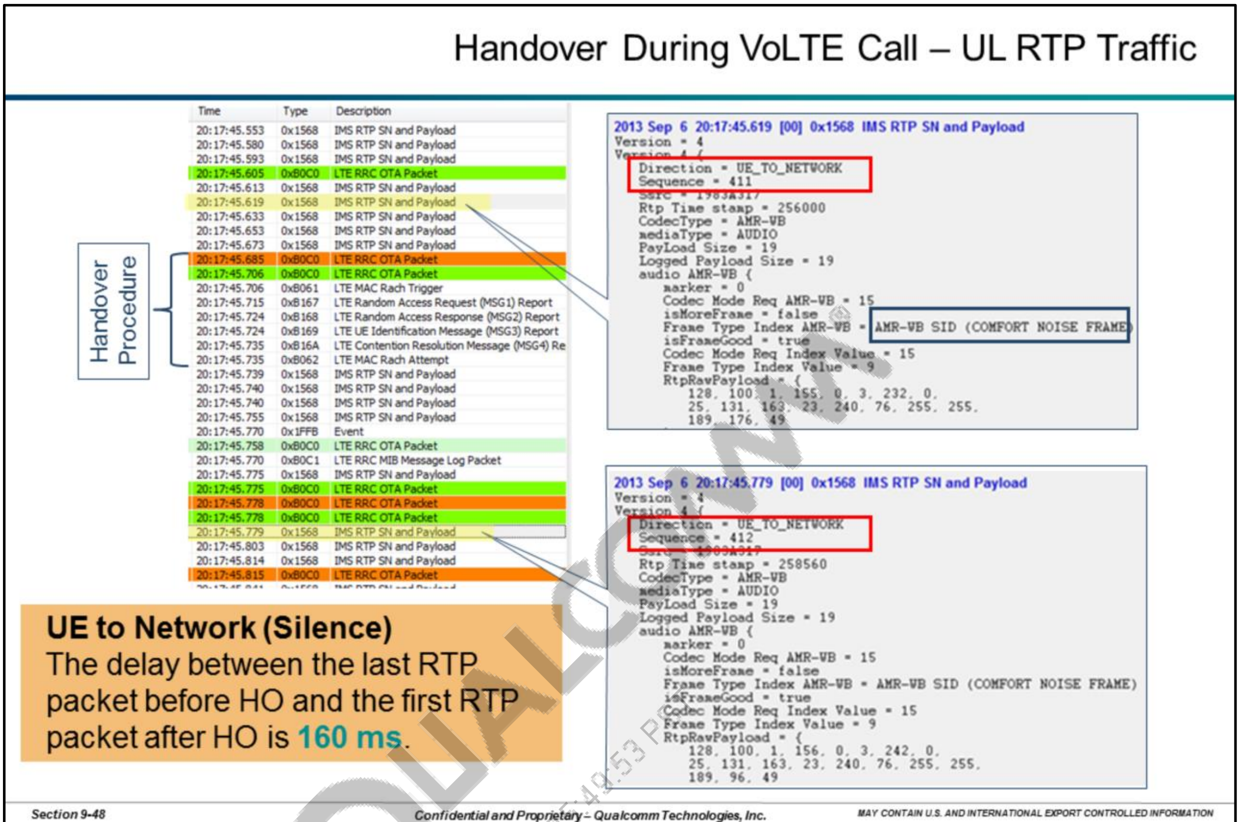
Notes



Handover During VoLTE Call – DL RTP Traffic

RTP packets are generated every 20 ms during talkspurts.

No packet is dropped as long as the HO delay is less than the discard timer, set to 100 ms in this case.



Handover During VoLTE Call – UL RTP Traffic

Comfort noise frames are generated every 160 ms during silence periods in both stationary and mobility scenarios.

Analysis Example – Handover during VoLTE Call

Log Analysis Procedure: Handover during VoLTE Call

Open File: 09-05-HO_during_call

Notes

VoLTE Call During Handover: Log Walk-Through

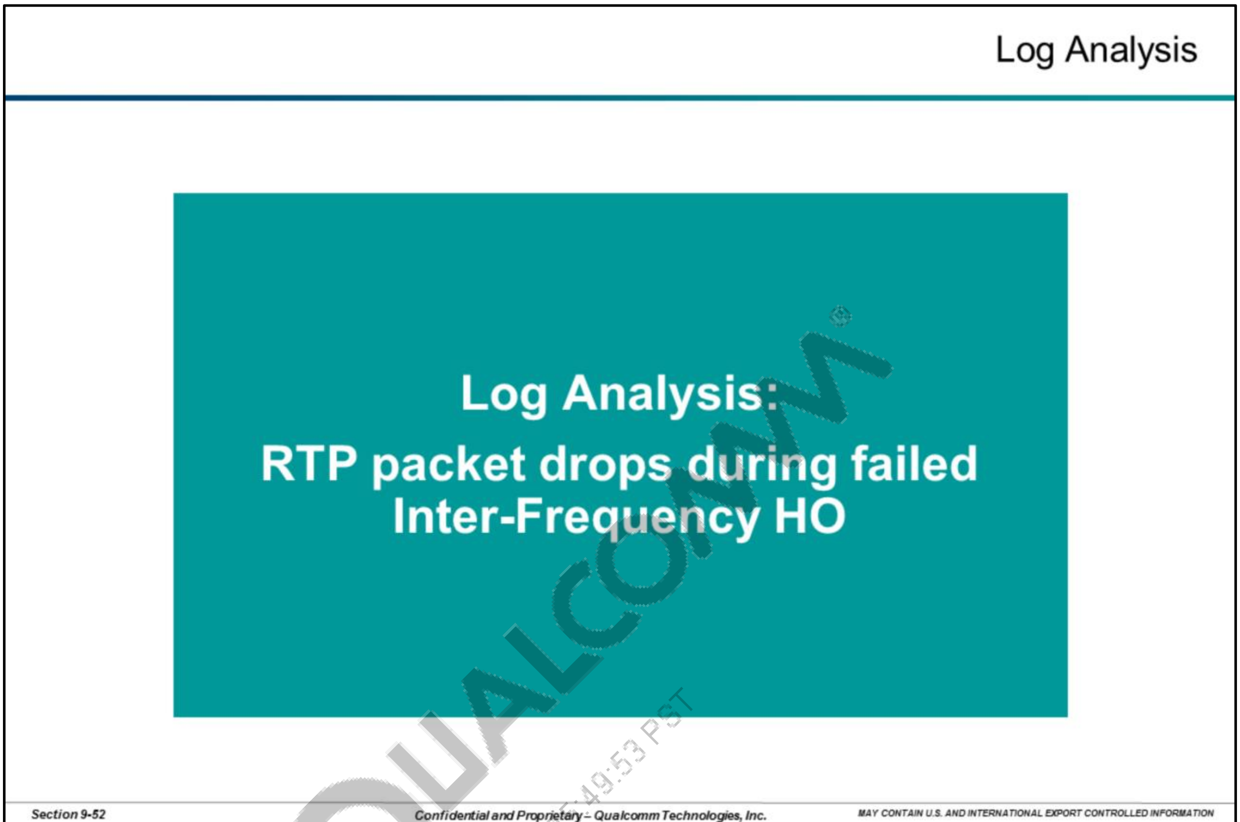
Step	Look for	Log Packet	Time Stamp	Verify
1	RRC Connection Request	0xB0C0	20:17:45.605	Measurement report
2	IMS RTP SN and Payload	0x1568	20:17:45.619	Last RTP UE-to-Network packet before HO. Sequence number = 411
3	IMS RTP SN and Payload	0x1568	20:17:45.673	Last RTP Network-to-UE packet before HO. Sequence number = 455
4	RRC Connection Request	0xB0C0	20:17:45.685	mobilityControlInfo. Handover command to PCI 210
5	RACH Trigger	0xB061	20:17:45.706	RACH Reason = HO
6	RACH Procedure	0xB167 0xB168 0xB169 0xB16A	20:17:45.715 through 20:17:45.735	MSG1 through MSG4
7	RACH Attempt	0xB062	20:17:45.735	Rach result = Success
8	IMS RTP SN and Payload	0x1568	20:17:45.739	First RTP Network-to-UE packet before HO. Sequence number = 456
9	IMS RTP SN and Payload	0x1568	20:17:45.779	First RTP UE-to-Network packet before HO. Sequence number = 412

Notes

Summary: Debugging Scenarios

- Case Study-1 (Intra-LTE, Intra-frequency Handover during Call Setup – Good Case)
- Case Study-2 (Handover during Call Setup: No UM Bearer Setup at Target Cell)
- Case Study-3 (Impact of Handover on Call Setup Latency)
- Case Study-4 (RoHC Context Reset during Inter-eNB HO – Good Case)
- Case Study-5 (Intra-Frequency Handover during VoLTE call in session – Good Case)
- **Case Study-6 (RTP Packet Loss due to Failed Inter-Frequency Handover and RLF)**

Notes


Log Analysis
Log Analysis:
RTP packet drops during failed Inter-Frequency HO
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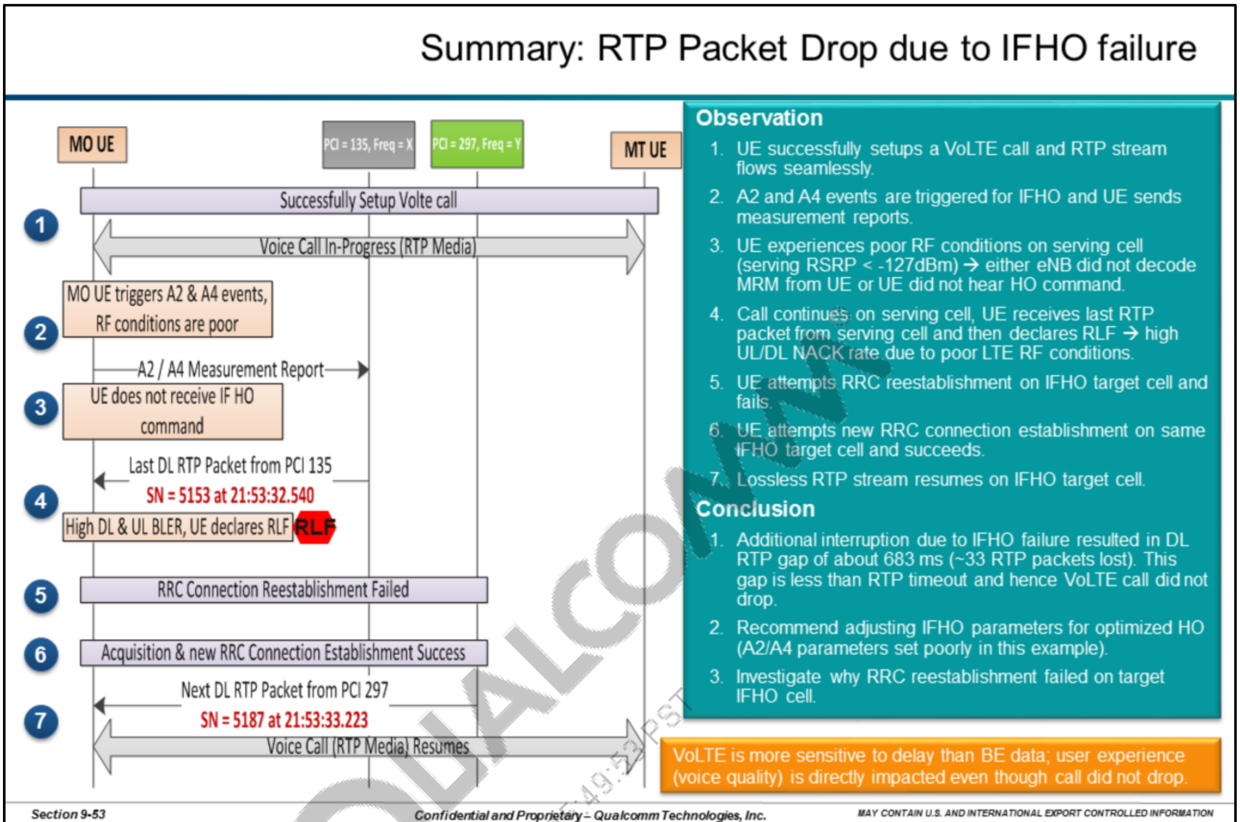
Notes


Summary: RTP Packet Drop due to IFHO failure
MO UE
PCI = 135, Freq = X
PCI = 297, Freq = Y
MT UE
1
Successfully Setup Volte call
Voice Call In-Progress (RTP Media)
2
MO UE triggers A2 & A4 events, RF conditions are poor
A2 / A4 Measurement Report
3
UE does not receive IF HO command
4
Last DL RTP Packet from PCI 135
SN = 5153 at 21:53:32.540
High DL & UL BLER, UE declares RLF
RLF
5
RRC Connection Reestablishment Failed
6
Acquisition & new RRC Connection Establishment Success
7
Next DL RTP Packet from PCI 297
SN = 5187 at 21:53:33.223
Voice Call (RTP Media) Resumes
Observation
1. UE successfully setups a VoLTE call and RTP stream flows seamlessly.
2. A2 and A4 events are triggered for IFHO and UE sends measurement reports.
3. UE experiences poor RF conditions on serving cell (serving RSRP < -127dBm) → either eNB did not decode MRM from UE or UE did not hear HO command.
4. Call continues on serving cell, UE receives last RTP packet from serving cell and then declares RLF → high UL/DL NACK rate due to poor LTE RF conditions.
5. UE attempts RRC reestablishment on IFHO target cell and fails.
6. UE attempts new RRC connection establishment on same IFHO target cell and succeeds.
7. Lossless RTP stream resumes on IFHO target cell.
Conclusion
1. Additional interruption due to IFHO failure resulted in DL RTP gap of about 683 ms (~33 RTP packets lost). This gap is less than RTP timeout and hence VoLTE call did not drop.
2. Recommend adjusting IFHO parameters for optimized HO (A2/A4 parameters set poorly in this example).
3. Investigate why RRC reestablishment failed on target IFHO cell.
VoLTE is more sensitive to delay than BE data; user experience (voice quality) is directly impacted even though call did not drop.
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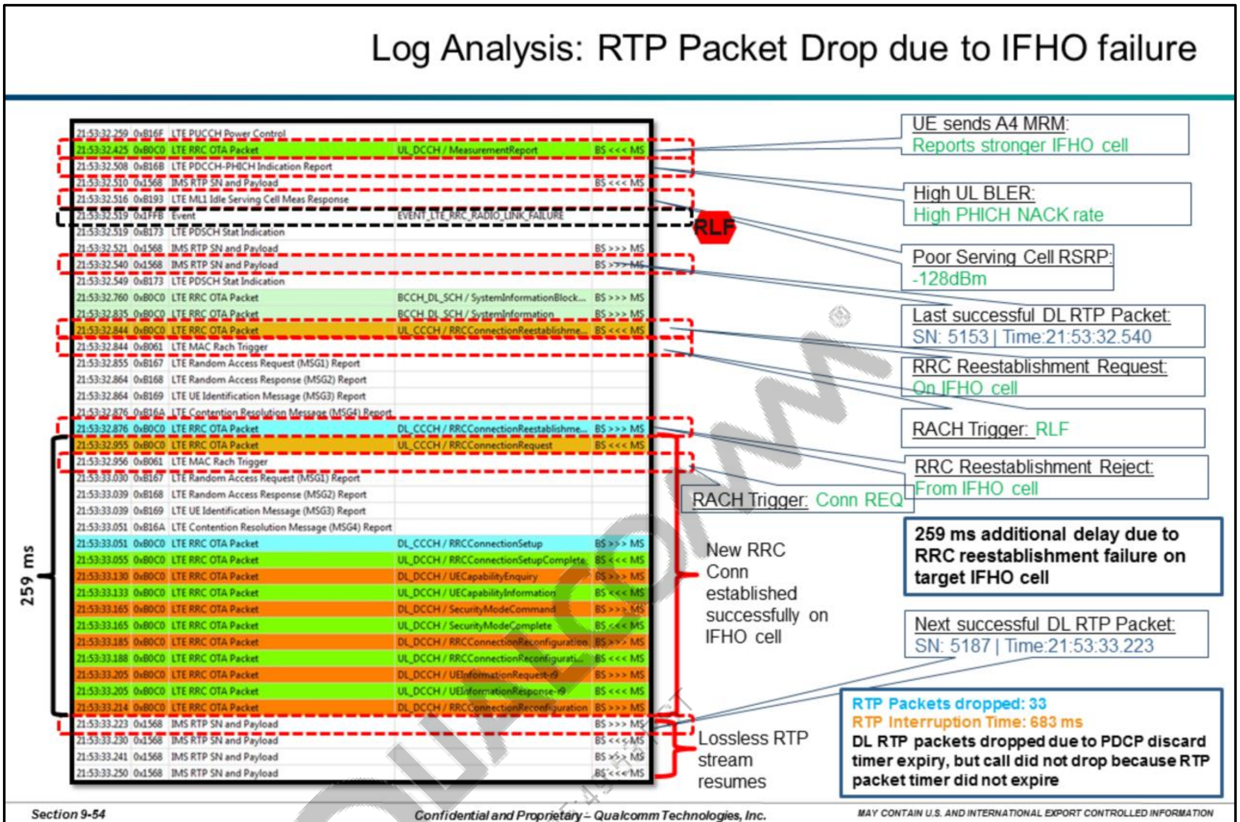
Notes


Log Analysis: RTP Packet Drop due to IFHO failure
21:53:32.259 0xB16F LTE PUCCH Power Control
21:53:32.425 0xB0C0 LTE RRC OTA Packet UL_DCCH / MeasurementReport BS <<< MS
21:53:32.508 0xB16B LTE PDCCH-PHICH Indication Report
21:53:32.510 0x1568 IMS RTP SN and Payload BS <<< MS
21:53:32.516 0xB193 LTE ML1 Idle Serving Cell Meas Response
21:53:32.519 0x1FFB Event EVENT_LTE_RRC_RADIO_LINK_FAILURE
21:53:32.519 0xB173 LTE PDSCH Stat Indication
21:53:32.521 0x1568 IMS RTP SN and Payload BS >>> MS
21:53:32.540 0x1568 IMS RTP SN and Payload BS >>> MS
21:53:32.549 0xB173 LTE PDSCH Stat Indication
21:53:32.760 0xB0C0 LTE RRC OTA Packet BCCH_DL_SCH / SystemInformationBlock... BS >>> MS
21:53:32.835 0xB0C0 LTE RRC OTA Packet BCCH_DL_SCH / SystemInformation BS >>> MS
21:53:32.844 0xB0C0 LTE RRC OTA Packet UL_CCCH / RRCConnectionReestablishme... BS <<< MS
21:53:32.844 0xB061 LTE MAC Rach Trigger
21:53:32.855 0xB167 LTE Random Access Request (MSG1) Report
21:53:32.864 0xB168 LTE Random Access Response (MSG2) Report
21:53:32.864 0xB169 LTE UE Identification Message (MSG3) Report
21:53:32.876 0xB16A LTE Contention Resolution Message (MSG4) Report
21:53:32.876 0xB0C0 LTE RRC OTA Packet DL_CCCH / RRCConnectionReestablishme... BS >>> MS
21:53:32.955 0xB0C0 LTE RRC OTA Packet UL_CCCH / RRCConnectionRequest BS <<< MS
21:53:32.956 0xB061 LTE MAC Rach Trigger
21:53:33.030 0xB167 LTE Random Access Request (MSG1) Report
21:53:33.039 0xB168 LTE Random Access Response (MSG2) Report
21:53:33.039 0xB169 LTE UE Identification Message (MSG3) Report
21:53:33.051 0xB16A LTE Contention Resolution Message (MSG4) Report
21:53:33.051 0xB0C0 LTE RRC OTA Packet DL_CCCH / RRCConnectionSetup BS >>> MS
21:53:33.055 0xB0C0 LTE RRC OTA Packet UL_DCCH / RRCConnectionSetupComplete BS <<< MS
21:53:33.130 0xB0C0 LTE RRC OTA Packet DL_DCCH / UECapabilityEnquiry BS >>> MS
21:53:33.133 0xB0C0 LTE RRC OTA Packet UL_DCCH / UECapabilityInformation BS <<< MS
21:53:33.165 0xB0C0 LTE RRC OTA Packet DL_DCCH / SecurityModeCommand BS >>> MS
21:53:33.165 0xB0C0 LTE RRC OTA Packet UL_DCCH / SecurityModeComplete BS <<< MS
21:53:33.185 0xB0C0 LTE RRC OTA Packet DL_DCCH / RRCConnectionReconfiguration BS >>> MS
21:53:33.188 0xB0C0 LTE RRC OTA Packet UL_DCCH / RRCConnectionReconfigurati... BS <<< MS
21:53:33.205 0xB0C0 LTE RRC OTA Packet DL_DCCH / UEInformationRequest-r9 BS >>> MS
21:53:33.205 0xB0C0 LTE RRC OTA Packet UL_DCCH / UEInformationResponse-r9 BS <<< MS
21:53:33.214 0xB0C0 LTE RRC OTA Packet DL_DCCH / RRCConnectionReconfiguration BS >>> MS
21:53:33.223 0x1568 IMS RTP SN and Payload BS >>> MS
21:53:33.230 0x1568 IMS RTP SN and Payload BS <<< MS
21:53:33.241 0x1568 IMS RTP SN and Payload BS >>> MS
21:53:33.250 0x1568 IMS RTP SN and Payload BS <<< MS
259 ms
RLF
UE sends A4 MRM:
Reports stronger IFHO cell
High UL BLER:
High PHICH NACK rate
Poor Serving Cell RSRP:
-128dBm
Last successful DL RTP Packet:
SN: 5153 | Time:21:53:32.540
RRC Reestablishment Request:
On IFHO cell
RACH Trigger: RLF
RRC Reestablishment Reject:
From IFHO cell
RACH Trigger: Conn REQ
New RRC Conn established successfully on IFHO cell
259 ms additional delay due to RRC reestablishment failure on target IFHO cell
Next successful DL RTP Packet:
SN: 5187 | Time:21:53:33.223
Lossless RTP stream resumes
RTP Packets dropped: 33
RTP Interruption Time: 683 ms
DL RTP packets dropped due to PDCP discard timer expiry, but call did not drop because RTP packet timer did not expire
Section 9-54
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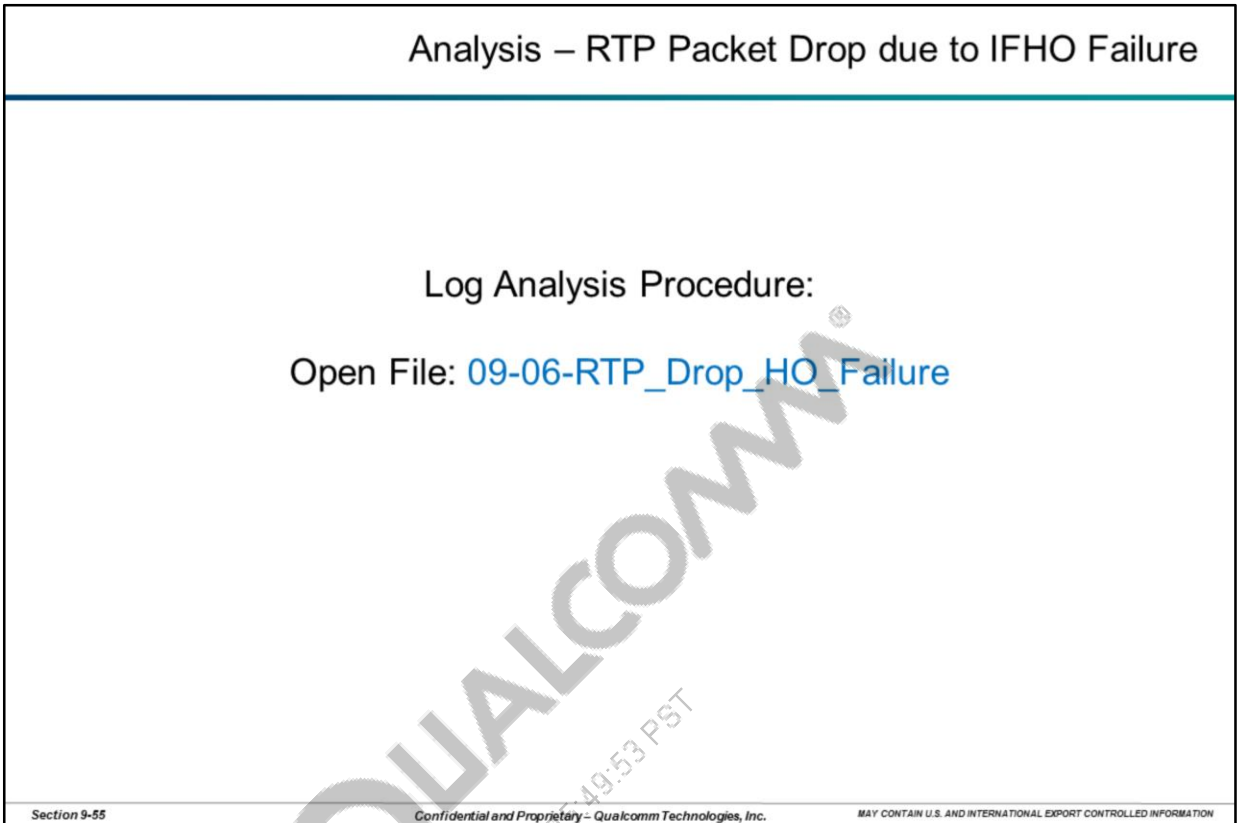
Notes


Analysis – RTP Packet Drop due to IFHO Failure
Log Analysis Procedure:
Open File: 09-06-RTP_Drop_HO_Failure
Section 9-55
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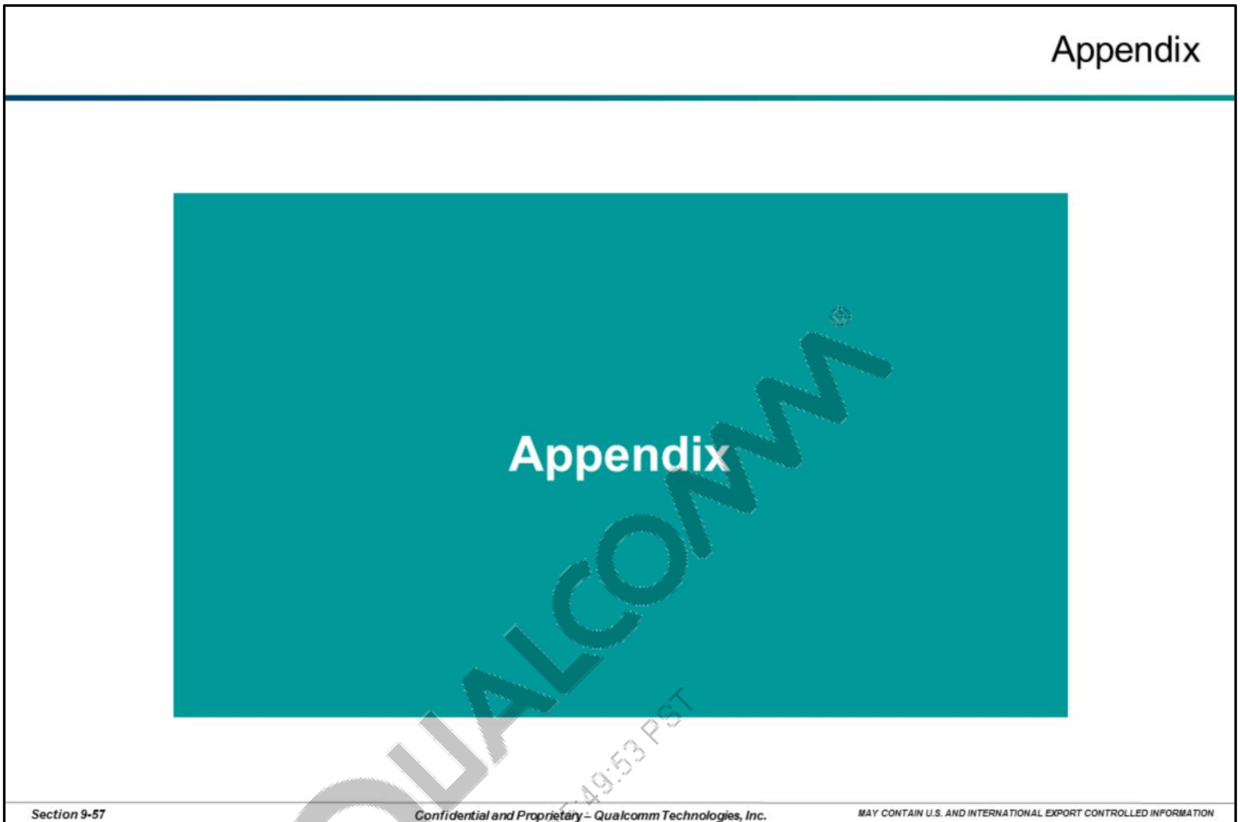
Notes

RTP Packet Drop due to IFHO Failure: Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	LTE RRC OTA Packer	0xB0C0	21:53:32.425	MRM for IFHO cell (PCI: 297)
2	LTE PDCCH-PHICH Indication Report	0xB16B	21:53:32.508	High UL BLER (high PHICH NACK rate)
3	LTE ML1 Idle Serving Cell Meas Response	0xB193	21:53:32.516	Poor serving cell RSRP: -128dBm
4	RLF Event	0x1FFB	21:53:32.519	RLF
5	LTE PDSCH Stat Indication	0xB173	21:53:32.519	High DL BLER (high CRC failure rate)
6	IMS RTP SN and Payload	0x1568	21:53:32.540	Last DL RTP packet before RLF (SN = 5153)
7	RRC Reestablishment Process		21:53:32.844 to 21:53:32.876	RRC Reestablishment reject
8	New RRC Connection Establishment process		21:53:32.955 to 21:53:33.214	IFHO cell selected (PCI = 297)
9	IMS RTP SN and Payload	0x1568	21:53:33.223	Next DL RTP packet after IFHO failure (SN = 5187)

Notes


Appendix
Appendix
Section 9-57
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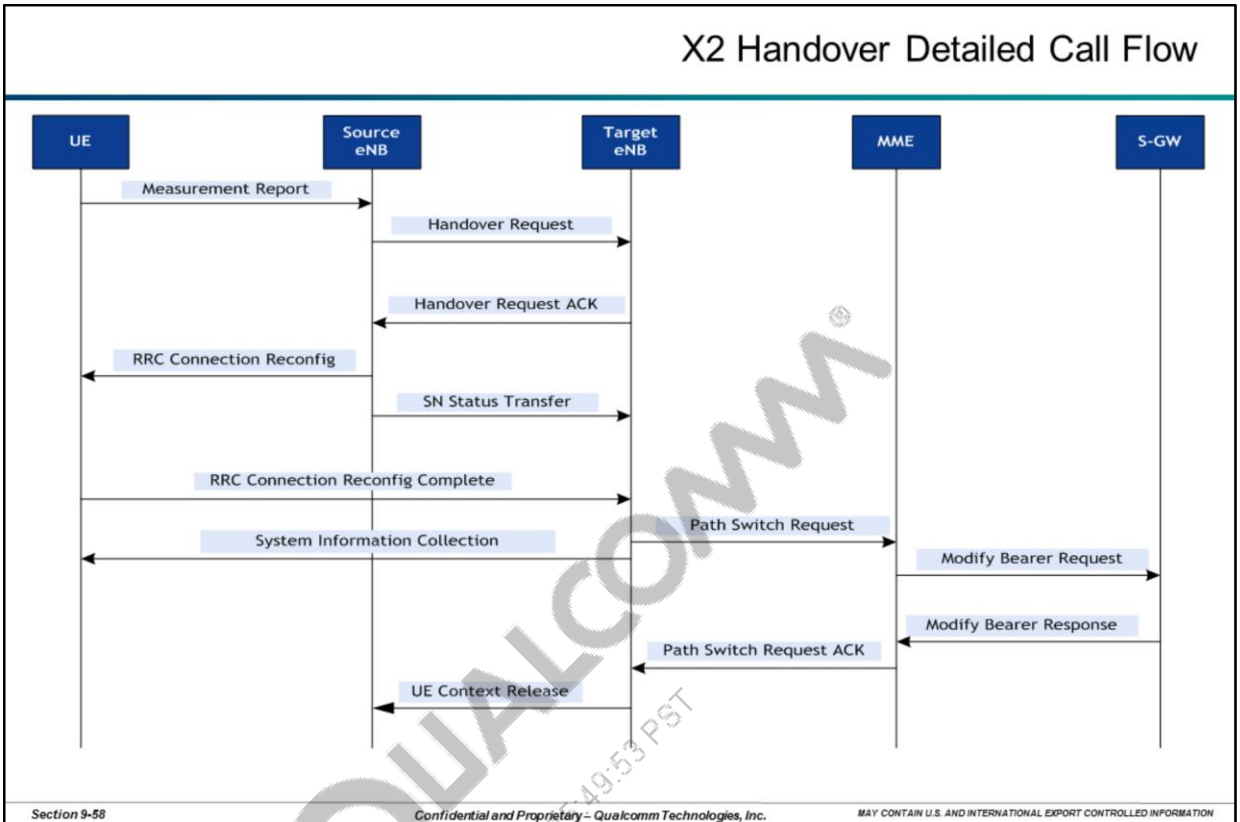
Notes


X2 Handover Detailed Call Flow
UE
Source eNB
Target eNB
MME
S-GW
Measurement Report
Handover Request
Handover Request ACK
RRC Connection Reconfig
SN Status Transfer
RRC Connection Reconfig Complete
Path Switch Request
System Information Collection
Modify Bearer Request
Modify Bearer Response
Path Switch Request ACK
UE Context Release
Section 9-58
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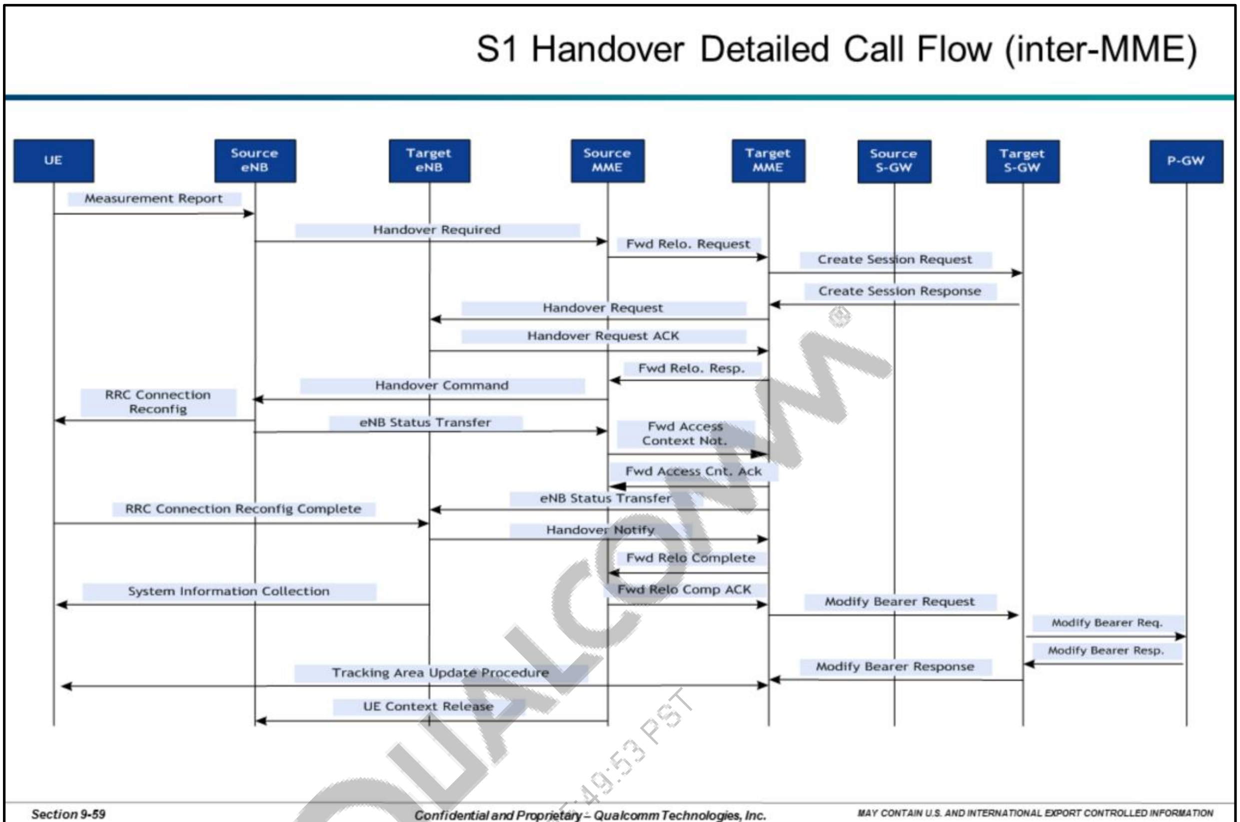
Notes


S1 Handover Detailed Call Flow (inter-MME)
UE
Source eNB
Target eNB
Source MME
Target MME
Source S-GW
Target S-GW
P-GW
Measurement Report
Handover Required
Fwd Relo. Request
Create Session Request
Create Session Response
Handover Request
Handover Request ACK
Fwd Relo. Resp.
Handover Command
RRC Connection Reconfig
eNB Status Transfer
Fwd Access Context Not.
Fwd Access Cnt. Ack
eNB Status Transfer
RRC Connection Reconfig Complete
Handover Notify
Fwd Relo Complete
Fwd Relo Comp ACK
System Information Collection
Modify Bearer Request
Modify Bearer Req.
Modify Bearer Resp.
Modify Bearer Response
Tracking Area Update Procedure
UE Context Release
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Notes

Comments/Notes


10
VoLTE Call Drop Analysis
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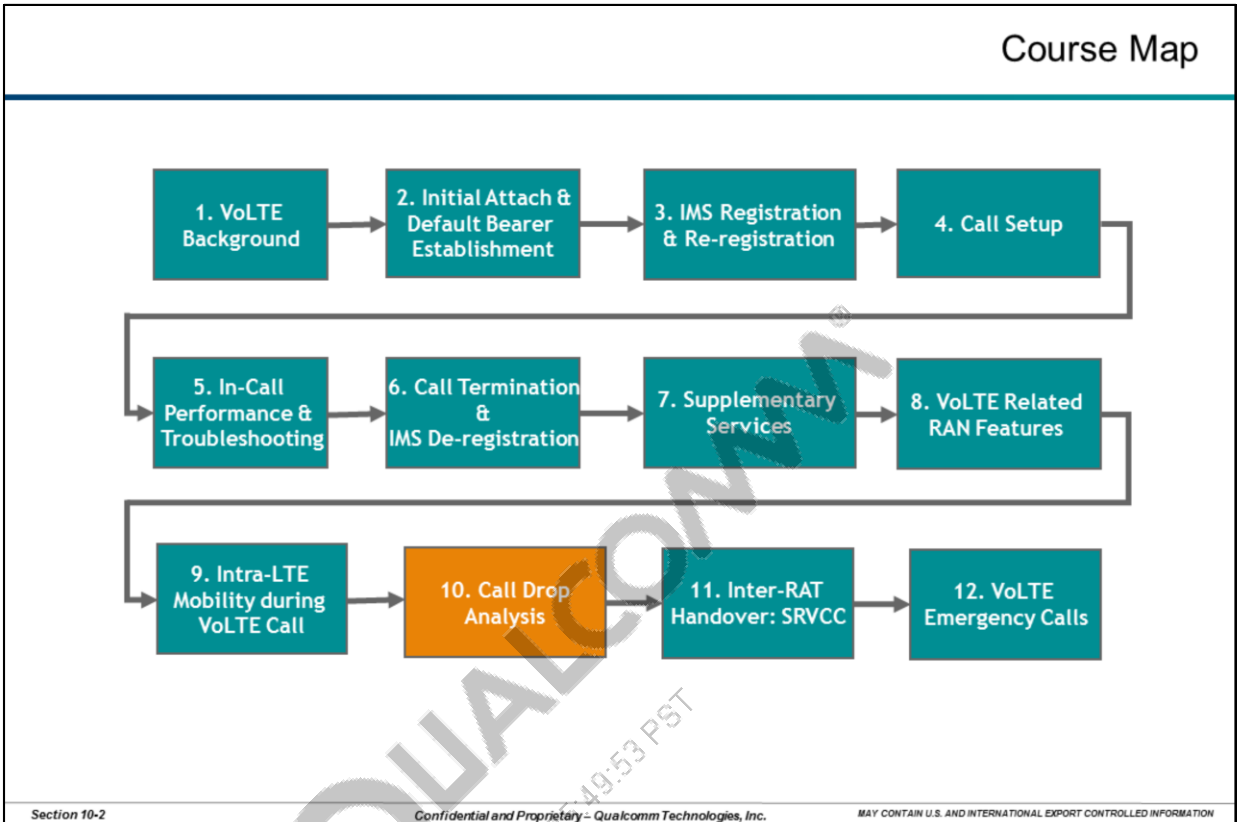
Course Map
1. VoLTE Background
2. Initial Attach & Default Bearer Establishment
3. IMS Registration & Re-registration
4. Call Setup
5. In-Call Performance & Troubleshooting
6. Call Termination & IMS De-registration
7. Supplementary Services
8. VoLTE Related RAN Features
9. Intra-LTE Mobility during VoLTE Call
10. Call Drop Analysis
11. Inter-RAT Handover: SRVCC
12. VoLTE Emergency Calls
Section 10-2
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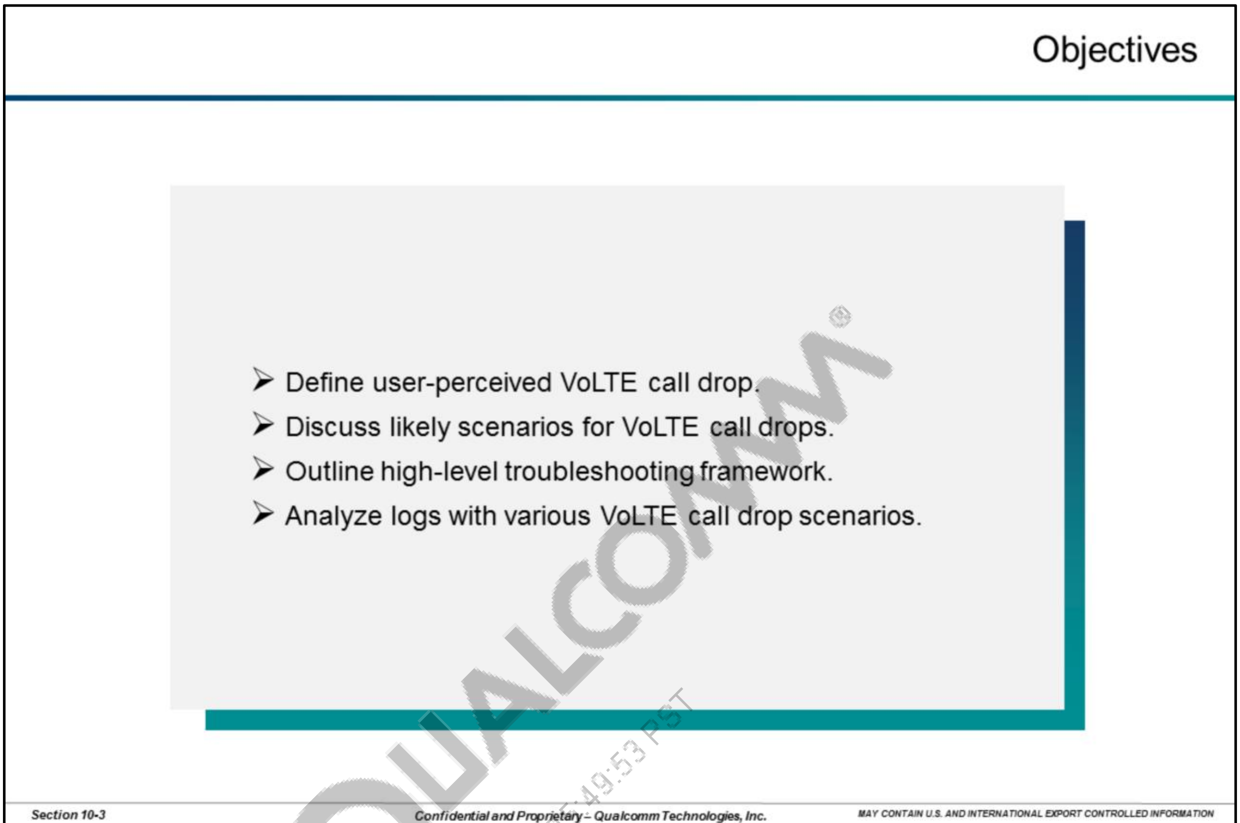
Notes


Objectives
➢ Define user-perceived VoLTE call drop.
➢ Discuss likely scenarios for VoLTE call drops.
➢ Outline high-level troubleshooting framework.
➢ Analyze logs with various VoLTE call drop scenarios.
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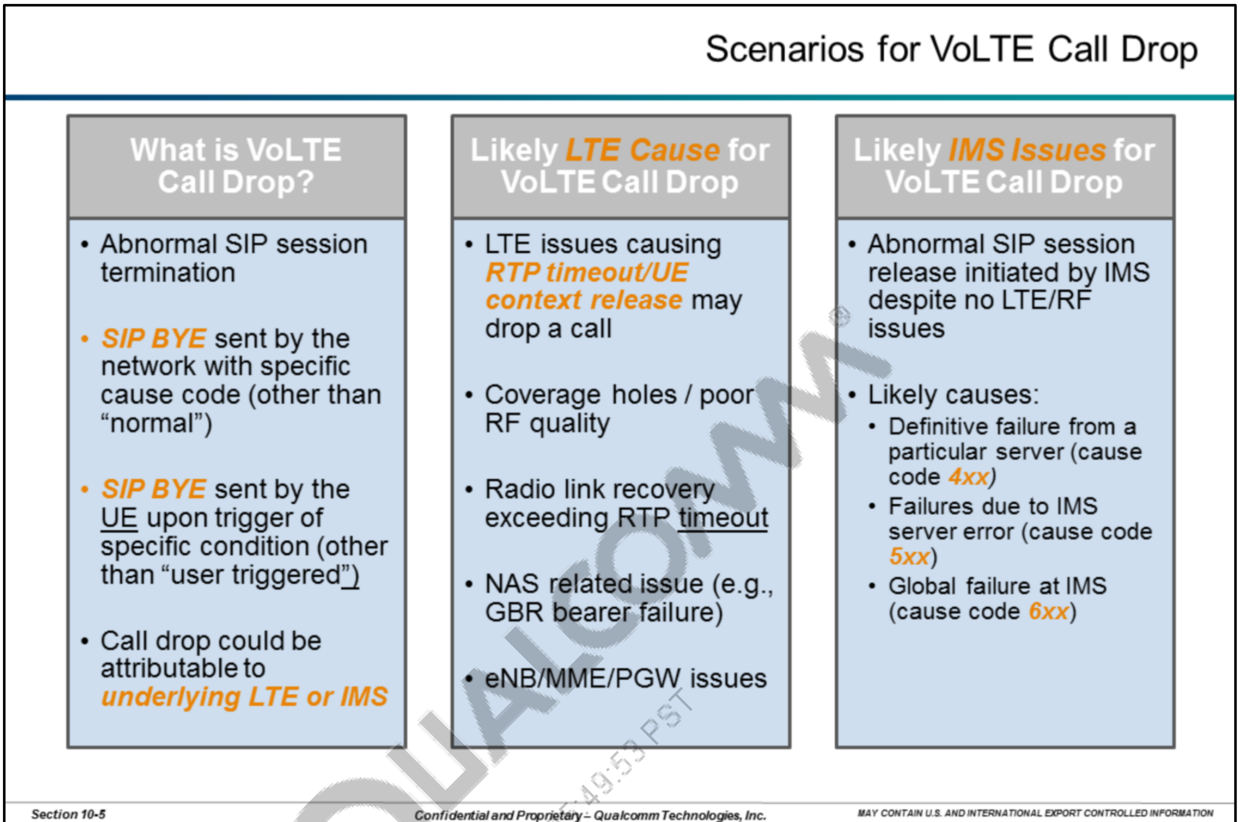
Notes

Topic Map

- **VoLTE Call Drop Scenarios**
- VoLTE Call Drop Debugging Framework
- Case Studies

Notes



Necessary Condition for VoLTE Call Drop

Unlike the LTE BE scenario, it is essential to know that while a VoLTE call is in progress, occurrence of RLF or temporary transition of the UE to RRC-idle state does NOT necessarily mean VoLTE call drop. As long as the RTP SIP session is in progress, technically it is not a user-perceived call drop scenario. If however, any ongoing LTE issue results in a scenario where RTP timeout happens, this will lead to SIP session termination and can be termed a call drop. Such a call drop could be attributed to LTE network related issues.

In addition to the LTE related reasons, despite excellent RF condition and successful operation of the LTE stack, some issues associated with IMS may result in session termination and, hence, call drop. Such IMS termination is usually associated with cause codes as outlined in RFC3261 (https://www.ietf.org/rfc/rfc3261.txt), a few examples from which are given below.

Cause Code (404: Not Found)

The server has definitive information that the user does not exist at the domain specified in the Request-URI. This status is also returned if the domain in the Request-URI does not match any of the domains handled by the recipient of the request.

Cause Code (480: Temporarily Unavailable)

The callee's end system was contacted successfully but the callee is currently unavailable (for example, is not logged in, logged in but in a state that precludes communication with the callee, or has activated the "do not disturb" feature). The response MAY indicate a better time to call in the Retry-After header field. The user could also be available elsewhere (unbeknownst to this server). The reason phrase SHOULD indicate a more precise cause as to why the callee is unavailable. This value SHOULD be settable by the UA. Status 486 (Busy Here) MAY be used to more precisely indicate a particular reason for the call failure.

Cause Code (503: Service Unavailable)

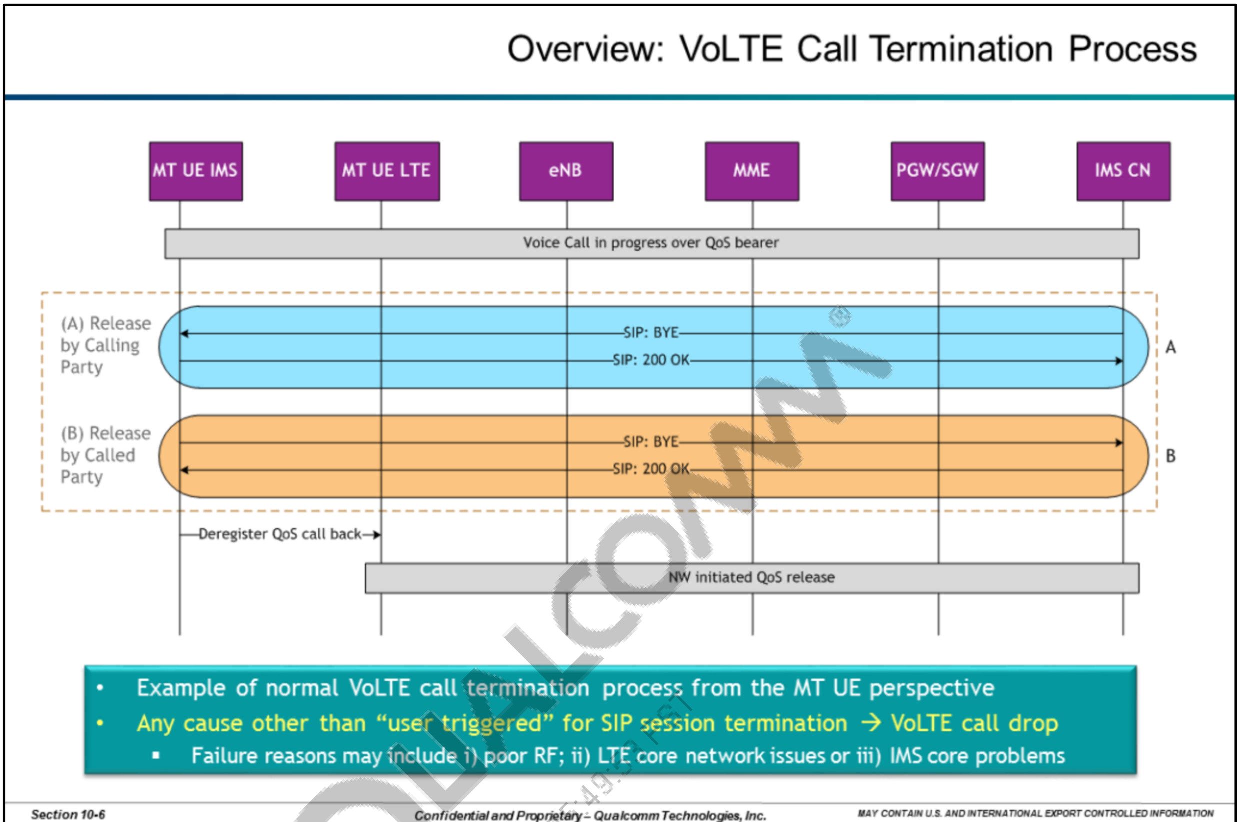
The server is temporarily unable to process the request due to a temporary overloading or maintenance of the server. The server MAY indicate when the client should retry the request in a Retry-After header field. If no Retry-After is given, the client MUST act as if it had received a 500 (Server Internal Error) response.

A client (proxy or UAC) receiving a 503 (Service Unavailable) SHOULD attempt to forward the request to an alternate server. It SHOULD NOT forward any other requests to that server for the duration specified in the Retry-After header field, if present.

Servers MAY refuse the connection or drop the request instead of responding with 503 (Service Unavailable).

Cause Code (603: Decline)

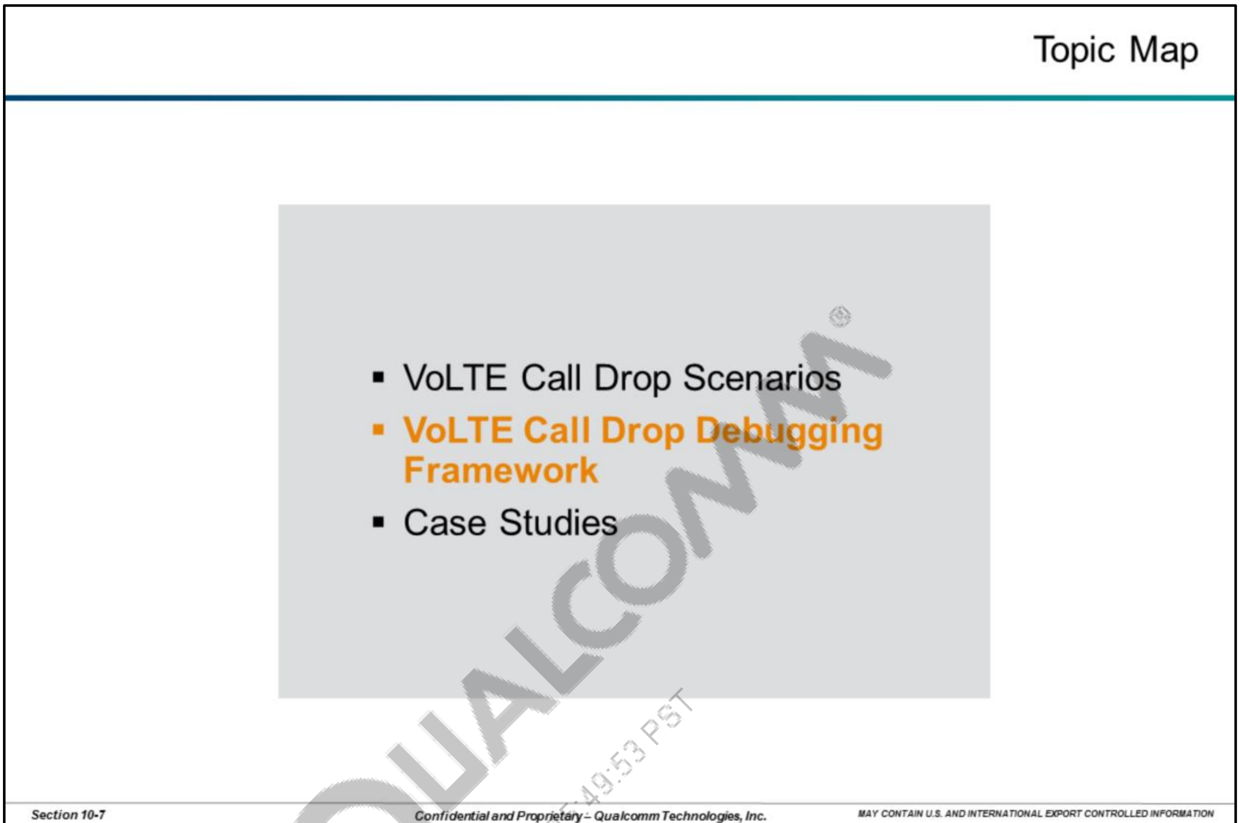
The callee's machine was successfully contacted but the user explicitly does not wish to or cannot participate. The response MAY indicate a better time to call in the Retry-After header field. This status response is returned only if the client knows that no other end point will answer the request.



VoLTE Call Termination – Normal Release

VoLTE call termination by remote or local user follows these steps:

1. The UE is involved in a VoLTE session. The media stream has been established and is carrying VoLTE frames.
2. The ongoing media session can be terminated by the remote user (Option A) or by the local user (Option B).
    - In option A, the remote user ends the session, hence the UE receives a SIP:BYE from the IMS CN and, in response, sends a SIP:200 OK.
    - In option B, the local user's IMS stack sends a SIP:BYE to the IMS CN, which responds with a SIP:200 OK.
    - In either option, the UE IMS stack deletes the QoS it had originally installed during call set up.
3. At the end of the call, the IMS CN triggers network initiated deactivation of the Dedicated Radio Bearer to carry VoLTE voice traffic assigned to the source and target UEs.
4. Subsequently, the network may transition the UE to RRC Idle (using an inactivity timer) and release bearers for IMS signaling until the UE is paged and requests to set up RRC Connection again.


Topic Map
▪ VoLTE Call Drop Scenarios
▪ VoLTE Call Drop Debugging Framework
▪ Case Studies
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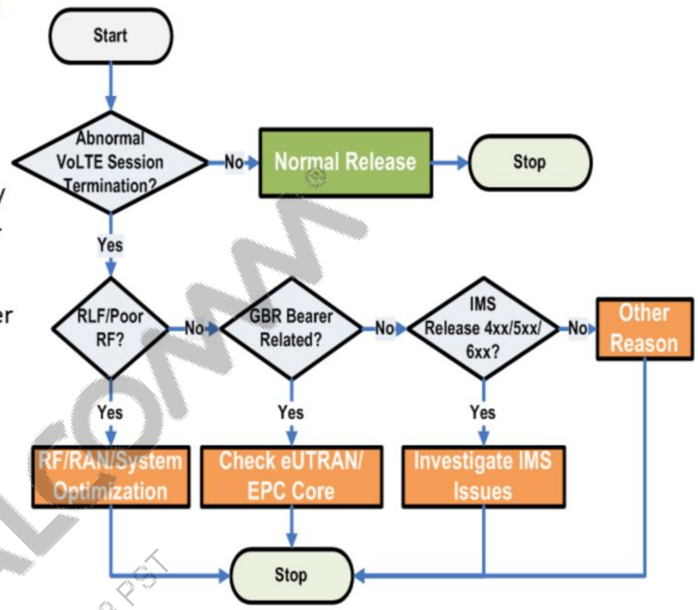
Notes

VoLTE Call Drop: High Level Debugging Framework

- **Three main reasons for VoLTE drop**
  - Poor RF condition
  - LTE core network issues
  - IMS problem
- **Poor RF condition**
  - Can be characterized by low RSRP / RSRQ / RS-SINR / high UE Tx power
- **LTE Core Network Issue**
  - Other reasons including GBR bearer negotiation issues or abrupt EPS bearer termination
- **IMS Problem**
  - IMS session termination is associated with cause code
- **Miscellaneous Issue**
  - Any reason other than the above



VoLTE Call Drop due to Poor RF

Poor RF will very commonly be associated with radio link failure (RLF), which will impact call quality and may ultimately result in session termination due to prolonged RTP inactivity.

In certain cases, one way communication may continue due to poor UL or DL coverage/quality without causing any RLF, which may still result in call drop due to RTP timeout timer expiry.

VoLTE Call Drop due to IMS Issues

In many scenarios, IMS issues may result in call drop (abnormal session termination) despite good RF condition and smooth LTE operation. Such terminations are generally associated with relevant cause codes as outlined in RFC3261 (such as 4xx, 5xx, 6xx), which are good indicators that the problems might have been caused by some issues relating to the IMS network.

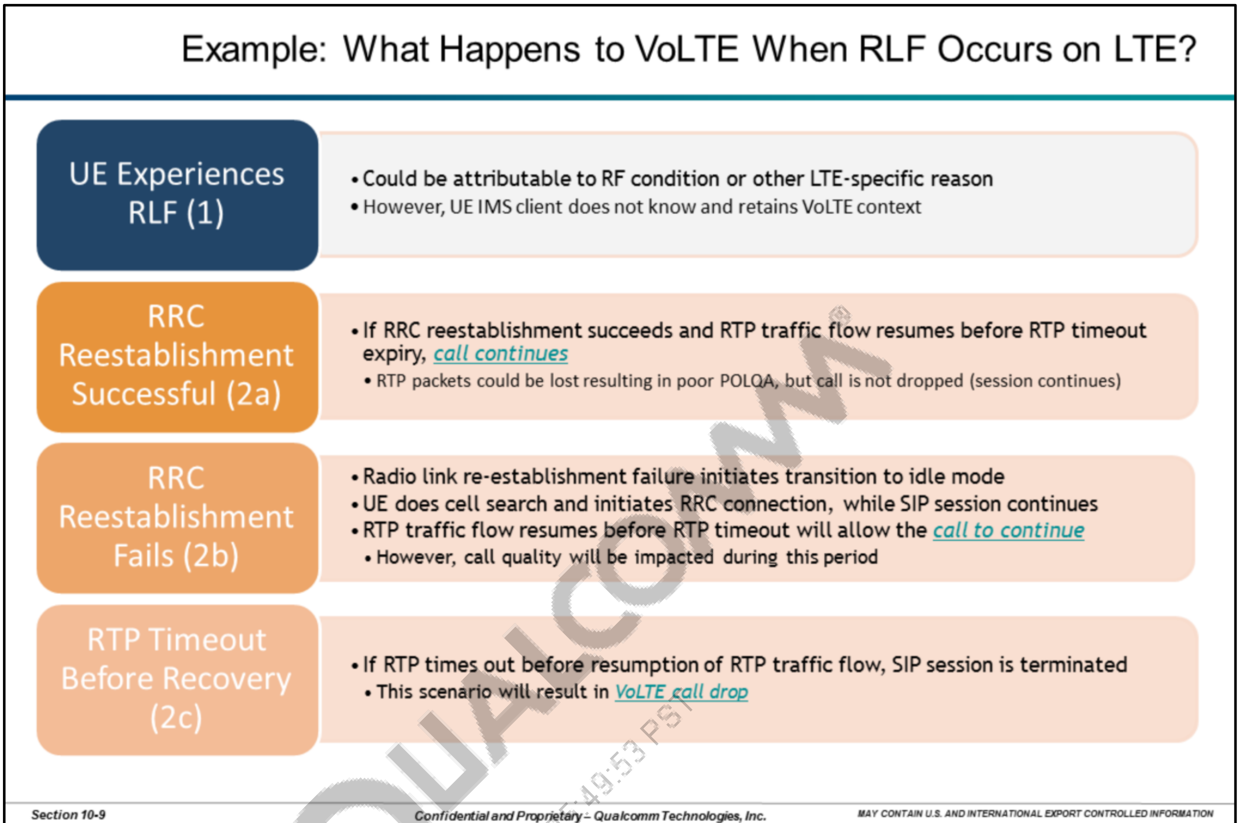
VoLTE Call Drop due to LTE Core Network

In certain scenarios, it may happen that despite good RF condition, there might have been some issues associated with GBR bearer setup or their negotiations, which may then result in UM bearer release. As bearer setup is the responsibility of the LTE core network and if RF issues can be excluded, such issues may then be attributed to LTE EPC core network.

VoLTE Call Drop due to Other Reasons

In some less common scenarios, VoLTE feature related issues like RoHC context mismatch may result in VoLTE call drop.

Note that the above debugging framework is merely a high-level outline of how to investigate call drop analyses. Thorough analyses including both UE and network logs should enable an optimization engineers to accurately identify the root causes of the problems.



VoLTE Call Termination – Loss of Radio Link

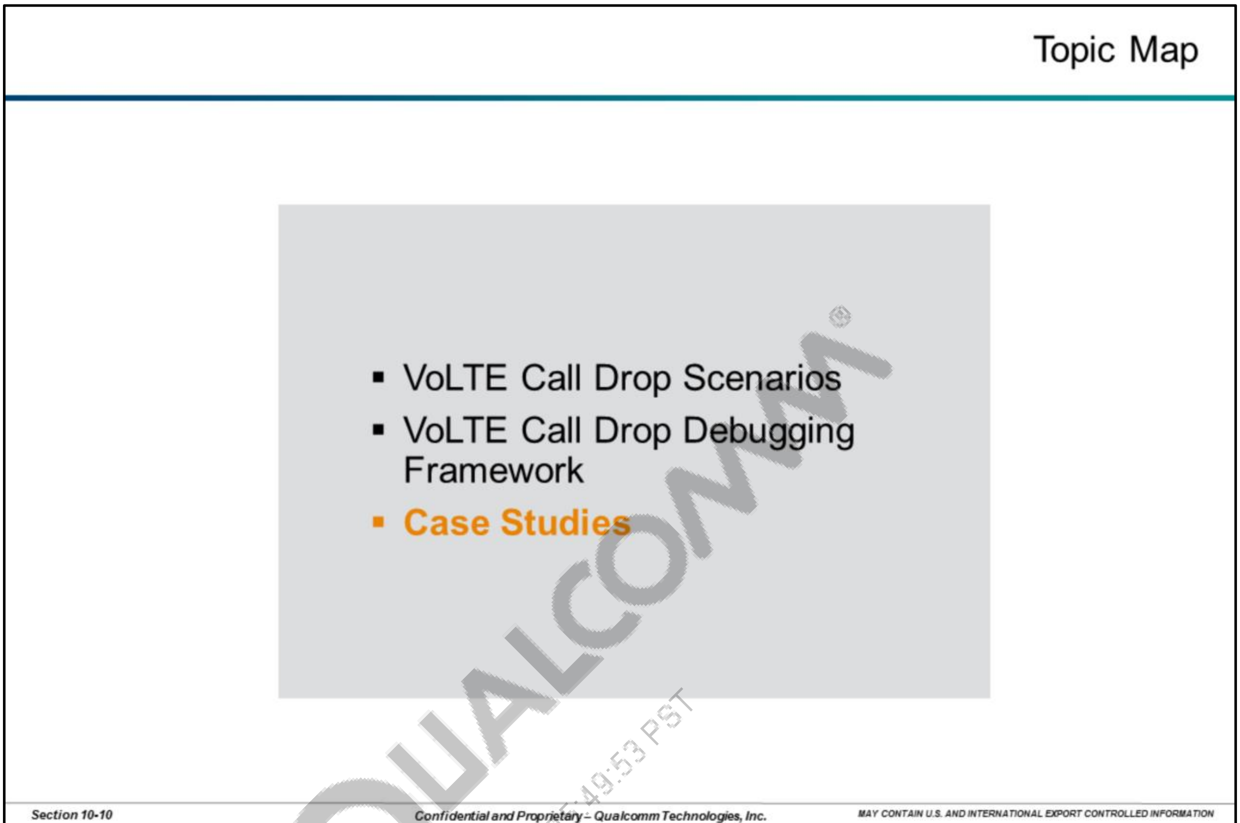
If an RLF is encountered, the UE attempts RLF recovery as it would for a PS call. The IMS client in the UE does not react to an RLF. The UE performs a radio link recovery procedure.

If this fails, the call may be released by either party (due to lack of activity). Alternatively, the IMS core or client may detect the lack of RTP flow and release the call or EPC may detect the loss of bearer.

If a Guaranteed Bit Rate (GBR) bearer used for VoLTE is lost, then the network must terminate the associated session according to the procedures in TS 24.229 section 5.2.8 (P-CSCF must be informed about loss of bearer by the PCRF). Further, the UE must have internal logic to react to the detection of loss of bearer/radio connection to handle its internal state.

The call will be released if the UE receives a SIP:BYE or SIP:CANCEL from the network. Note the SIP:BYE message is generated if the other user terminates the call. SIP:CANCEL message is generated by the IMS core network to terminate the call.

If the UE, having lost radio connectivity, then regains radio connectivity, the UE must perform a new initial registration to IMS, in case the IMS registration expired during the absence of radio connectivity.


Topic Map
▪ VoLTE Call Drop Scenarios
▪ VoLTE Call Drop Debugging Framework
▪ Case Studies
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Notes

Summary: Debugging Scenarios

- **Case Study-1 (RF Problem)**
  - Poor RF condition caused DL RTP packet loss with subsequent session termination
- **Case Study-2 (IMS Issue)**
  - Despite good RF and smooth LTE operation, IMS abruptly terminated the session
    - Cause code 503 points to IMS issues (service based local policy function abortion)
- **Case Study-3 (IMS Issue)**
  - IMS core network issues resulted in no DL RTP packet delivery
  - DL RTP inactivity resulted in timer expiry followed by session termination (drop)
- **Case Study-4 (EPC Core Issue)**
  - GBR bearer modification request from the UE was rejected by the LTE core
  - This prompted UE to send SIP BYE for abnormal session termination
  - GBR bearer modification issues point to EPC core related issues
- **Case Study-5 (Other Issue)**
  - RoHC context mismatch resulted in abnormal session termination

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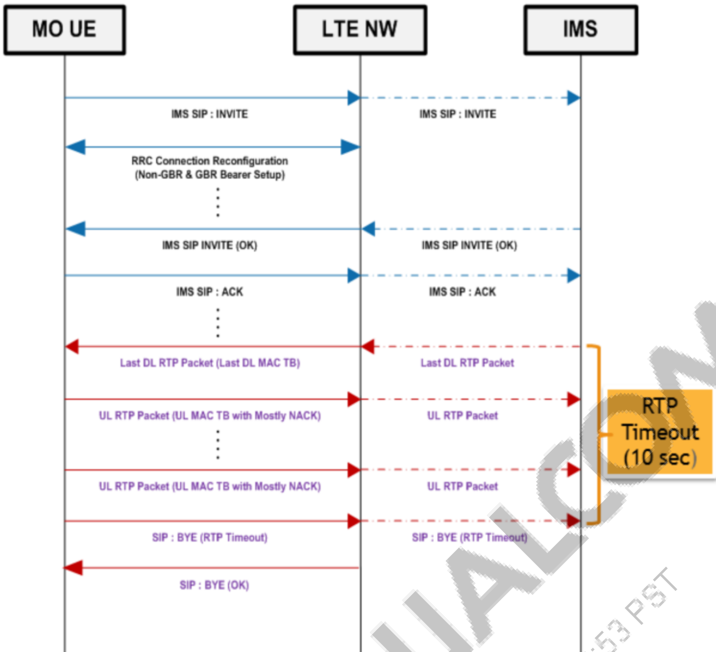
Notes

VoLTE Call Drop Case Studies

- **Case Study-1 (VoLTE Call Drop due to Poor RF)**
- Case Study-2 (Abnormal VoLTE Session Termination by Core)
- Case Study-3 (Core Issues Causing DL RTP Inactivity)
- Case Study-4 (GBR Bearer Modification Reject)
- Case Study-5 (RoHC Context Mismatch)

Notes

Summary: VoLTE Call Drop Due to Poor RF



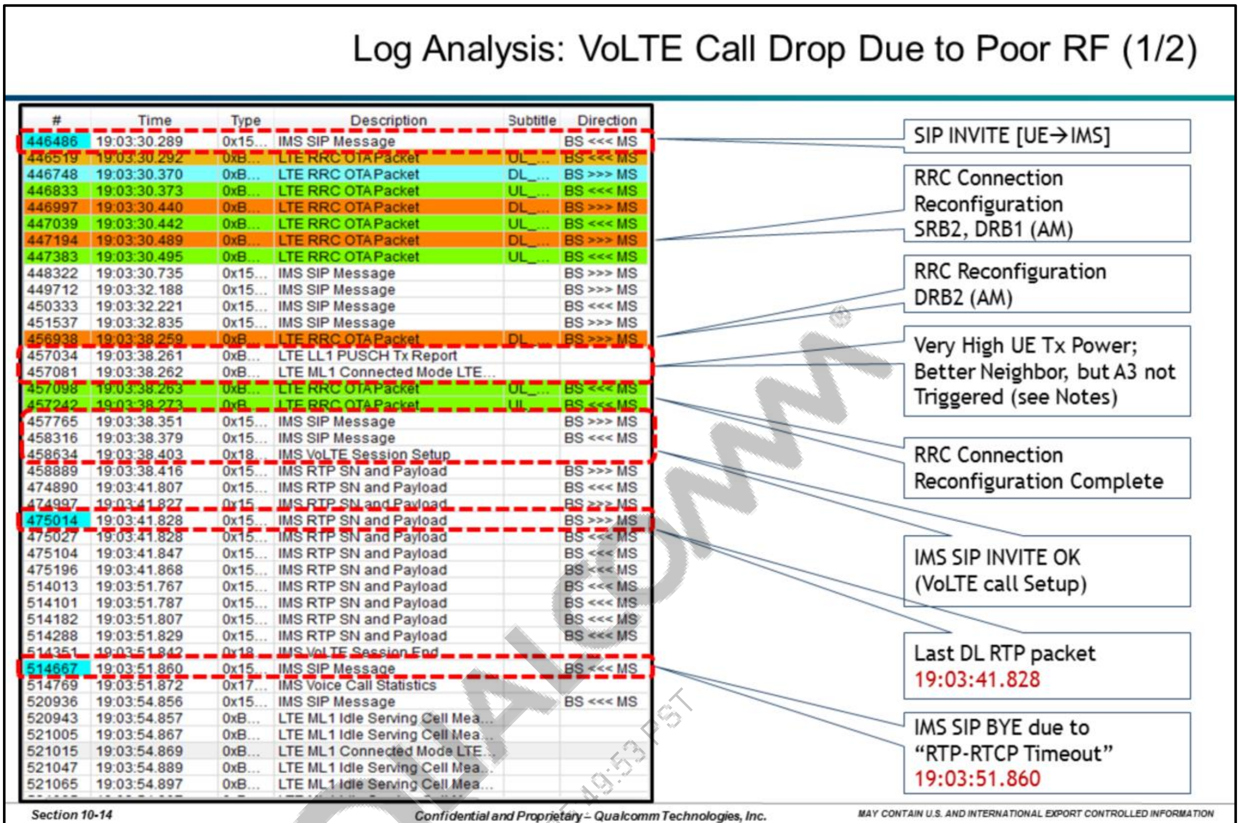
Observation

- UE RF condition was very poor (RSRP (-103 dBm); RSRQ (-20 dB); RS SINR (-10 dB)
- It successfully set up SRB1, SRB2, non-GBR1 (AM), & GBR2 (UM) bearers
- After successful call set up, bi-directional RTP packet exchange happened
- However, very poor RF led to non-receipt of DL RTP packets
- UE continued to send UL RTP packets, but UL MAC TBs were mostly NACKed
- UE occasionally sent measurement reports, but trigger was late and neighbors were also very weak (no handover happened)
- After RTP timeout timer expiry due to non-receipt of DL RTP packets, UE sent SIP BYE to terminate the call

Conclusion

- Poor RF quality led to RTP timeout and call drop
- Recommend RF optimization as well as review of intra/inter-carrier HO triggers (were too late)

Notes



Non-GBR Bearers: DRB1 → EPS ID 5; DRB ID 3 [AM]

GBR Bearer: DRB5 → EPS ID 6; DRB ID 4 [UM]

Very High UE Tx Power (PCI 349): Reached up to +23 dBm

Serving Cell Quality (PCI 349): RSRP: -103 dBm; RSRQ: -19 dB

Neighbor Cell Quality (PCI 265): RSRP: -101 dBm; RSRQ: -16 dB

A3 Event Setting: A3 Offset: 5 dB; Hysteresis: 2 dB; Measurement Quantity: RSRP

Observation

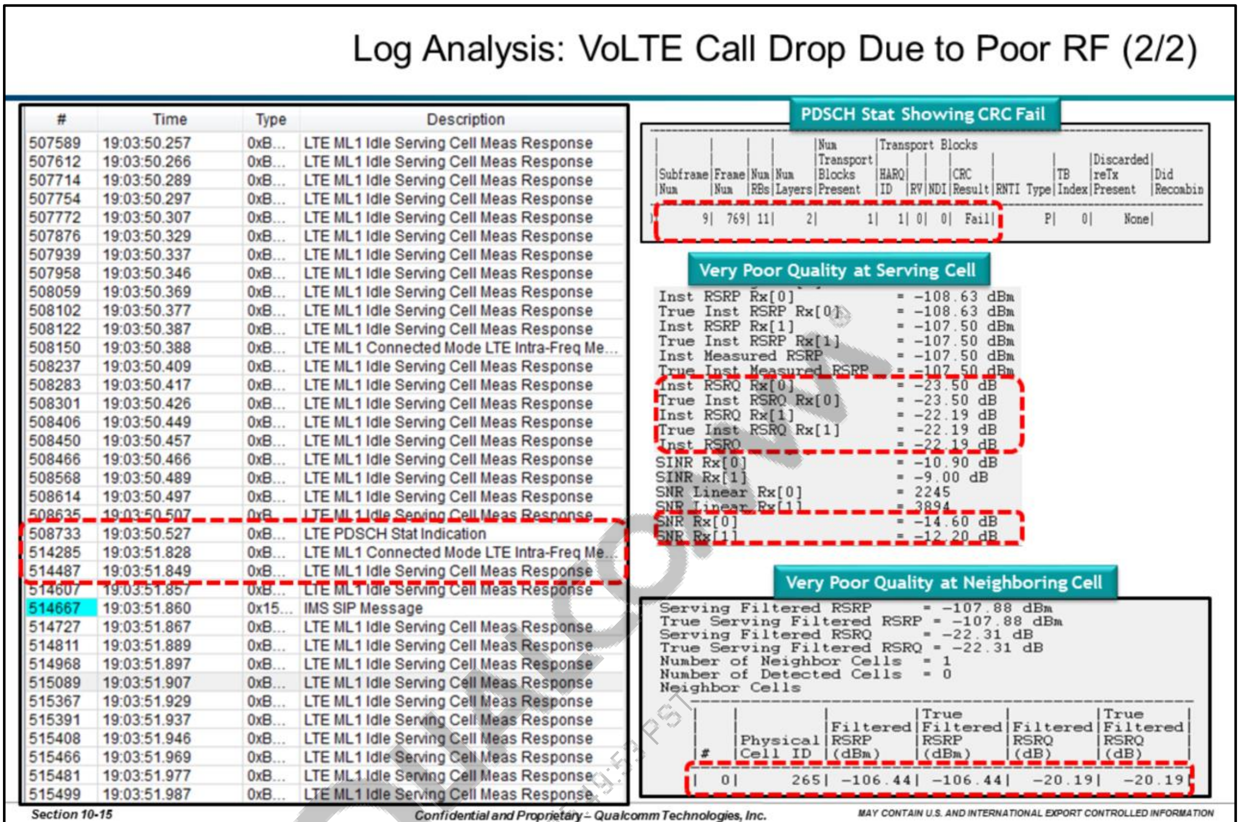
Event A3 was not triggered due to relatively large A3-offset setting. Also, better RSRQ could not help, as measurement quantity was set to RSRP. As a result, event A3 did not trigger and measurement report was not sent (despite relatively better quality at the target cell).

Recommendation

a) Perform RF optimization → -19 dB RSRQ and -10 dB SINR at RSRP of -108 dBm points to significant interference.

b) Review A3 parameter settings, especially A3 offset, to facilitate early measurement reporting.

c) Consider using both RSRP and RSRQ as the trigger quantities.



Observation

The RF quality at both serving and neighboring cells was very poor:

- RSRP ~ -110 dBm
- RSRQ ~ -20 dB
- RS SINR ~-12 dB

Very poor RF quality resulted in high DL BLER and CRC failure.

Analysis – VoLTE Call Drop Due to Poor RF

Log Analysis Procedure:

Open File: 10-01-Call_Drop_Poor_RF

Notes

VoLTE Call Drop Due to Poor RF: Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	IMS SIP Message	0x156E	19:03:30.289	IMS SIP INVITE (UE→IMS)
2	LTE RRC OTA Packet	0xB0C0	19:03:30.489	RRC Connection Reconfig (AM Bearer Setup)
3	LTE RRC OTA Packet	0xB0C0	19:03:38.259	RRC Connection Reconfig (UM Bearer Setup)
4	LTE LL1 PUSCH Tx Report	0xB139	19:03:38.261	PUSCH Tx Power (~23 dBm)
5	LTE ML1 Connected Mode Intra-Freq Measurement	0xB179	19:03:38.262	Neighbor Cell PCI265 (RSRP: -101 dBm; RSRQ: -16 dB)
6	IMS SIP Message	0x156E	19:03:38.351	IMS SIP INVITE OK [IMS→UE]
7	IMS RTP SN and Payload	0x1568	19:03:41.828	Last DL RTP Packet [IMS→UE]
8	LTE ML1 Idle Serving Cell Meas	0xB193	19:03:51.857	Serving Cell RSRP, RSRQ and RS SINR
9	LTE ML1 Connected Mode LTE Intra-Freq Meas	0xB179	19:03:51.828	Neighboring Cell RSRP, RSRQ, RS SINR
10	LTE PDSCH Stat Indication	0xB173	19:03:50.527	Verify CRC Results
11	IMS SIP Message	0x156E	19:03:51.860	IMS SIP BYE [UE→IMS] due to “RTP-RTCP Timeout”
12	ISM VoLTE Session End	0x156E	19:03:51.842	End Cause: “RTP Inactivity”

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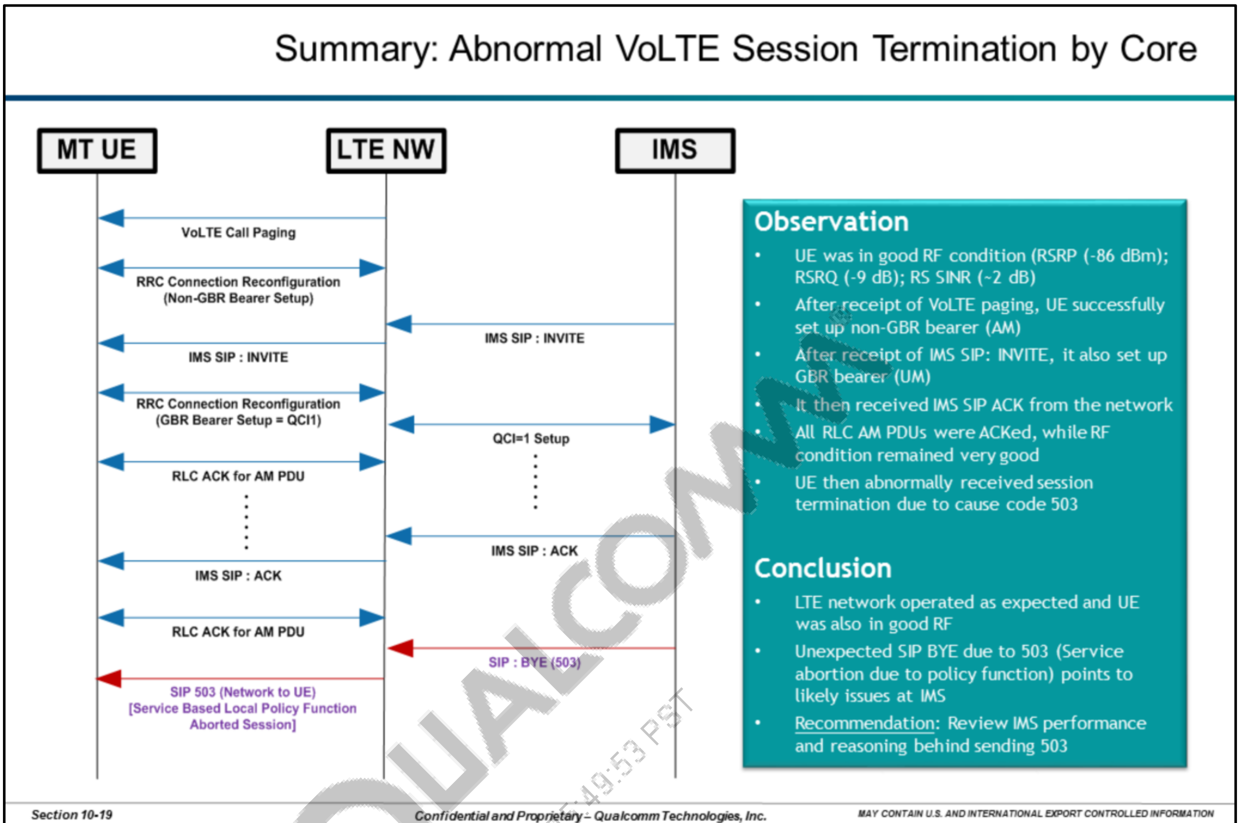
Notes

VoLTE Call Drop Case Studies

- Case Study-1 (VoLTE Call Drop due to Poor RF)
- **Case Study-2 (Abnormal VoLTE Session Termination by Core)**
- Case Study-3 (Core Issues Causing DL RTP Inactivity)
- Case Study-4 (GBR Bearer Modification Reject)
- Case Study-5 (RoHC Context Mismatch)

Notes

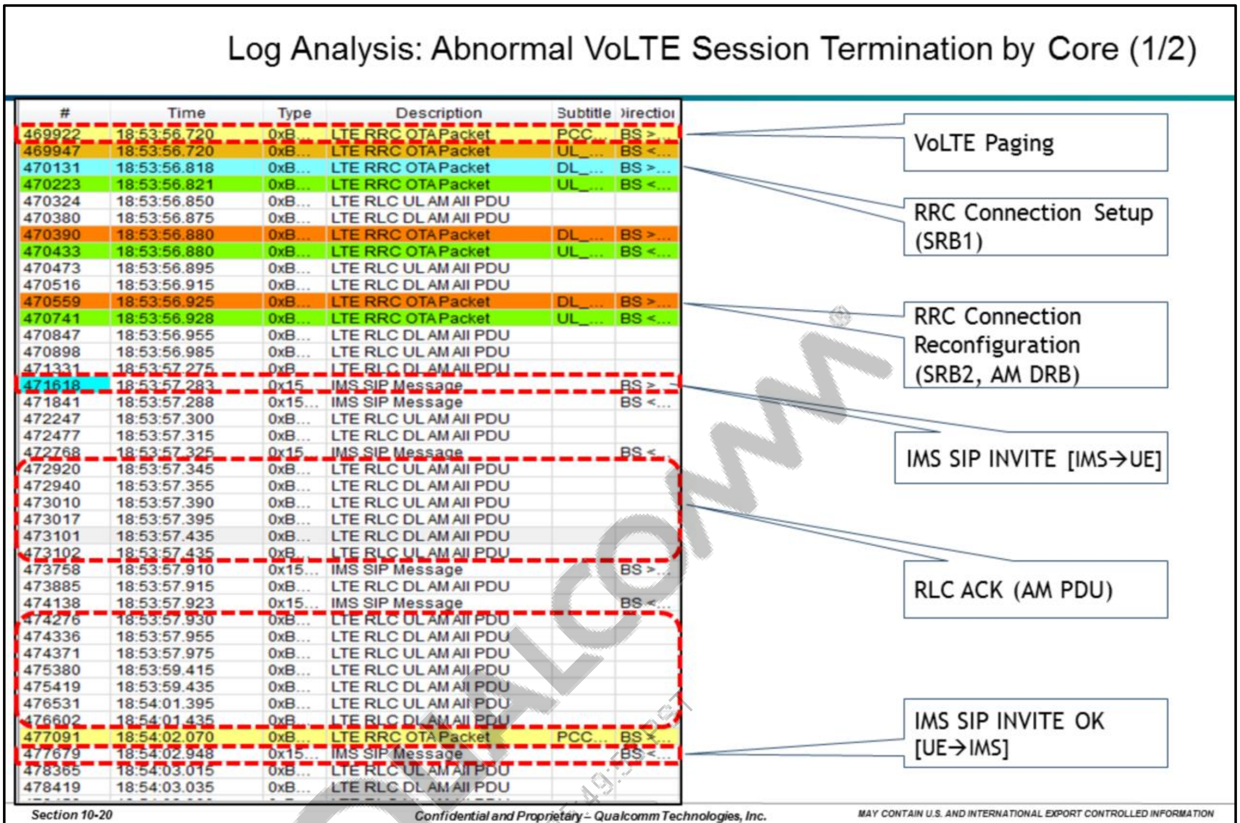


503 Service Unavailable (as per RFC3261)

The server is temporarily unable to process the request due to a temporary overloading or maintenance of the server. The server MAY indicate when the client should retry the request in a Retry-After header field. If no Retry-After is given, the client MUST act as if it had received a 500 (Server Internal Error) response.

A client (proxy or UAC) receiving a 503 (Service Unavailable) SHOULD attempt to forward the request to an alternate server. It SHOULD NOT forward any other requests to that server for the duration specified in the Retry-After header field, if present.

Servers MAY refuse the connection or drop the request instead of responding with 503 (Service Unavailable).



#	Time	Type	Description	Subtitle	Direction
469922	18:53:56.720	0xB...	LTE RRC OTA Packet	PCC...	BS >...
469947	18:53:56.720	0xB...	LTE RRC OTA Packet	UL_...	BS <...
470131	18:53:56.818	0xB...	LTE RRC OTA Packet	DL_...	BS >...
470223	18:53:56.821	0xB...	LTE RRC OTA Packet	UL_...	BS <...
470324	18:53:56.850	0xB...	LTE RLC UL AM All PDU		
470380	18:53:56.875	0xB...	LTE RLC DL AM All PDU		
470390	18:53:56.880	0xB...	LTE RRC OTA Packet	DL_...	BS >...
470433	18:53:56.880	0xB...	LTE RRC OTA Packet	UL_...	BS <...
470473	18:53:56.895	0xB...	LTE RLC UL AM All PDU		
470516	18:53:56.915	0xB...	LTE RLC DL AM All PDU		
470559	18:53:56.925	0xB...	LTE RRC OTA Packet	DL_...	BS >...
470741	18:53:56.928	0xB...	LTE RRC OTA Packet	UL_...	BS <...
470847	18:53:56.955	0xB...	LTE RLC DL AM All PDU		
470898	18:53:56.985	0xB...	LTE RLC UL AM All PDU		
471331	18:53:57.275	0xB...	LTE RLC DL AM All PDU		
471618	18:53:57.283	0x15...	IMS SIP Message		BS >...
471841	18:53:57.288	0x15...	IMS SIP Message		BS <...
472247	18:53:57.300	0xB...	LTE RLC UL AM All PDU		
472477	18:53:57.315	0xB...	LTE RLC DL AM All PDU		
472768	18:53:57.325	0x15...	IMS SIP Message		BS <...
472920	18:53:57.345	0xB...	LTE RLC UL AM All PDU		
472940	18:53:57.355	0xB...	LTE RLC DL AM All PDU		
473010	18:53:57.390	0xB...	LTE RLC UL AM All PDU		
473017	18:53:57.395	0xB...	LTE RLC DL AM All PDU		
473101	18:53:57.435	0xB...	LTE RLC DL AM All PDU		
473102	18:53:57.435	0xB...	LTE RLC UL AM All PDU		
473758	18:53:57.910	0x15...	IMS SIP Message		BS >...
473885	18:53:57.915	0xB...	LTE RLC DL AM All PDU		
474138	18:53:57.923	0x15...	IMS SIP Message		BS <...
474276	18:53:57.930	0xB...	LTE RLC UL AM All PDU		
474336	18:53:57.955	0xB...	LTE RLC DL AM All PDU		
474371	18:53:57.975	0xB...	LTE RLC UL AM All PDU		
475380	18:53:59.415	0xB...	LTE RLC UL AM All PDU		
475419	18:53:59.435	0xB...	LTE RLC DL AM All PDU		
476531	18:54:01.395	0xB...	LTE RLC UL AM All PDU		
476602	18:54:01.435	0xB...	LTE RLC DL AM All PDU		
477091	18:54:02.070	0xB...	LTE RRC OTA Packet	PCC...	BS >...
477679	18:54:02.948	0x15...	IMS SIP Message		BS <...
478365	18:54:03.015	0xB...	LTE RLC UL AM All PDU		
478419	18:54:03.035	0xB...	LTE RLC DL AM All PDU		

Non-GBR Bearers

DRB1 → EPS ID 5; DRB ID 3 [AM]

DRB2 → EPS ID 6; DRB ID 4 [AM]

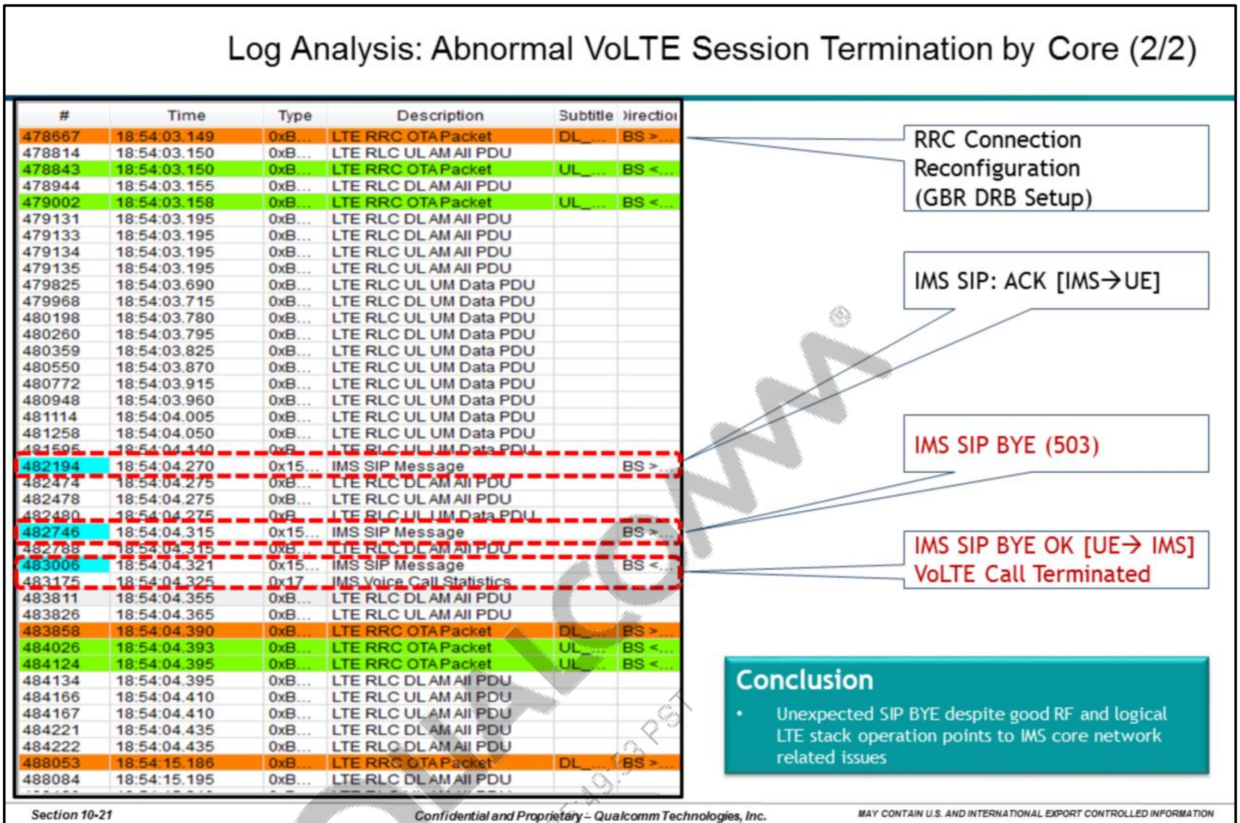
RLC RB Config Index

SRB1 → 33

SRB2 → 34

DRB1 → 3

DRB2 → 4



A few likely reasons for unexpected BYE could be

a) IMS configuration issue

b) eNB/MME issues resulting in illegal configuration prompting IMS to send across 503

Non-GBR Bearers

DRB1 → EPS ID 5; DRB ID 3 [AM]

DRB2 → EPS ID 6; DRB ID 4 [AM]

GBR Bearer

DRB3 → EPS ID 7; DRB ID 5 [UM]

RLC RB Config Index

SRB1 → 33

SRB2 → 34

DRB1 → 3

DRB2 → 4

DRB3 → 5

Analysis – Abnormal VoLTE Session Termination by Core

Log Analysis Procedure:

Open File: 10-02-Abnormal_Termination_by_Core

Notes

Abnormal VoLTE Session Termination by Core: Log Walk-Through

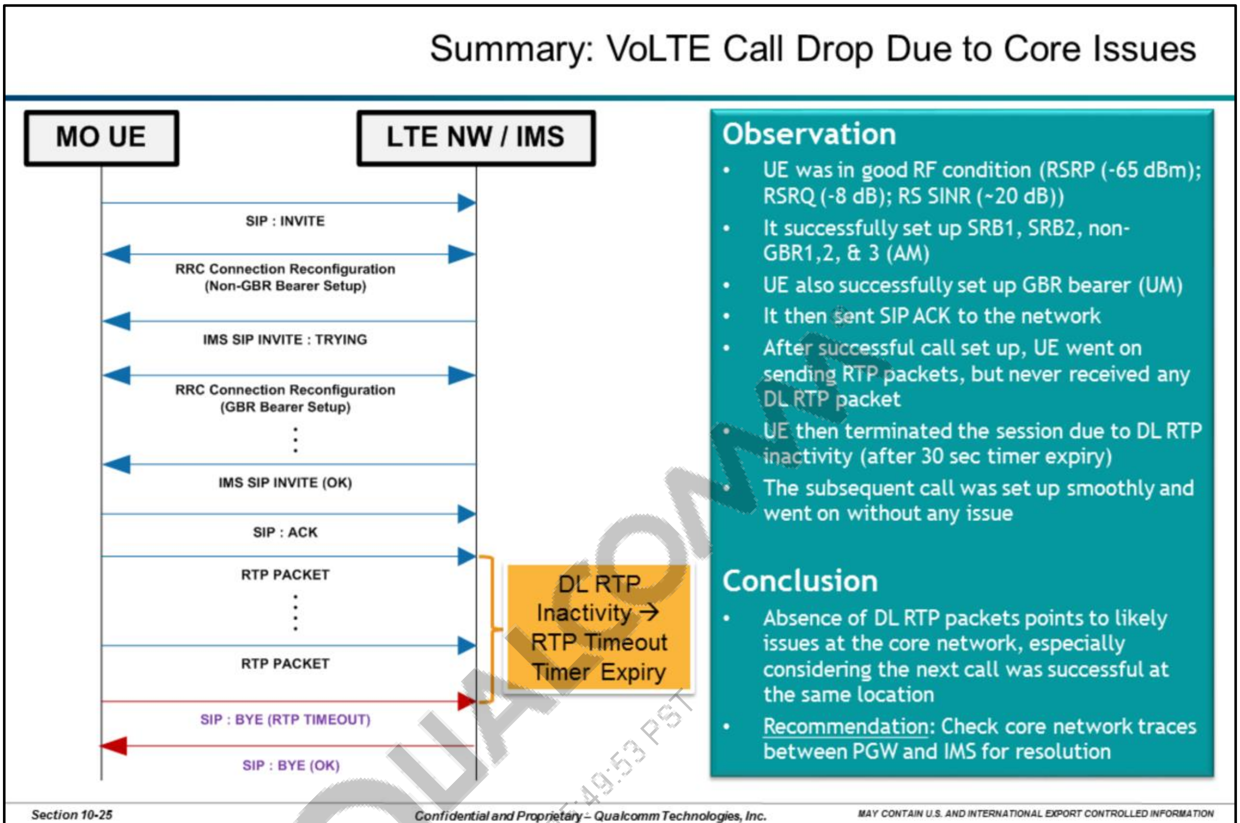
Step	Look for	Log Packet	Time Stamp	Verify
1	LTE RRC OTA Packet	0xB0C0	18:53:56.720	VoLTE MT Call Paging
2	LTE RRC OTA Packet	0xB0C0	18:53:56.818	RRC Connection Setup
3	LTE RRC OTA Packet	0xB0C0	18:53:56.925	RRC Connection Reconfig (non-GBR Bearer Setup)
4	IMS SIP Message	0x156E	18:53:57.283	IMS SIP INVITE (BS > UE)
5	LTE RLC DL AM All PDU	0xB082	18:53:57.355	RLC ACK
6	IMS SIP Message	0x156E	18:54:02.948	IMS SIP INVITE OK (UE > BS)
7	LTE RRC OTA Packet	0xB0C0	18:54:03.149	RRC Connection Reconfig (GBR Bearer Setup)
8	IMS SIP Message	0x156E	18:54:04.270	IMS SIP: ACK (IMS→ UE]
9	IMS SIP message	0x156E	18:54:04.315	IMS SIP BYE (503) [BS > UE]
10	IMS SIP message	0x156E	18:54:04.321	IMS SIP BYE: OK [UE > BS]
11	Event	0x1FFB	18:54:04.323	Event: IMS SIP Session Terminated

Notes

VoLTE Call Drop Case Studies

- Case Study-1 (VoLTE Call Drop due to Poor RF)
- Case Study-2 (Abnormal VoLTE Session Termination by Core)
- **Case Study-3 (Core Issues Causing DL RTP Inactivity)**
- Case Study-4 (GBR Bearer Modification Reject)
- Case Study-5 (RoHC Context Mismatch)

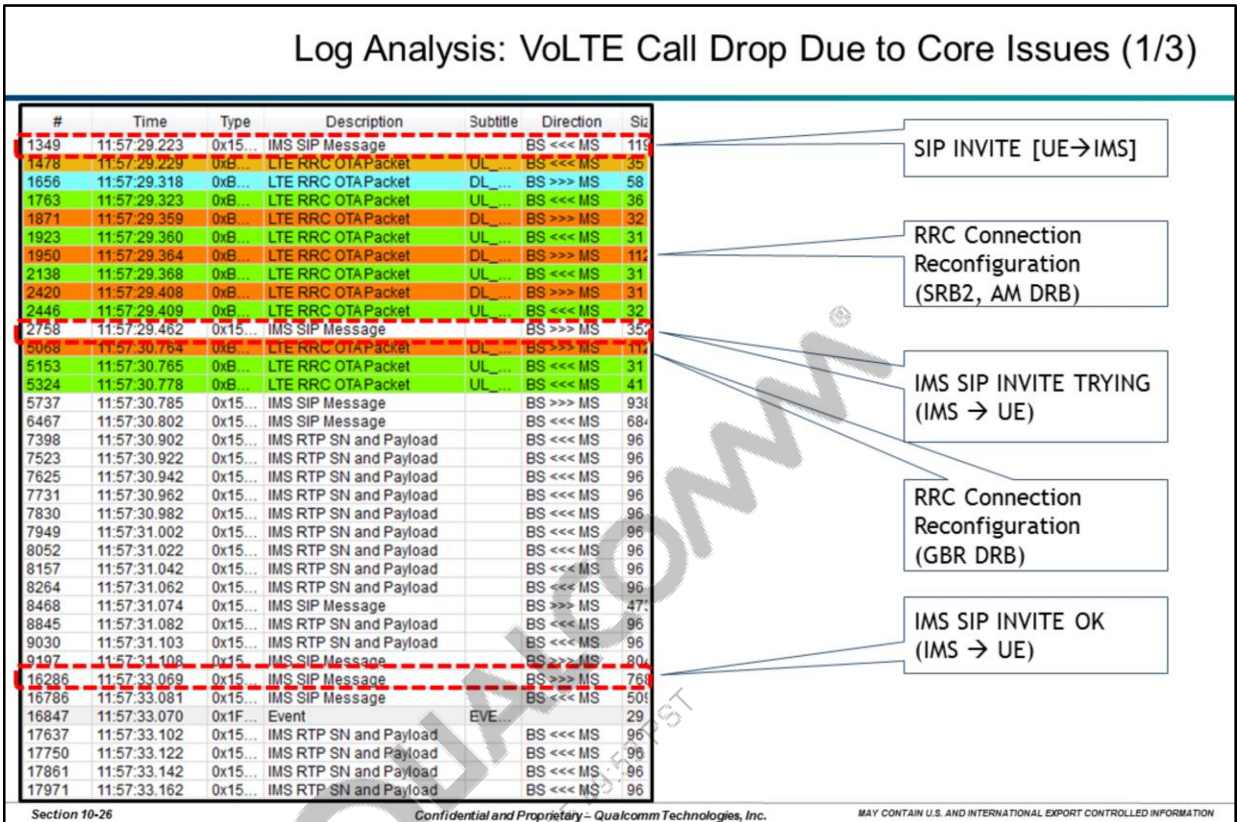
Notes



VoLTE Call Drop due to Core Issues

Referring to the MT log files (not discussed here), it was concluded that there was no performance issue at the MT side that could prompt this occurrence.

A probable cause of failure could be eNB issues that might have resulted in failure to direct RTP traffic on the right bearer and prompting UE (IMS) to release the session after RTP timeout timer expiry.



#	Time	Type	Description	Subtitle	Direction	Siz
1349	11:57:29.223	0x15...	IMS SIP Message		BS <<< MS	119
1478	11:57:29.229	0xB...	LTE RRC OTA Packet	UL_...	BS <<< MS	35
1656	11:57:29.318	0xB...	LTE RRC OTA Packet	DL_...	BS >>> MS	58
1763	11:57:29.323	0xB...	LTE RRC OTA Packet	UL_...	BS <<< MS	36
1871	11:57:29.359	0xB...	LTE RRC OTA Packet	DL_...	BS >>> MS	32
1923	11:57:29.360	0xB...	LTE RRC OTA Packet	UL_...	BS <<< MS	31
1950	11:57:29.364	0xB...	LTE RRC OTA Packet	DL_...	BS >>> MS	112
2138	11:57:29.368	0xB...	LTE RRC OTA Packet	UL_...	BS <<< MS	31
2420	11:57:29.408	0xB...	LTE RRC OTA Packet	DL_...	BS >>> MS	31
2446	11:57:29.409	0xB...	LTE RRC OTA Packet	UL_...	BS <<< MS	32
2758	11:57:29.462	0x15...	IMS SIP Message		BS >>> MS	352
5068	11:57:30.764	0xB...	LTE RRC OTA Packet	DL_...	BS >>> MS	112
5153	11:57:30.765	0xB...	LTE RRC OTA Packet	UL_...	BS <<< MS	31
5324	11:57:30.778	0xB...	LTE RRC OTA Packet	UL_...	BS <<< MS	41
5737	11:57:30.785	0x15...	IMS SIP Message		BS >>> MS	938
6467	11:57:30.802	0x15...	IMS SIP Message		BS <<< MS	684
7398	11:57:30.902	0x15...	IMS RTP SN and Payload		BS <<< MS	96
7523	11:57:30.922	0x15...	IMS RTP SN and Payload		BS <<< MS	96
7625	11:57:30.942	0x15...	IMS RTP SN and Payload		BS <<< MS	96
7731	11:57:30.962	0x15...	IMS RTP SN and Payload		BS <<< MS	96
7830	11:57:30.982	0x15...	IMS RTP SN and Payload		BS <<< MS	96
7949	11:57:31.002	0x15...	IMS RTP SN and Payload		BS <<< MS	96
8052	11:57:31.022	0x15...	IMS RTP SN and Payload		BS <<< MS	96
8157	11:57:31.042	0x15...	IMS RTP SN and Payload		BS <<< MS	96
8264	11:57:31.062	0x15...	IMS RTP SN and Payload		BS <<< MS	96
8468	11:57:31.074	0x15...	IMS SIP Message		BS >>> MS	473
8845	11:57:31.082	0x15...	IMS RTP SN and Payload		BS <<< MS	96
9030	11:57:31.103	0x15...	IMS RTP SN and Payload		BS <<< MS	96
9197	11:57:31.108	0x15...	IMS SIP Message		BS >>> MS	804
16286	11:57:33.069	0x15...	IMS SIP Message		BS >>> MS	768
16786	11:57:33.081	0x15...	IMS SIP Message		BS <<< MS	509
16847	11:57:33.070	0x1F...	Event	EVE...		29
17637	11:57:33.102	0x15...	IMS RTP SN and Payload		BS <<< MS	96
17750	11:57:33.122	0x15...	IMS RTP SN and Payload		BS <<< MS	96
17861	11:57:33.142	0x15...	IMS RTP SN and Payload		BS <<< MS	96
17971	11:57:33.162	0x15...	IMS RTP SN and Payload		BS <<< MS	96

Non-GBR Bearers

DRB1 → EPS ID 5; DRB ID 1 [AM]

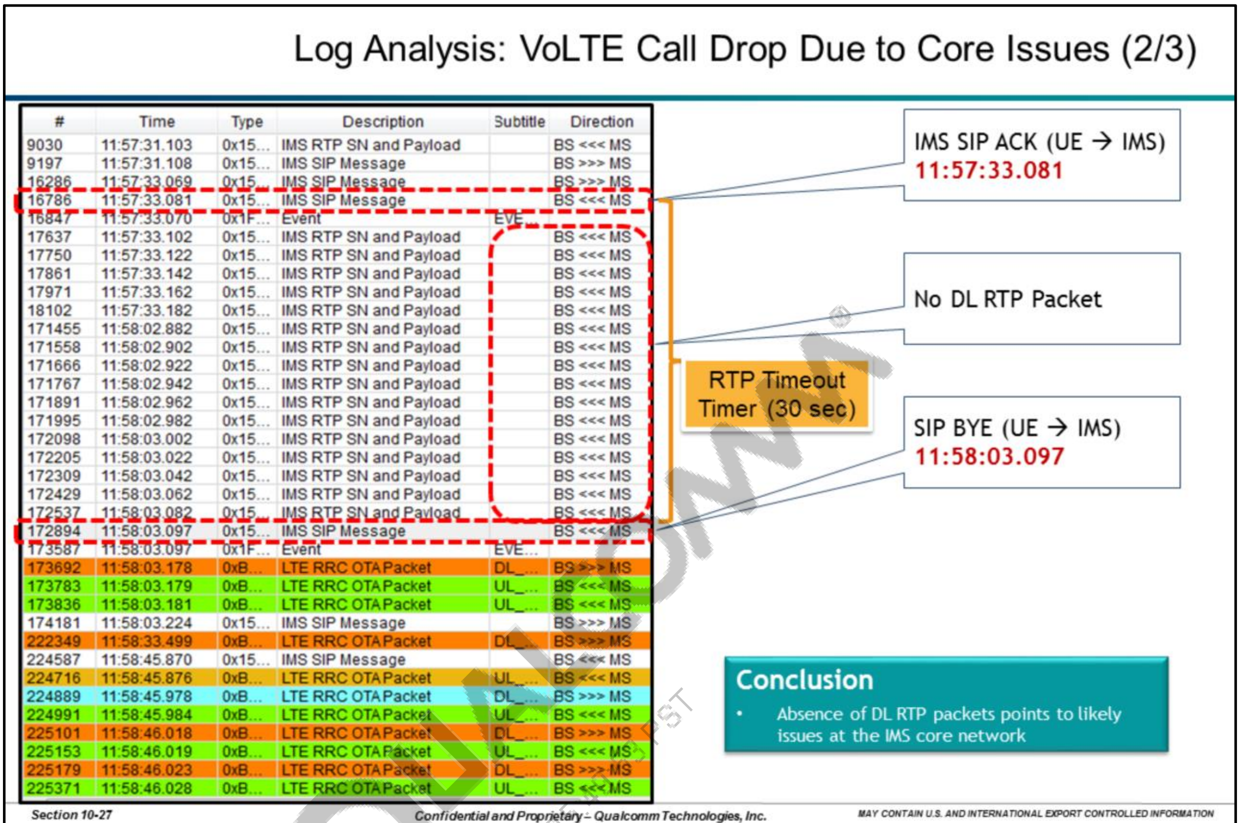
DRB2 → EPS ID 6; DRB ID 2 [AM]

DRB3 → EPS ID 7; DRB ID 3 [AM]

DRB4 → EPS ID 8; DRB ID 4 [AM]

GBR Bearer

DRB5 → EPS ID 9; DRB ID 5 [UM]



VoLTE Call Drop due to Core Issues

In addition to the core network issues, eNB/MME could also be a probable reason causing the core network to be unable to deliver RTP packets.

Log Analysis: VoLTE Call Drop Due to Core Issues (3/3)

#	Time	Type	Description
155718	11:57:59.713	0xB...	LTE LL1 Radio Link Monitoring
156024	11:57:59.763	0xB...	LTE LL1 Radio Link Monitoring
156263	11:57:59.813	0xB...	LTE LL1 Radio Link Monitoring
156580	11:57:59.863	0xB...	LTE LL1 Radio Link Monitoring
156806	11:57:59.913	0xB...	LTE LL1 Radio Link Monitoring
157108	11:57:59.963	0xB...	LTE LL1 Radio Link Monitoring
157348	11:58:00.013	0xB...	LTE LL1 Radio Link Monitoring
157649	11:58:00.063	0xB...	LTE LL1 Radio Link Monitoring
157889	11:58:00.113	0xB...	LTE LL1 Radio Link Monitoring
157906	11:58:00.121	0xB...	LTE LL1 PDSCH Decoding Results
158429	11:58:00.205	0xB...	LTE PDSCH Stat Indication
[illegible]	[illegible]	[illegible]	[illegible]
172450	11:58:03.063	0xB...	LTE LL1 Radio Link Monitoring
172636	11:58:03.089	0x17...	IMS Voice Call Statistics
172894	11:58:03.097	0x15...	IMS SIP Message
173524	11:58:03.113	0xB...	LTE LL1 Radio Link Monitoring
173605	11:58:03.148	0xB...	LTE LL1 PDSCH Decoding Results
173659	11:58:03.163	0xB...	LTE LL1 Radio Link Monitoring
173972	11:58:03.205	0xB...	LTE PDSCH Stat Indication
173981	11:58:03.213	0xB...	LTE LL1 Radio Link Monitoring
174181	11:58:03.224	0x15...	IMS SIP Message
174695	11:58:03.263	0xB...	LTE LL1 Radio Link Monitoring
174832	11:58:03.313	0xB...	LTE LL1 Radio Link Monitoring
174910	11:58:03.363	0xB...	LTE LL1 Radio Link Monitoring
174983	11:58:03.413	0xB...	LTE LL1 Radio Link Monitoring
175060	11:58:03.463	0xB...	LTE LL1 Radio Link Monitoring
175124	11:58:03.505	0xB...	LTE PDSCH Stat Indication
175137	11:58:03.513	0xB...	LTE LL1 Radio Link Monitoring
175213	11:58:03.563	0xB...	LTE LL1 Radio Link Monitoring
175310	11:58:03.613	0xB...	LTE LL1 Radio Link Monitoring
175388	11:58:03.663	0xB...	LTE LL1 Radio Link Monitoring
175461	11:58:03.713	0xB...	LTE LL1 Radio Link Monitoring
175539	11:58:03.763	0xB...	LTE LL1 Radio Link Monitoring
175611	11:58:03.813	0xB...	LTE LL1 Radio Link Monitoring
175690	11:58:03.863	0xB...	LTE LL1 Radio Link Monitoring
175766	11:58:03.913	0xB...	LTE LL1 Radio Link Monitoring

CRC Pass

Subframe Num	Frame Num	Num RBs	Num Layers	Num Transport Blocks Present	Serving Cell Index	Transport Blocks HARQ ID	RV	NDI	CRC Result	RNTI Type	TB Index
1	713	4	2	2	PCell	0	0	1	Pass	C	0
						0	0	0	Pass	C	1

DL SINR was Very High

```
Cycle Start Subframe Number     = 5
Cycle Start Frame Number        = 1002
Cycle Length                    = 10
Number of Active Subframes      = 6
Out_of_Sync Filtered BLER       = 0.000
In_Sync Filtered BLER           = 0.000
Number of Subrecords            = 6
```

Sub-fn	SFN	Average SNR (dB)	Out_of_Sync per-subfn BLER	In_Sync per-subfn BLER
5	1002	22.30	0.000	0.000
8	1002	22.59	0.000	0.000
9	1002	22.59	0.000	0.000
0	1003	21.96	0.000	0.000
3	1003	22.32	0.000	0.000
4	1003	22.32	0.000	0.000

No DL RTP Packet Received

```
CodecType = AMR_WB
Tx Ssrc = 0xF5022147
Rx Ssrc = 0x00000000
Num Tx Rtp = 1305
Num Rx Rtp = 0
Num Rx Lost  = 0
Ave Rel Jitter = 0
Max Rel Jitter = 0
Avg Inst Jitter = 1
Max Inst Jitter = 0
Num Frames Rcvd = 0
Frames Not Enqued = 0
Frames UnderFlow = 0
Avg UnderFlow Rate = 0
Avg Frame Delay = 0
```

Conclusion

- Absence of DL RTP packets points to likely issues at the core network, especially considering next call was ok

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Notes

Analysis – VoLTE Call Drop Due to Core Issues

Log Analysis Procedure:

Open File: 10-03-Call_Drop_Core_Causing_RTP_Inactivity

Notes

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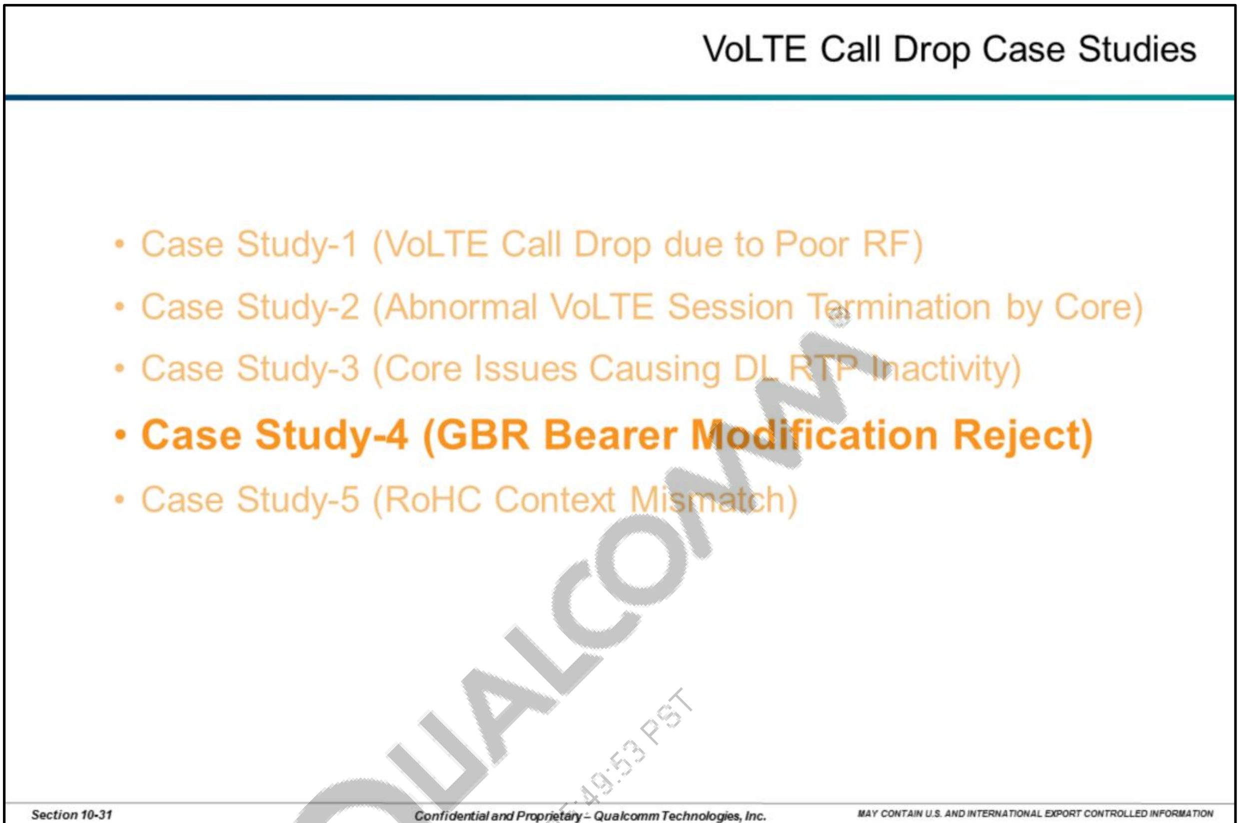
VoLTE Call Drop Due to Core Issues: Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	IMS SIP Message	0x156E	11:57:29.223	SIP INVITE (UE → IMS)
2	LTE RRC OTA Packet	0xB0C0	11:57:29.364	RRC Connection Reconfig (non-GBR Bearer Setup)
3	IMS SIP Message	0x156E	11:57:29.462	IMS SIP INVITE TRYING [IMS→UE]
4	LTE RRC OTA Packet	0xB0C0	11:57:30.764	RRC Connection Reconfig (GBR Bearer Setup)
5	IMS SIP Message	0x156E	11:57:33.069	IMS SIP INVITE OK (IMS → UE)
6	IMS SIP Message	0x156E	11:57:33.081	IMS SIP ACK (UE → IMS)
7	LTE PDSCH Stat Indication	0xB173	11:58:00.205	CRC Results "Pass"
8	LTE LL1 Radio Link Monitoring	0xB129	11:58:03.063	Avg SNR > 22 dB; Avg BLER: 0
9	IMS RTP SN and Payload	0x1568	11:58:03.082	UL RTP Packet (UE → IMS); No DL RTP Packet
10	IMS VoLTE Call Statistics	0x17F2	11:58:03.089	Num Tx RTP: 1305; Num Rx RTP: 0
11	IMS SIP Message	0x156E	11:58:03.097	IMS SIP BYE (UE → IMS)
12	Event	0x1FFB	11:58:03.097	IMS SIP Session Terminated
13	IMS SIP Message	0x156E	11:58:50.393	IMS SIP ACK [UE→IMS]; Next Call Setup Ok
14	IMS Voice Call Statistics	0x17F2	11:59:43.224	Num Tx RTP: 2245; Num Rx RTP: 2334; Num Rx Lost: 0

Notes


VoLTE Call Drop Case Studies
• Case Study-1 (VoLTE Call Drop due to Poor RF)
• Case Study-2 (Abnormal VoLTE Session Termination by Core)
• Case Study-3 (Core Issues Causing DL RTP Inactivity)
• Case Study-4 (GBR Bearer Modification Reject)
• Case Study-5 (RoHC Context Mismatch)
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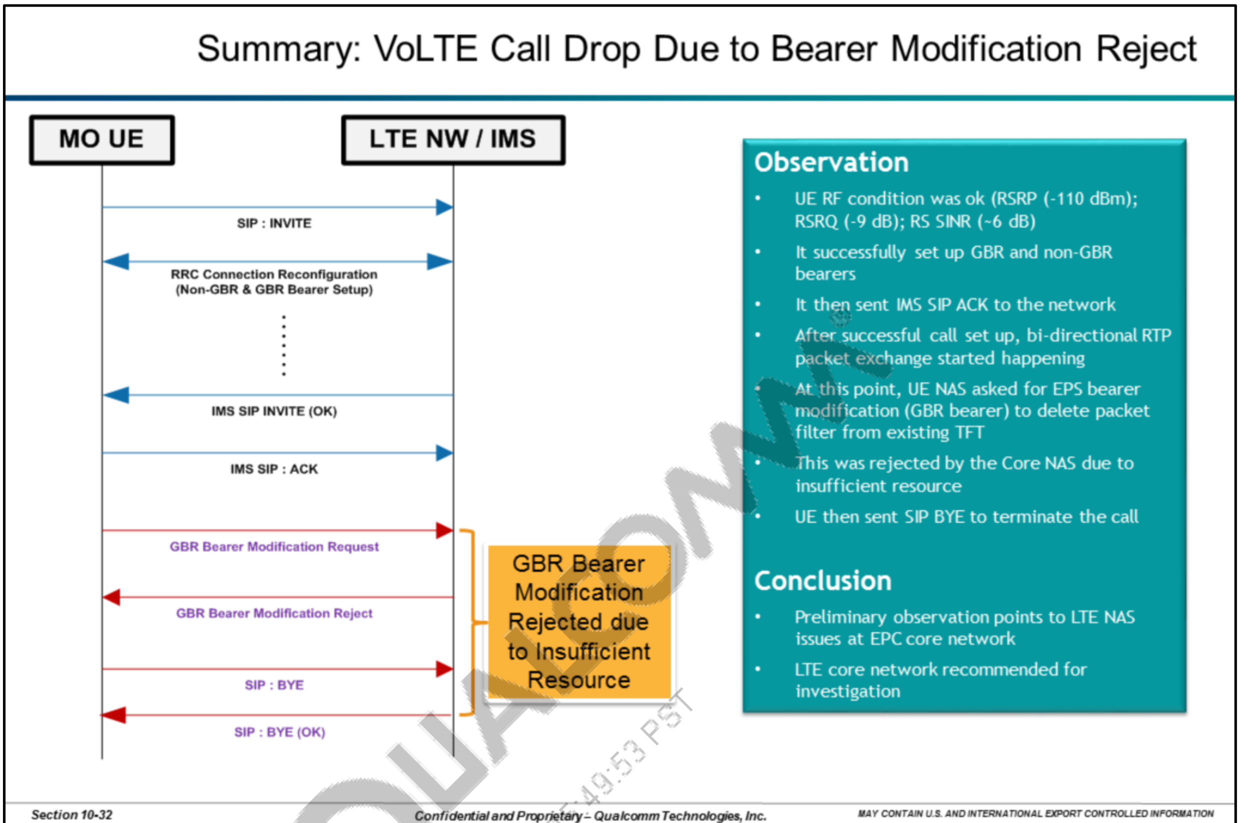
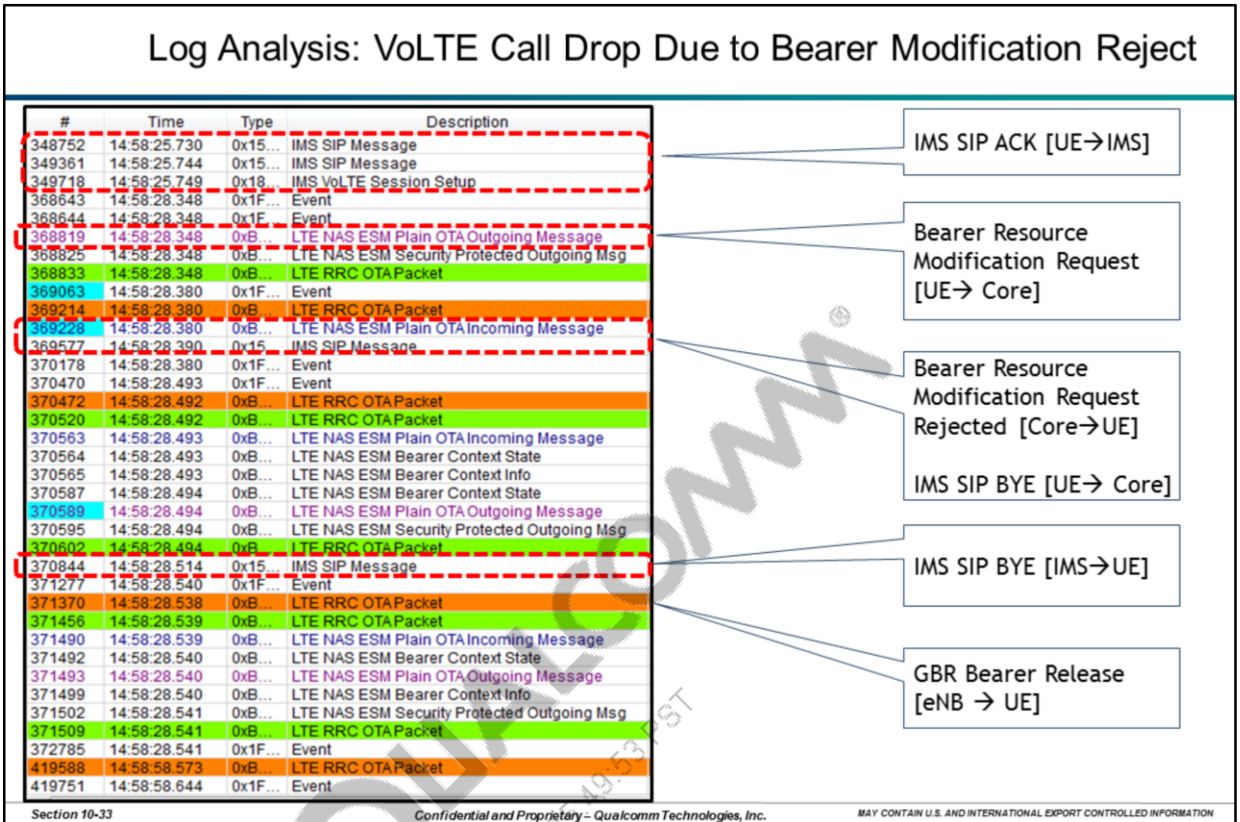
Notes



VoLTE Call Drop due to Bearer Modification Reject

It is not clear why the UE requested GBR bearer modification. It is also not clear what kind of resource insufficiency prompted the core network to reject such a request, which ultimately resulted in the UE sending SIP BYE which caused the call drop.

The probable causes for bearer modification request could be additional data rate requirement to support other service types, absence of release of GBR bearers from the previous VoLTE calls, LTE eUTRAN/EPC core network bugs, etc.



VoLTE Call Drop due to Bearer Modification Reject

Bearer Resource Modification Request was sent by the UE NAS to the core network, requesting to delete packet filters from existing TFT. However, this request was rejected by the core network with ESM cause code "Insufficient Resource".

The likely causes for rejection citing insufficient resource could be network congestion, throughput rate request exceeding HSS profile, lack of clarity at the EPC as to why UE requested this increase, etc.

Such rejection of the GBR bearer modification request resulted in the UE sending SIP BYE (i.e., VoLTE call drop).

Subsequent calls were handled by both the UE and the network as expected and such problem was not experienced.

Analysis – VoLTE Call Drop Due to Bearer Modification Reject

Log Analysis Procedure:

Open File: 10-04-Call_Drop_Bearer Modification Reject

Notes

VoLTE Call Drop Due to Bearer Modification Reject: Log Walk-Through

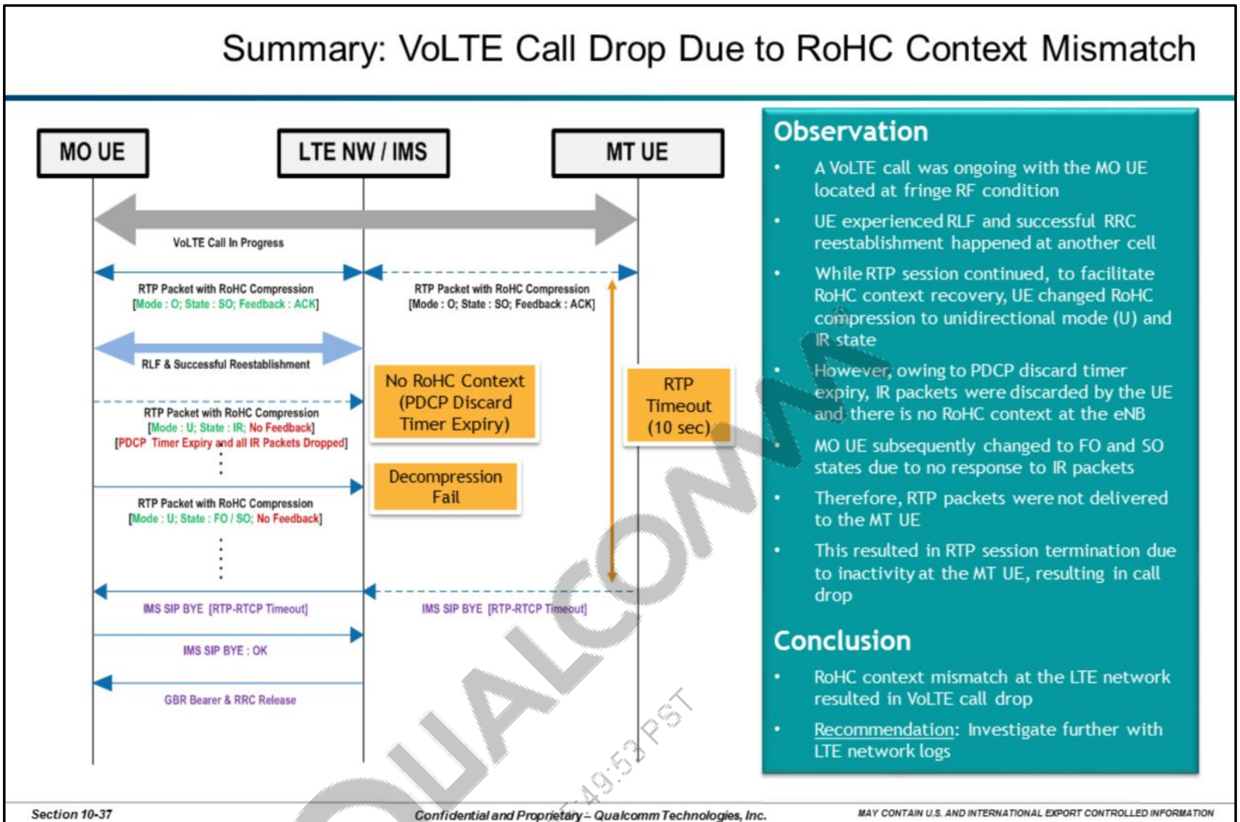
Step	Look for	Log Packet	Time Stamp	Verify
1	IMS SIP Message	0x156E	14:58:18.254	SIP INVITE (UE→ IMS)
2	LTE RRC OTA Packet	0xB0C0	14:58:18.392	RRC Connection Reconfig (Bearer Setup)
3	IMS SIP Message	0x156E	14:58:25.730	IMS SIP INVITE OK [IMS→UE]
4	IMS SIP Message	0x156E	14:58:25.744	IMS SIP ACK [UE→IMS]
5	LTE NAS ESM Plain OTA Outgoing Message	0xB0E3	14:58:28.348	Bearer Resource Modification Request (Delete packet filters from existing TFT) [UE→Core]
6	LTE NAS ESM Plain OTA Incoming Message	0xB0E2	14:58:28.380	Bearer Resource Modification Reject (Insufficient Resource) [Core→UE]
7	IMS SIP Message	0x156E	14:58:28.390	IMS SIP BYE [UE→IMS]
8	IMS SIP Message	0x156E	14:58:28.514	IMS SIP BYE OK {IMS→UE]
9	LTE RRC OTA Packet	0xB0C0	14:58:28.538	RRC Connection Reconfig (drb-ToReleaseList 5)

Notes

VoLTE Call Drop Case Studies

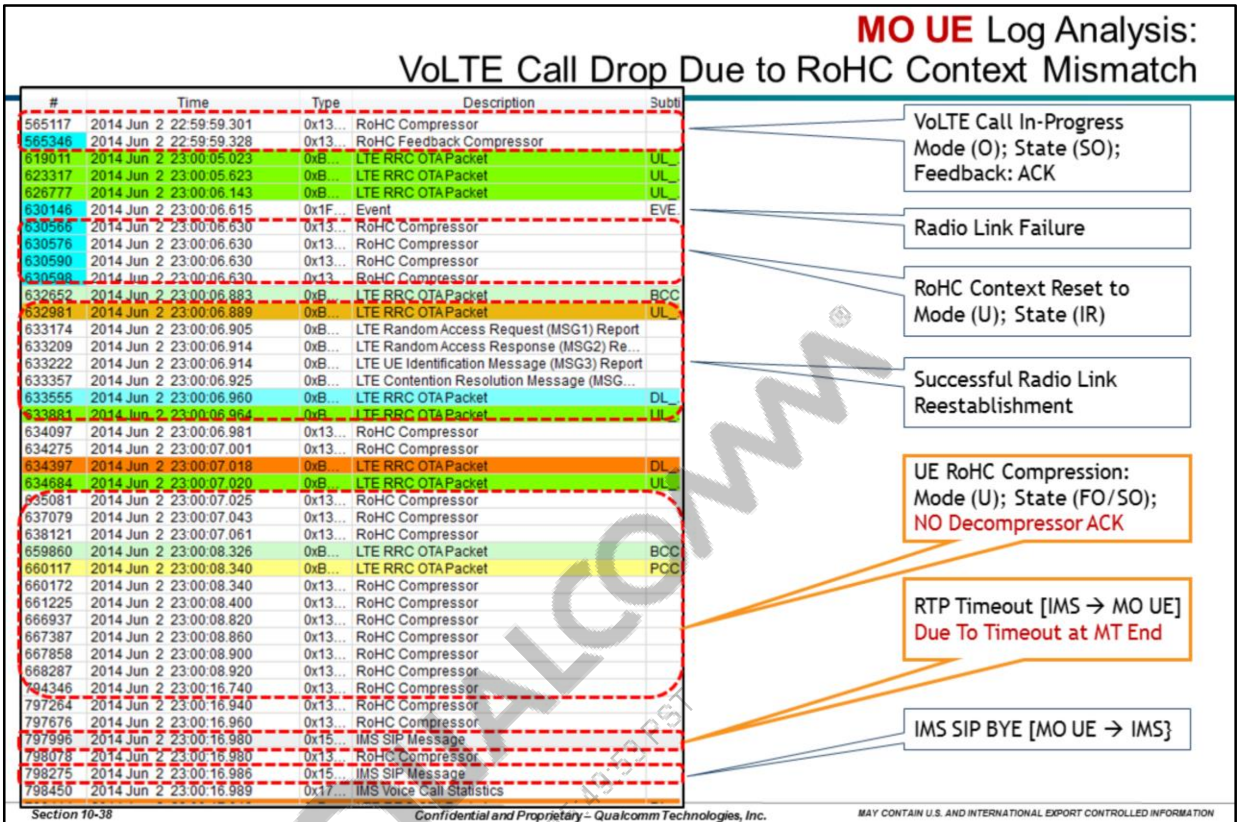
- Case Study-1 (VoLTE Call Drop due to Poor RF)
- Case Study-2 (Abnormal VoLTE Session Termination by Core)
- Case Study-3 (Core Issues Causing DL RTP Inactivity)
- Case Study-4 (GBR Bearer Modification Reject)
- **Case Study-5 (RoHC Context Mismatch)**

Notes



VoLTE Call Drop due to RoHC Context Mismatch

In this example, after successful reestablishment, MO UE continued sending RoHC contexts in U-mode with IR followed by FO/SO states, but never received ACK. In the DL, the MO UE continued receiving RTP packets in the usual manner. This signature points to RoHC context mismatch at the LTE network (eNB).



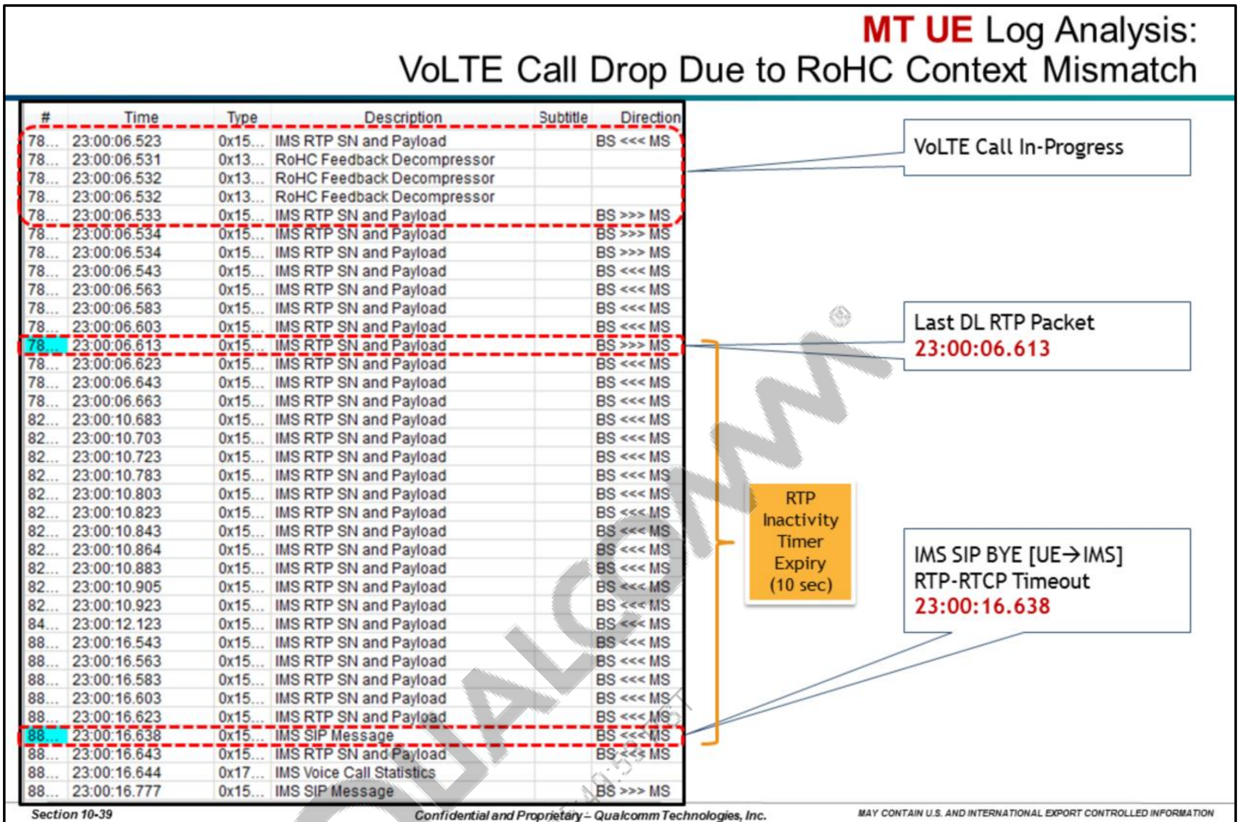
MO UE VoLTE Call Drop due to RoHC Context Mismatch

The MO UE, due to poor RF condition, had experienced RLF at 23:00:06.615 hr. It was then able to successfully reestablish the call at the target PCI for which it had sent measurement reports multiple times (but never received HO command). After successful reestablishment, MO UE changed mode to U (unidirectional) and state to IR. Subsequently, it changed mode to O (optimized) and toggled state between FO and SO.

However, the LTE network (eNB) did not send RoHC compressor feedback to the MO UE. While the r reason for this was not known (due to lack of suitable logs from the eNB side), referring to the corresponding log files of the MT UE, it was clear that the MT UE did not receive any RTP packet in the DL from the network. This indirectly points to the fact that RoHC context mismatch at the eNB might have resulted in drop context, which eventually resulted in no transfer of DL packet to the MT UE.

While this continued for a while, after expiry of RTP timeout timer (10 sec), the MT UE sent out SIP BYE due to RTP timeout. As a result, the network (IMS) sent out SIP BYE due to RTP timeout to the MO UE.

This abnormal RTP session termination, which finally resulted in the VoLTE call drop, was attributable to likely RoHC context drop at the eNB due to RoHC context mismatch and recommended for further investigation using eNB/network logs.



#	Time	Type	Description	Subtitle	Direction
78...	23:00:06.523	0x15...	IMS RTP SN and Payload		BS <<< MS
78...	23:00:06.531	0x13...	RoHC Feedback Decompressor		
78...	23:00:06.532	0x13...	RoHC Feedback Decompressor		
78...	23:00:06.532	0x13...	RoHC Feedback Decompressor		
78...	23:00:06.533	0x15...	IMS RTP SN and Payload		BS >>> MS
78...	23:00:06.534	0x15...	IMS RTP SN and Payload		BS >>> MS
78...	23:00:06.534	0x15...	IMS RTP SN and Payload		BS >>> MS
78...	23:00:06.543	0x15...	IMS RTP SN and Payload		BS <<< MS
78...	23:00:06.563	0x15...	IMS RTP SN and Payload		BS <<< MS
78...	23:00:06.583	0x15...	IMS RTP SN and Payload		BS <<< MS
78...	23:00:06.603	0x15...	IMS RTP SN and Payload		BS <<< MS
78...	23:00:06.613	0x15...	IMS RTP SN and Payload		BS >>> MS
78...	23:00:06.623	0x15...	IMS RTP SN and Payload		BS <<< MS
78...	23:00:06.643	0x15...	IMS RTP SN and Payload		BS <<< MS
78...	23:00:06.663	0x15...	IMS RTP SN and Payload		BS <<< MS
82...	23:00:10.683	0x15...	IMS RTP SN and Payload		BS <<< MS
82...	23:00:10.703	0x15...	IMS RTP SN and Payload		BS <<< MS
82...	23:00:10.723	0x15...	IMS RTP SN and Payload		BS <<< MS
82...	23:00:10.783	0x15...	IMS RTP SN and Payload		BS <<< MS
82...	23:00:10.803	0x15...	IMS RTP SN and Payload		BS <<< MS
82...	23:00:10.823	0x15...	IMS RTP SN and Payload		BS <<< MS
82...	23:00:10.843	0x15...	IMS RTP SN and Payload		BS <<< MS
82...	23:00:10.864	0x15...	IMS RTP SN and Payload		BS <<< MS
82...	23:00:10.883	0x15...	IMS RTP SN and Payload		BS <<< MS
82...	23:00:10.905	0x15...	IMS RTP SN and Payload		BS <<< MS
82...	23:00:10.923	0x15...	IMS RTP SN and Payload		BS <<< MS
84...	23:00:12.123	0x15...	IMS RTP SN and Payload		BS <<< MS
88...	23:00:16.543	0x15...	IMS RTP SN and Payload		BS <<< MS
88...	23:00:16.563	0x15...	IMS RTP SN and Payload		BS <<< MS
88...	23:00:16.583	0x15...	IMS RTP SN and Payload		BS <<< MS
88...	23:00:16.603	0x15...	IMS RTP SN and Payload		BS <<< MS
88...	23:00:16.623	0x15...	IMS RTP SN and Payload		BS <<< MS
88...	23:00:16.638	0x15...	IMS SIP Message		BS <<< MS
88...	23:00:16.643	0x15...	IMS RTP SN and Payload		BS <<< MS
88...	23:00:16.644	0x17...	IMS Voice Call Statistics		
88...	23:00:16.777	0x15...	IMS SIP Message		BS >>> MS

MT UE VoLTE Call Drop due to RoHC Context Mismatch

After expiry of RTP timeout timer (10 sec), the MT UE sent out SIP BYE due to RTP timeout. As a result, the network (IMS) sent out SIP BYE due to RTP timeout to the MO UE.

Analysis – VoLTE Call Drop due to RoHC Context Mismatch

Log Analysis Procedure:

Open File: 10-05_Call_Drop_RoHC_Context_Mismatch_MO
10-05_Call_Drop_RoHC_Context_Mismatch_MT

Notes

VoLTE Call Drop Due to RoHC Context Mismatch: Log Walk-Through

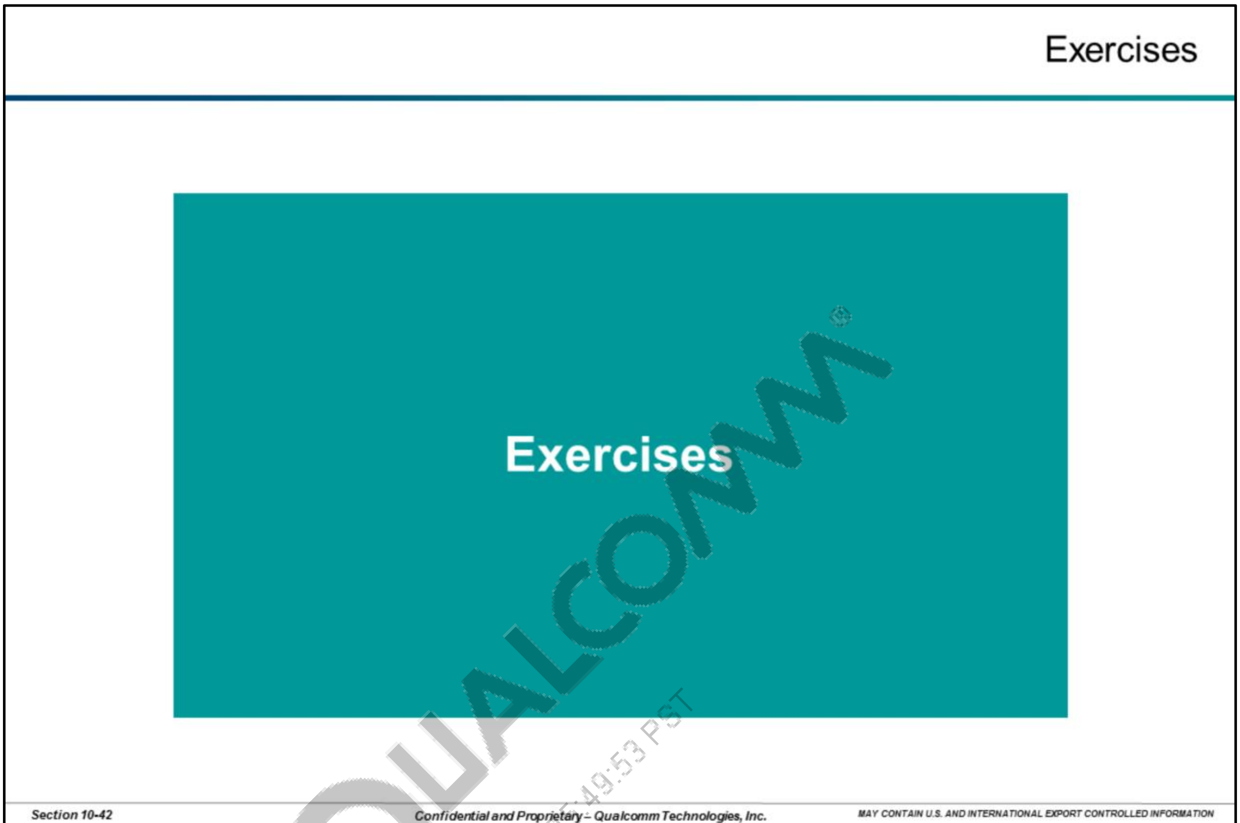
MO UE

Step	Look for	Log Packet	Time Stamp	Verify
1	RoHC Compressor	0x1361	22:59:59.301	Mode: O; State: SO
2	Event	0x1FFB	23:00:06.615	Radio Link Failure
3	RoHC Compressor	0x1361	23:00:06.630	Mode: U; State: IR
4	LTE RRC OTA Packet	0xB0C0	23:00:06.964	RRC Connection Reestablishment Complete
5	RoHC Compressor	0x1361	23:00:07.025 To 23:00:16.950	Mode: U; State: FO/SO; No decompressor ACK
6	IMS SIP Message	0x156E	23:00:16.980	RTP-RTCP Timeout [IMS→ MO UE]
7	IMS SIP message	0x156E	23:00:16.986	IMS SIP BYE [MO UE → IMS]

MT UE

Step	Look for	Log Packet	Time Stamp	Verify
1	IMS RTP SN & Payload	0x1568	23:00:06.613	Last DL RTP Packet [IMS→MT UE]
2	IMS SIP Message	0x1568	23:00:16.638	RTP-RTCP Timeout [MT UE→IMS]

Notes


Exercises
Exercises
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Notes

VoLTE Call Drop – Questions

1. What is VoLTE Call Drop?
   a) Radio link failure (RLF)
   b) RLF followed by RRC reestablishment failure
   c) Abnormal SIP session termination
   d) None of the above

2. Name likely LTE causes for VoLTE call drop
   a) RF coverage hole/poor quality
   b) eNB/MME/PGW/NAS configuration issue
   c) RRC recovery exceeding RTP timeout
   d) All of the above

Notes

VoLTE Call Drop – Answers

1. What is VoLTE Call Drop?
   a) Radio link failure (RLF)
   b) RLF followed by RRC reestablishment failure
   c) **Abnormal SIP session termination**
   d) None of the above

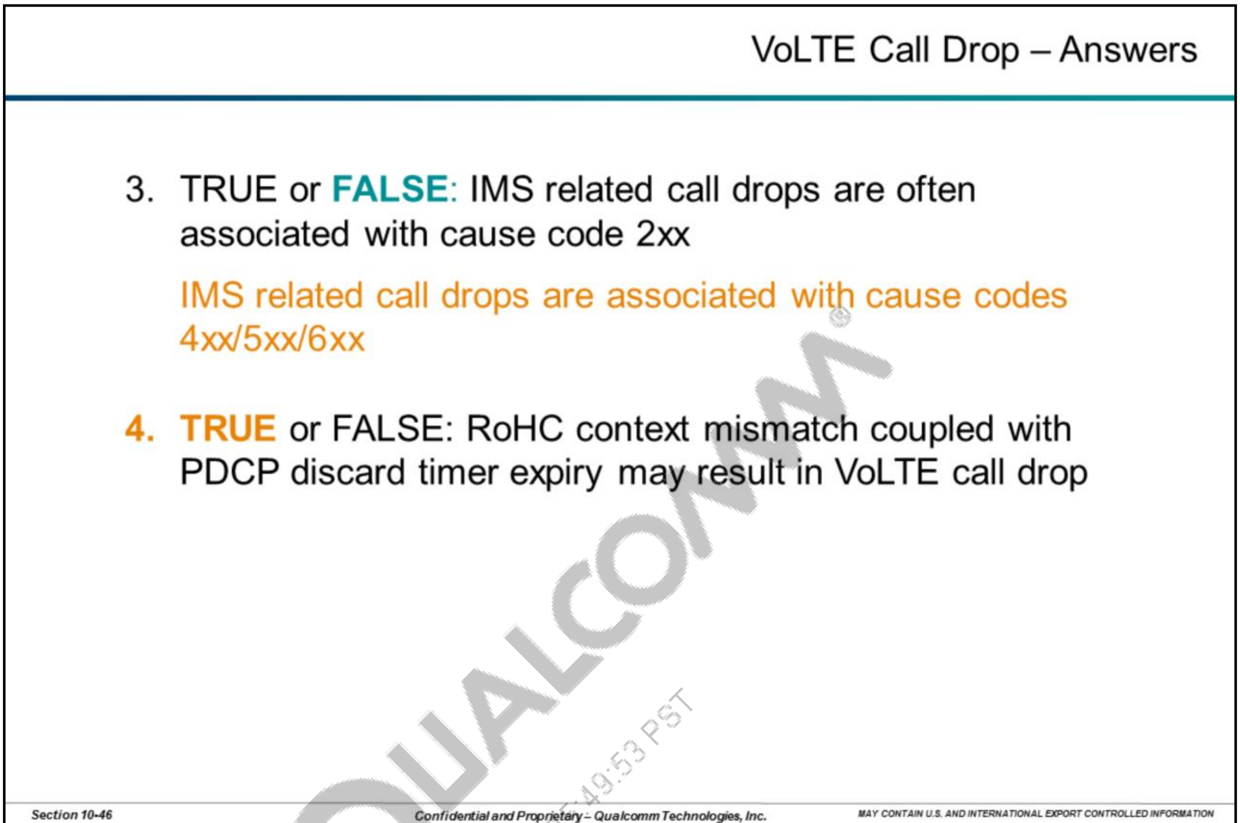
2. Name likely LTE causes for VoLTE call drop
   a) RF coverage hole/poor quality
   b) eNB/MME/PGW/NAS configuration issue
   c) RRC recovery exceeding RTP timeout
   d) **All of the above**

Notes

VoLTE Call Drop – Questions

3. TRUE or FALSE: IMS related call drops are often associated with cause code 2xx
4. TRUE or FALSE: RoHC context mismatch coupled with PDCP discard timer expiry may result in VoLTE call drop

Notes


VoLTE Call Drop – Answers
3. TRUE or FALSE: IMS related call drops are often associated with cause code 2xx
IMS related call drops are associated with cause codes 4xx/5xx/6xx
4. TRUE or FALSE: RoHC context mismatch coupled with PDCP discard timer expiry may result in VoLTE call drop
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Notes


11
Inter-RAT Handover: Single Radio Voice Call Continuity (SRVCC) to UTRAN
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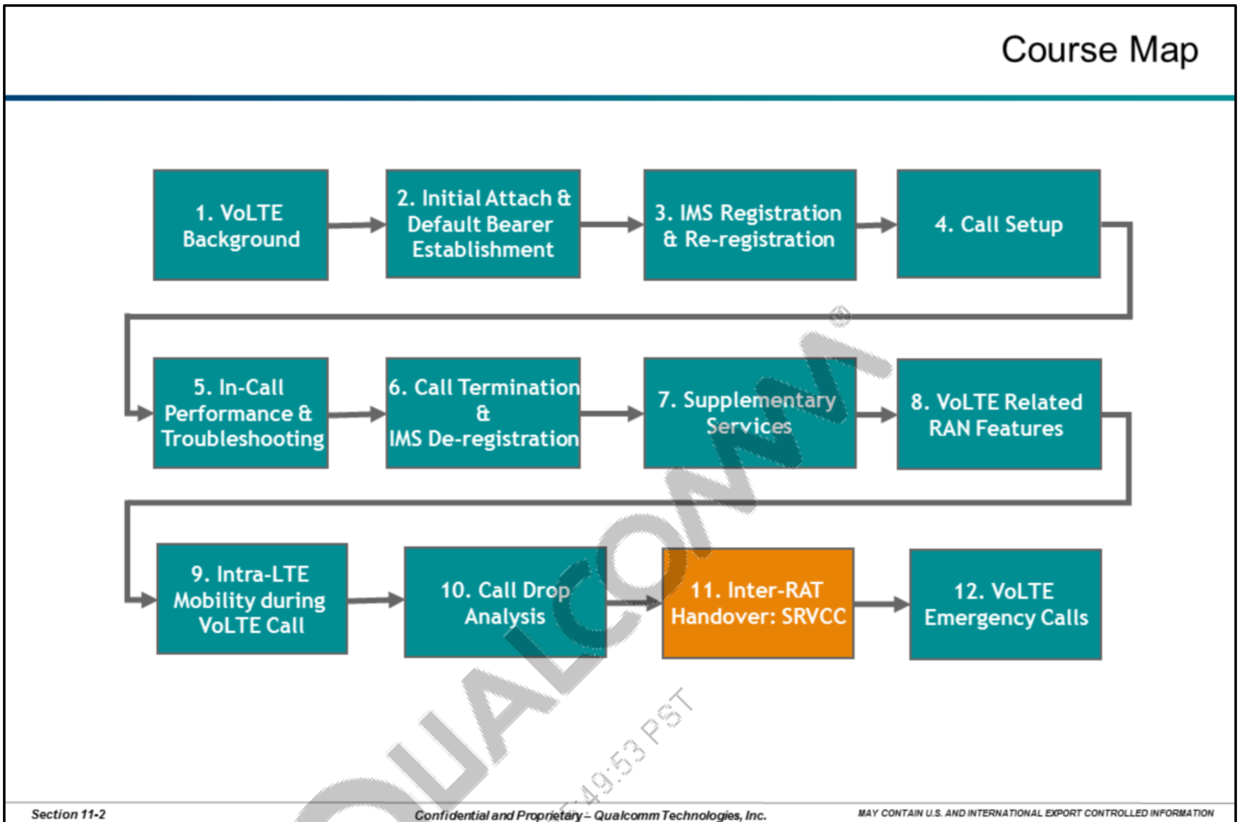
Course Map
1. VoLTE Background
2. Initial Attach & Default Bearer Establishment
3. IMS Registration & Re-registration
4. Call Setup
5. In-Call Performance & Troubleshooting
6. Call Termination & IMS De-registration
7. Supplementary Services
8. VoLTE Related RAN Features
9. Intra-LTE Mobility during VoLTE Call
10. Call Drop Analysis
11. Inter-RAT Handover: SRVCC
12. VoLTE Emergency Calls
Section 11-2
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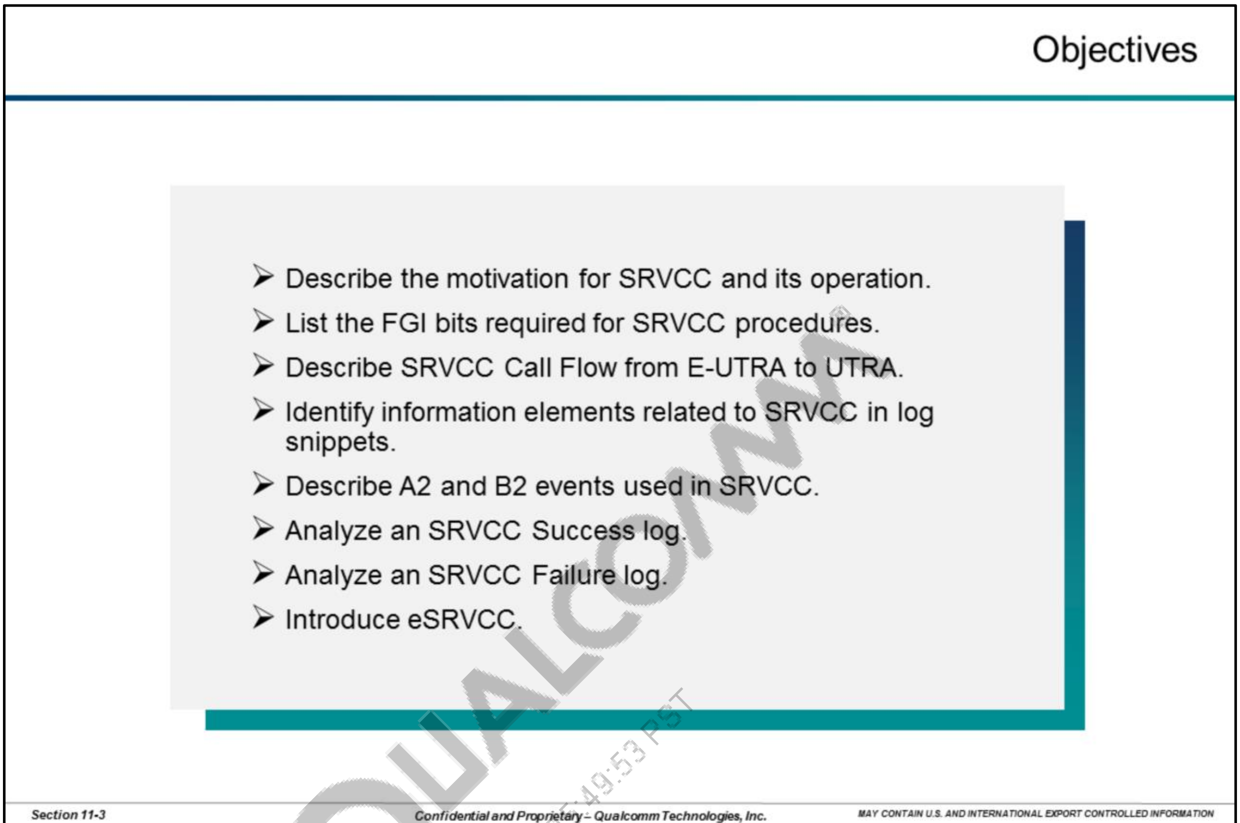
Notes


Objectives
Describe the motivation for SRVCC and its operation.
List the FGI bits required for SRVCC procedures.
Describe SRVCC Call Flow from E-UTRA to UTRA.
Identify information elements related to SRVCC in log snippets.
Describe A2 and B2 events used in SRVCC.
Analyze an SRVCC Success log.
Analyze an SRVCC Failure log.
Introduce eSRVCC.
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Notes

Topic Map

- **SRVCC Motivation**
- UE Capability Information
- SRVCC Operation
- SRVCC Failure
- eSRVCC

Notes

SRVCC

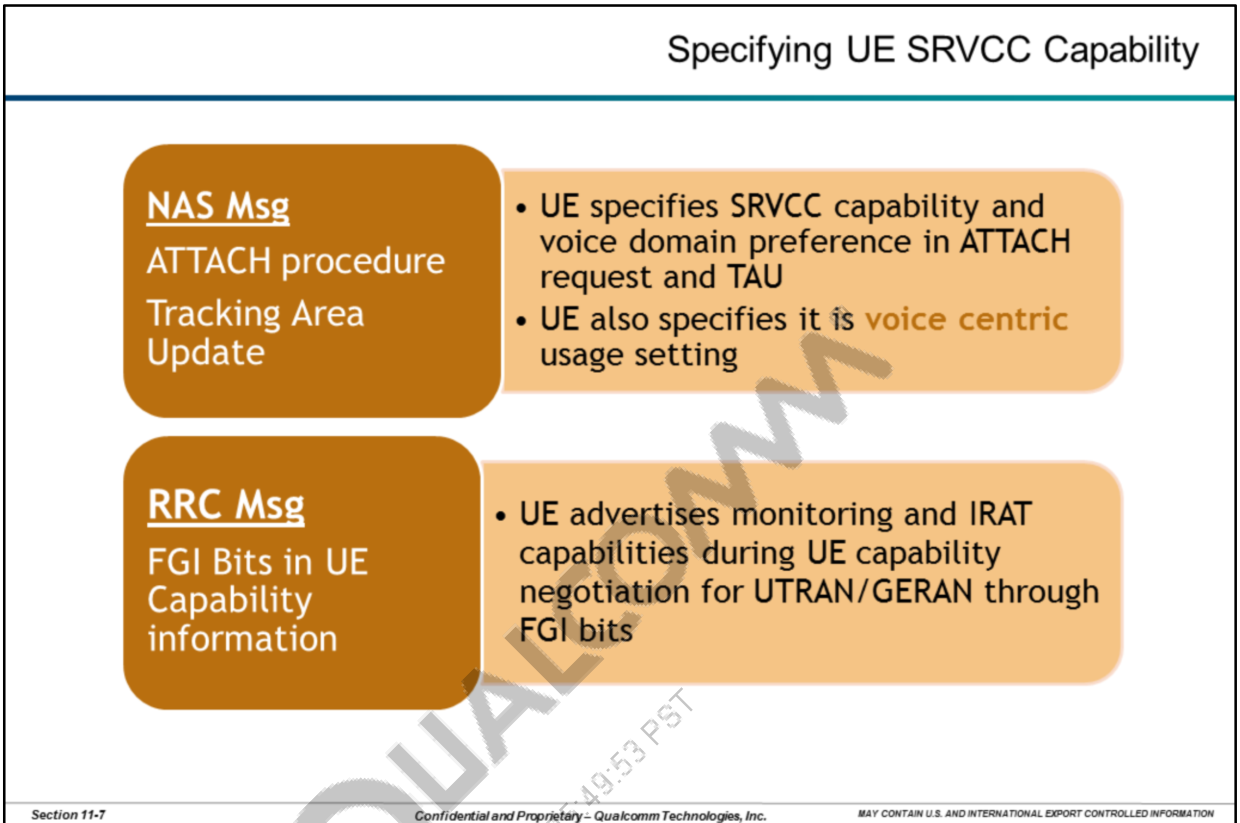
- SRVCC facilitates transition of a PS voice call from a VoIP/IMS domain to a legacy CS domain with minimal interruption.
  - Maintains voice call continuity
  - Voice call anchored in IMS domain
  - PS to PS session HO possible
- SRVCC is triggered during IRAT handover from E-UTRAN to UTRAN, GERAN or CDMA 1X
- UE requires PS Voice preference for VoLTE.
- SRVCC is required to maintain voice call continuity from PS to CS during IRAT handover scenarios
  - SRVCC may also be required when UE has CS voice preference (CSFB) and PS voice preference is secondary
    - If Combined Attach fails, EPC sends accept for PS Attach, in which case a VoIP/IMS capable UE initiates PS voice call

Notes

Topic Map

- SRVCC Motivation
- **UE Capability Information**
- SRVCC Operation
- SRVCC Failure
- eSRVCC

Notes


Specifying UE SRVCC Capability
NAS Msg
ATTACH procedure
Tracking Area Update
• UE specifies SRVCC capability and voice domain preference in ATTACH request and TAU
• UE also specifies it is voice centric usage setting
RRC Msg
FGI Bits in UE Capability information
• UE advertises monitoring and IRAT capabilities during UE capability negotiation for UTRAN/GERAN through FGI bits
Section 11-7
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Notes

SRVCC to UTRAN FGI Bits

FGI Bit	Description	Comment
8	EUTRA to UTRA CELL_DCH PS handover	Can only be set to 1 if the UE has set bit number 22 to '1'
9	EUTRA to GERAN GSM_Dedicated handover	Can only be set to 1 if the UE has set bit number 23 to '1'
15	Measurement reporting event: Event B1 - Neighbor > threshold	Can only be set to 1 if the UE has set at least one of the bit numbers 22, 23, 24, or 26 to '1'
22	UTRAN measurements, reporting, and measurement reporting event B2 in E-UTRA connected mode	
23	GERAN measurements, reporting, and measurement reporting event B2 in E-UTRA connected mode	
27	EUTRA to UTRA CELL_DCH CS handover	Can only be set to 1 if the UE has bit 8 set to '1'

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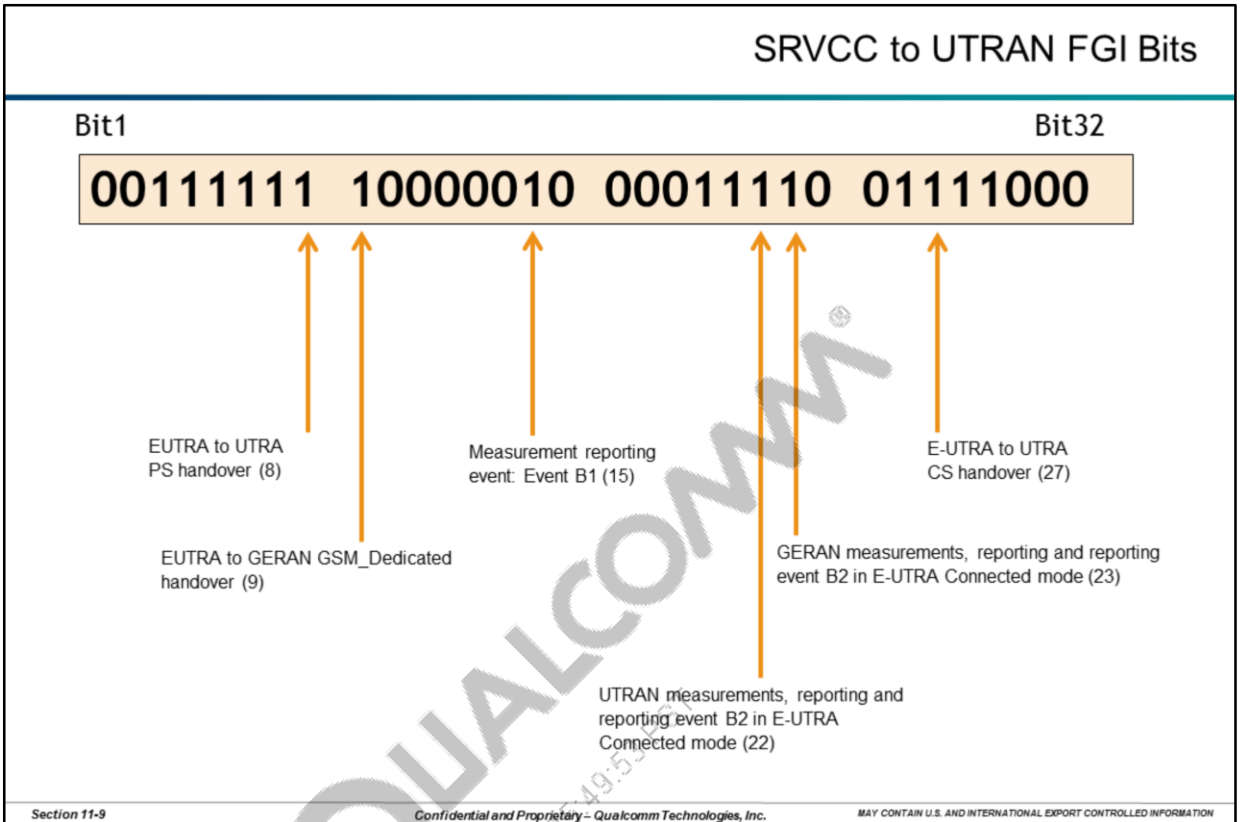
SRVCC to UTRAN FGI Bits

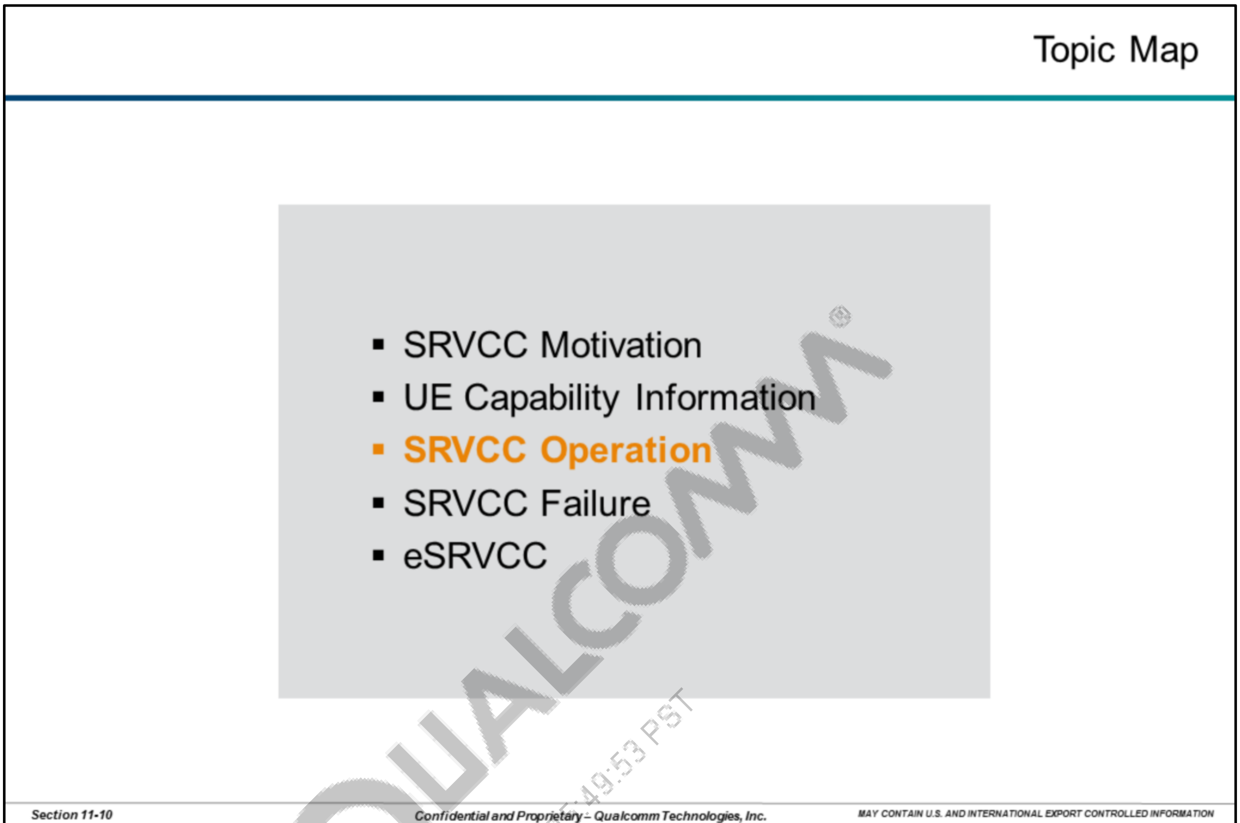
The UE shall also advertise during capability negotiation that it can monitor UTRAN and GERAN networks while in the RRC Connected state by:

- Including GERAN MS Class Mark 3 if GERAN access is supported
- Including MS Class Mark 2 if GERAN or UTRAN access or both are supported



SRVCC to UTRAN FGI Bits

This slide shows the SRVCC to UTRAN Feature Group Indicators (FGIs) positioning in the FGI bitmask.


Topic Map
SRVCC Motivation
UE Capability Information
SRVCC Operation
SRVCC Failure
eSRVCC
Section 11-10
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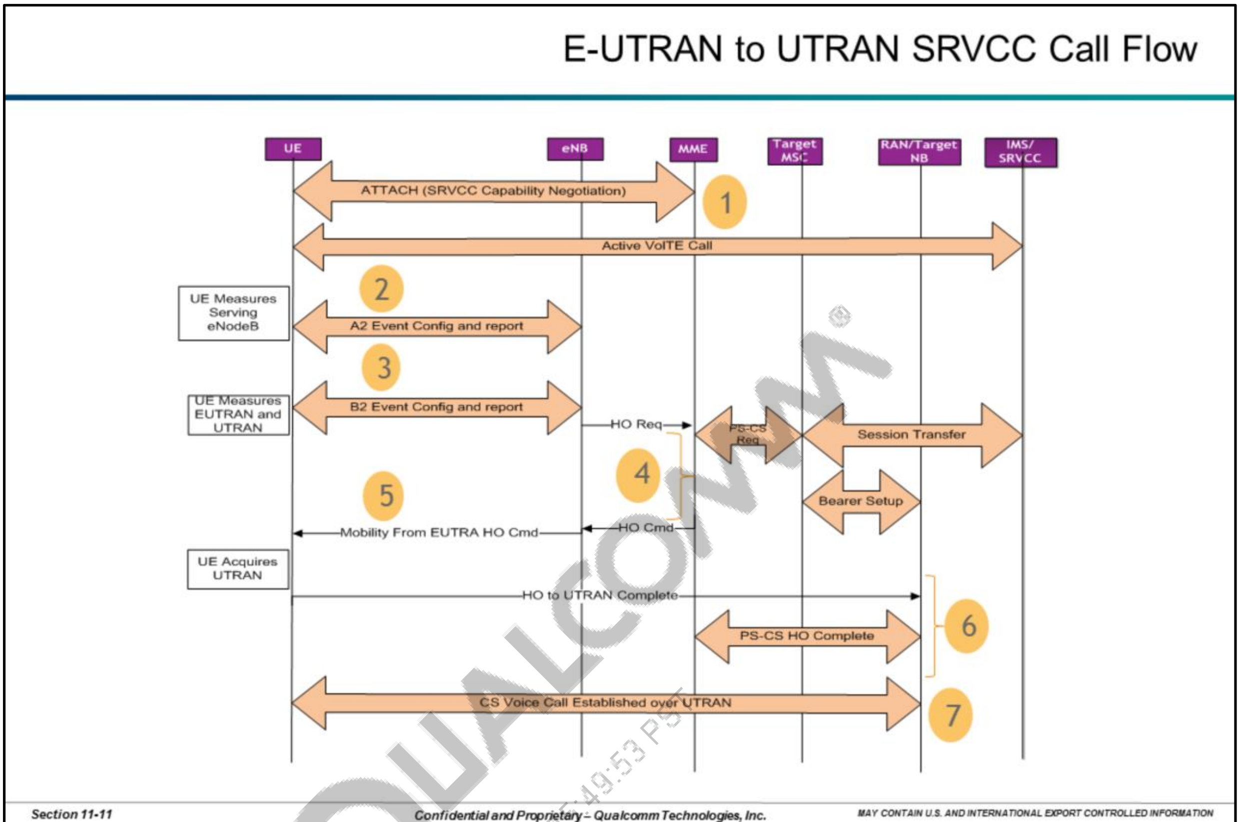
Notes



E-UTRAN to UTRAN SRVCC Call Flow

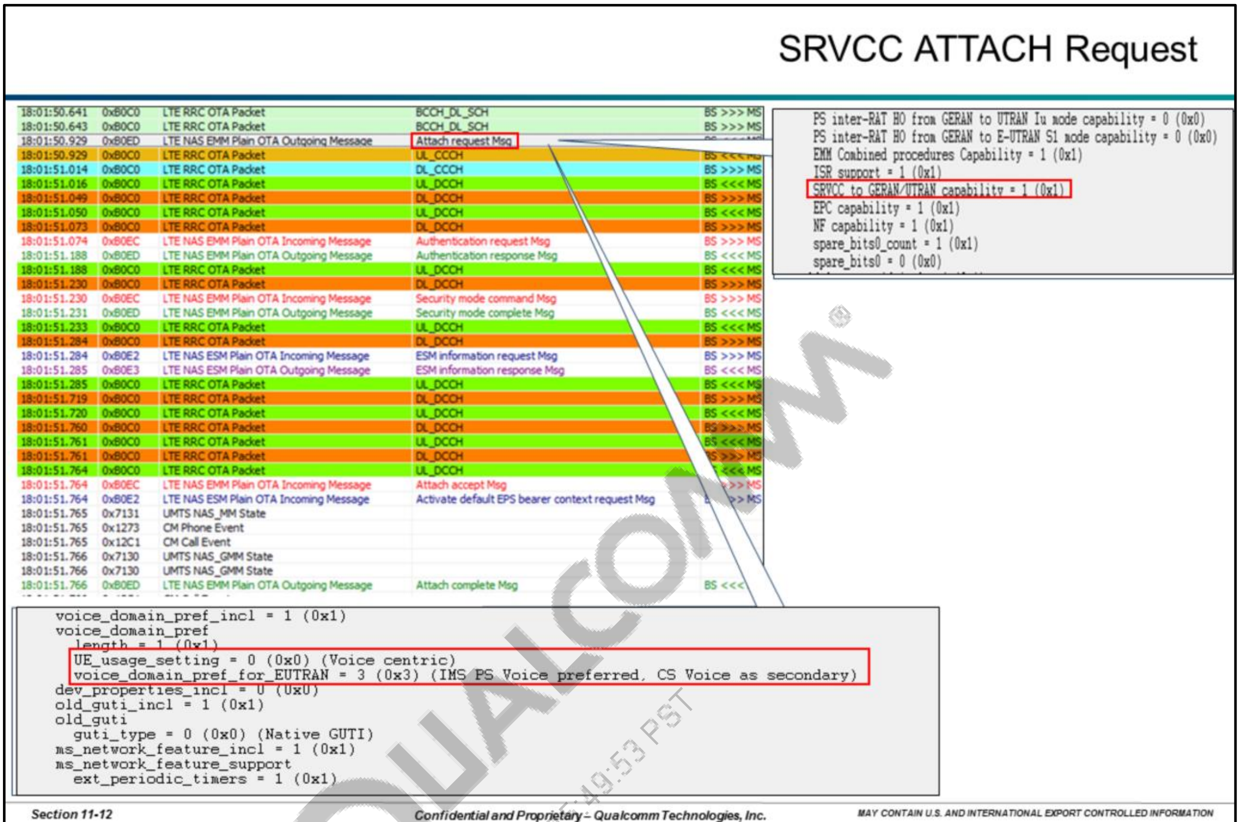
For a VoLTE call, the UE initiates an IMS multimedia session and uses only PS media flow. The request is forwarded to S-CSCF and the session is anchored at SCC AS to enable Session Transfer. The call flow steps are:

1. SRVCC capability negotiation during attach, UE capability Inquiry, and UE establishes PS VoIP call.

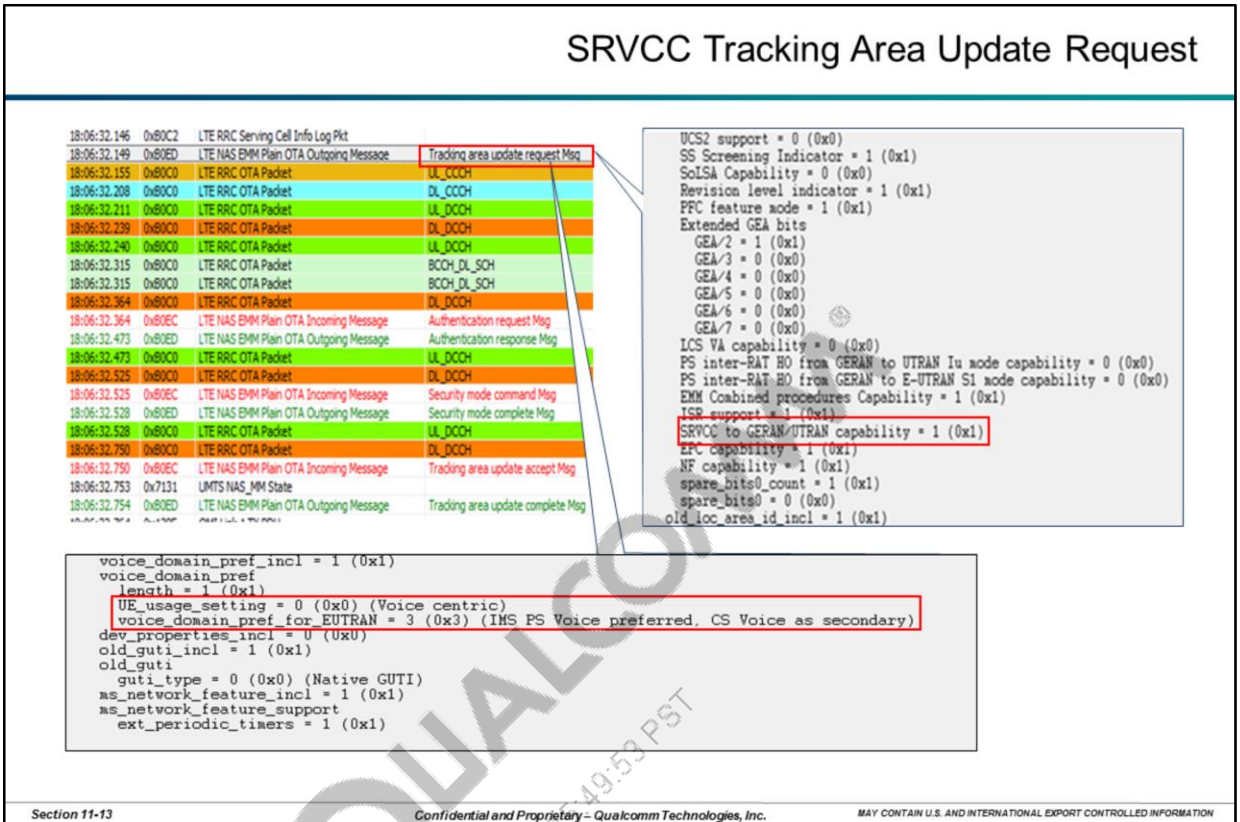
   SRVCC STN (Session Transfer Number) along with other information are downloaded to MME from HSS during the E-UTRAN attach procedure, and these are used by MSC for enabling PS-CS service continuity of IMS multimedia sessions.

2. UE measures the Serving Cell and reports an A2 event as the Serving Cell falls below a certain threshold.
3. Network configures UE with UTRAN channel measurements and measurement gap information. UE reports B2 event to eNB as E-UTRAN Serving Cell falls below a certain threshold and UTRAN Cell becomes better than another threshold.
4. E-UTRAN indicates to MME that this is an SRVCC handover.
   - MME sends a PS-CS request to UTRAN MSC enhanced with SRVCC capabilities along with IMSI, SRVCC STN, and other information.
   - The MSC initiates the SRVCC handover preparations and also initiates the SRVCC session transfer with IMS domain to maintain Voice call continuity. MSC then sends a PS-CS response to MME once preparations are complete on CS side.
5. eNB sends E-UTRAN to UTRAN IRAT HO command to UE.
6. UE acquires UTRAN and completes handover.
7. CS Voice call is established over UTRAN.

Section 11: Inter-RAT Handover: Single Radio Voice Call Continuity (SRVCC) to UTRAN



Notes


SRVCC Tracking Area Update Request
18:06:32.146 0xB0C2 LTE RRC Serving Cell Info Log Pkt
18:06:32.149 0xB0ED LTE NAS EMM Plain OTA Outgoing Message Tracking area update request Msg
18:06:32.155 0xB0C0 LTE RRC OTA Packet UL_CCCH
18:06:32.208 0xB0C0 LTE RRC OTA Packet DL_CCCH
18:06:32.211 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:06:32.239 0xB0C0 LTE RRC OTA Packet DL_DCCH
18:06:32.240 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:06:32.315 0xB0C0 LTE RRC OTA Packet BCCH_DL_SCH
18:06:32.315 0xB0C0 LTE RRC OTA Packet BCCH_DL_SCH
18:06:32.364 0xB0C0 LTE RRC OTA Packet DL_DCCH
18:06:32.364 0xB0EC LTE NAS EMM Plain OTA Incoming Message Authentication request Msg
18:06:32.473 0xB0ED LTE NAS EMM Plain OTA Outgoing Message Authentication response Msg
18:06:32.473 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:06:32.525 0xB0C0 LTE RRC OTA Packet DL_DCCH
18:06:32.525 0xB0EC LTE NAS EMM Plain OTA Incoming Message Security mode command Msg
18:06:32.528 0xB0ED LTE NAS EMM Plain OTA Outgoing Message Security mode complete Msg
18:06:32.528 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:06:32.750 0xB0C0 LTE RRC OTA Packet DL_DCCH
18:06:32.750 0xB0EC LTE NAS EMM Plain OTA Incoming Message Tracking area update accept Msg
18:06:32.753 0x7131 UMTS NAS_MM State
18:06:32.754 0xB0ED LTE NAS EMM Plain OTA Outgoing Message Tracking area update complete Msg
UCS2 support = 0 (0x0)
SS Screening Indicator = 1 (0x1)
SoLSA Capability = 0 (0x0)
Revision level indicator = 1 (0x1)
PFC feature mode = 1 (0x1)
Extended GEA bits
GEA/2 = 1 (0x1)
GEA/3 = 0 (0x0)
GEA/4 = 0 (0x0)
GEA/5 = 0 (0x0)
GEA/6 = 0 (0x0)
GEA/7 = 0 (0x0)
LCS VA capability = 0 (0x0)
PS inter-RAT HO from GERAN to UTRAN Iu mode capability = 0 (0x0)
PS inter-RAT HO from GERAN to E-UTRAN S1 mode capability = 0 (0x0)
EMM Combined procedures Capability = 1 (0x1)
ISR support = 1 (0x1)
SRVCC to GERAN/UTRAN capability = 1 (0x1)
EPC capability = 1 (0x1)
NF capability = 1 (0x1)
spare_bits0_count = 1 (0x1)
spare_bits0 = 0 (0x0)
old_loc_area_id_incl = 1 (0x1)
voice_domain_pref_incl = 1 (0x1)
voice_domain_pref
length = 1 (0x1)
UE_usage_setting = 0 (0x0) (Voice centric)
voice_domain_pref_for_EUTRAN = 3 (0x3) (IMS PS Voice preferred, CS Voice as secondary)
dev_properties_incl = 0 (0x0)
old_guti_incl = 1 (0x1)
old_guti
guti_type = 0 (0x0) (Native GUTI)
ms_network_feature_incl = 1 (0x1)
ms_network_feature_support
ext_periodic_timers = 1 (0x1)
Section 11-13
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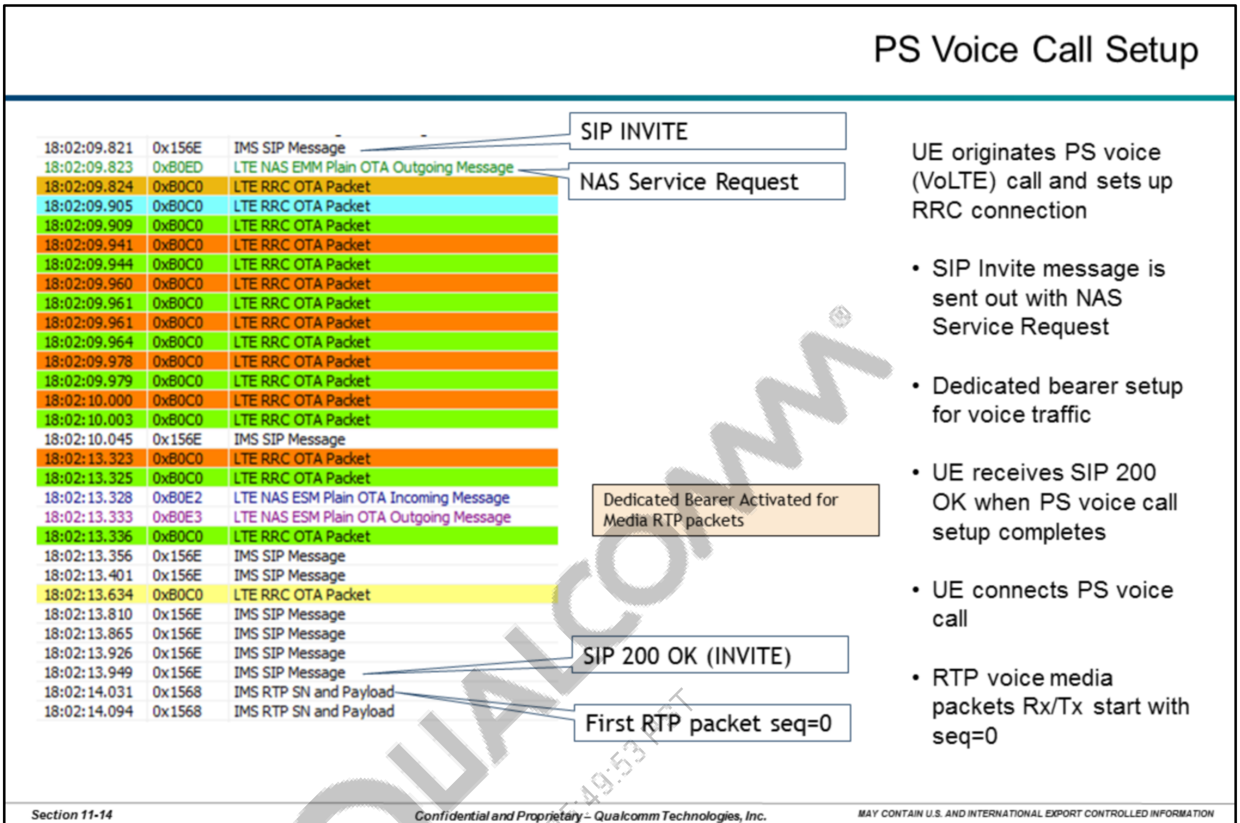
Notes


PS Voice Call Setup
18:02:09.821 0x156E IMS SIP Message
18:02:09.823 0xB0ED LTE NAS EMM Plain OTA Outgoing Message
18:02:09.824 0xB0C0 LTE RRC OTA Packet
18:02:09.905 0xB0C0 LTE RRC OTA Packet
18:02:09.909 0xB0C0 LTE RRC OTA Packet
18:02:09.941 0xB0C0 LTE RRC OTA Packet
18:02:09.944 0xB0C0 LTE RRC OTA Packet
18:02:09.960 0xB0C0 LTE RRC OTA Packet
18:02:09.961 0xB0C0 LTE RRC OTA Packet
18:02:09.961 0xB0C0 LTE RRC OTA Packet
18:02:09.964 0xB0C0 LTE RRC OTA Packet
18:02:09.978 0xB0C0 LTE RRC OTA Packet
18:02:09.979 0xB0C0 LTE RRC OTA Packet
18:02:10.000 0xB0C0 LTE RRC OTA Packet
18:02:10.003 0xB0C0 LTE RRC OTA Packet
18:02:10.045 0x156E IMS SIP Message
18:02:13.323 0xB0C0 LTE RRC OTA Packet
18:02:13.325 0xB0C0 LTE RRC OTA Packet
18:02:13.328 0xB0E2 LTE NAS ESM Plain OTA Incoming Message
18:02:13.333 0xB0E3 LTE NAS ESM Plain OTA Outgoing Message
18:02:13.336 0xB0C0 LTE RRC OTA Packet
18:02:13.356 0x156E IMS SIP Message
18:02:13.401 0x156E IMS SIP Message
18:02:13.634 0xB0C0 LTE RRC OTA Packet
18:02:13.810 0x156E IMS SIP Message
18:02:13.865 0x156E IMS SIP Message
18:02:13.926 0x156E IMS SIP Message
18:02:13.949 0x156E IMS SIP Message
18:02:14.031 0x1568 IMS RTP SN and Payload
18:02:14.094 0x1568 IMS RTP SN and Payload
SIP INVITE
NAS Service Request
Dedicated Bearer Activated for Media RTP packets
SIP 200 OK (INVITE)
First RTP packet seq=0
UE originates PS voice (VoLTE) call and sets up RRC connection
• SIP Invite message is sent out with NAS Service Request
• Dedicated bearer setup for voice traffic
• UE receives SIP 200 OK when PS voice call setup completes
• UE connects PS voice call
• RTP voice media packets Rx/Tx start with seq=0
Section 11-14
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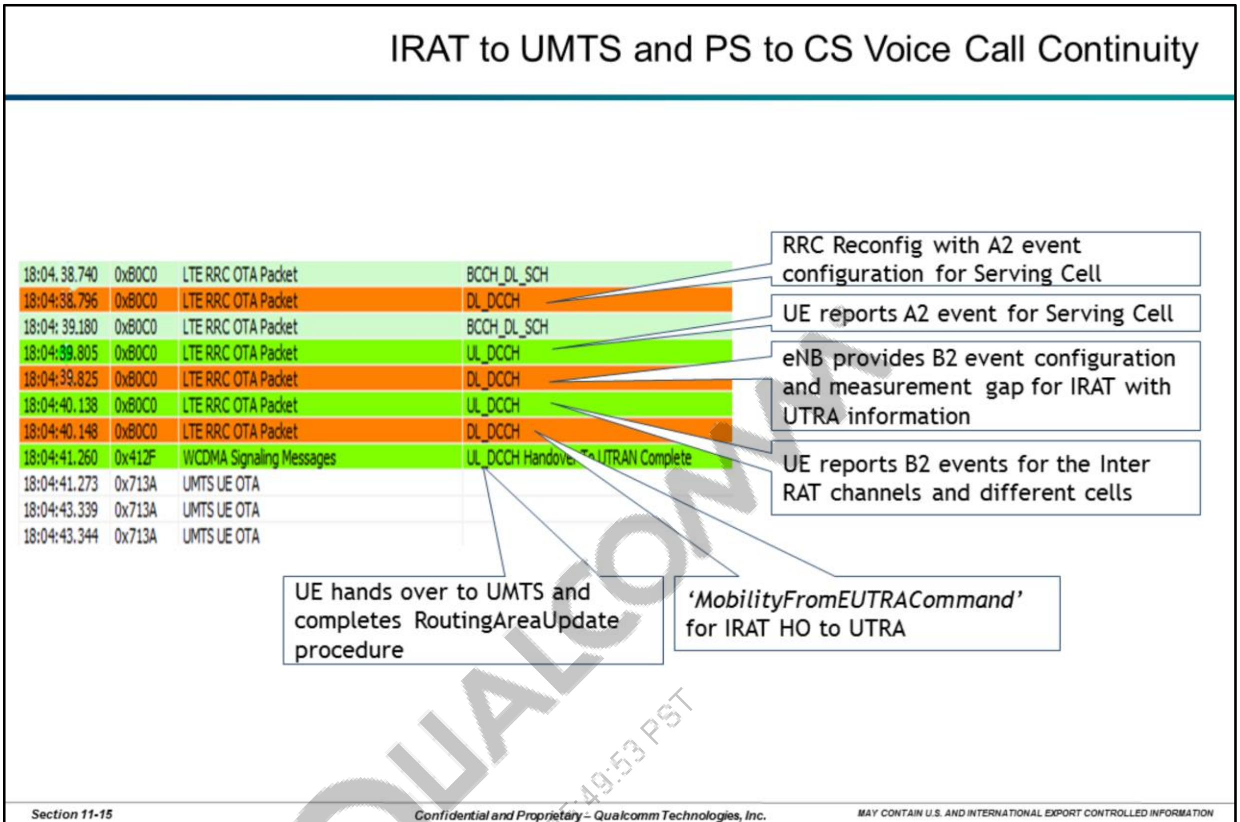
Notes

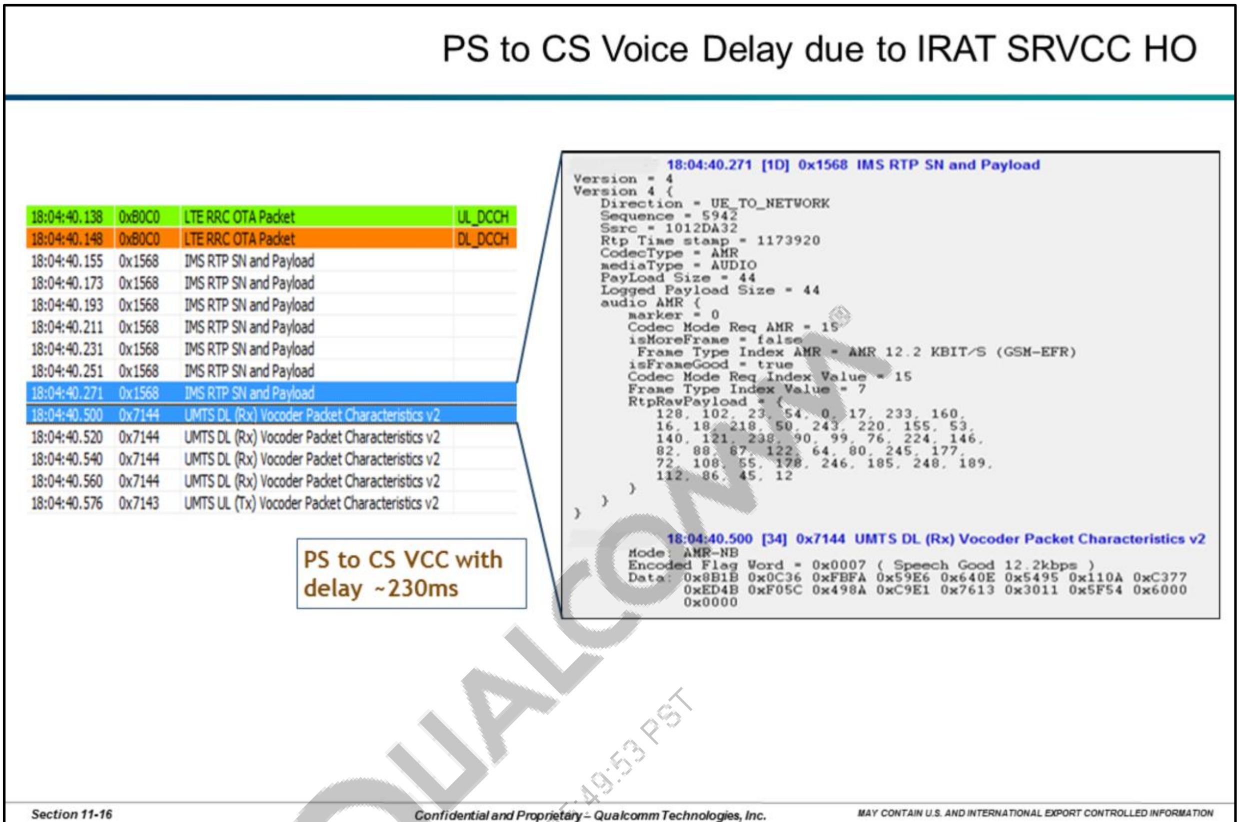


IRAT to UMTS and PS to CS Voice Call Continuity

SRVCC PS → CS switch can be with or without PS handovers.

- SRVCC→UTRAN without PS Handover: Data calls are not transferred to the UTRAN PS domain.
  - The UE shall reestablish the PS bearers after performing a routing area update after successful handover to the target.

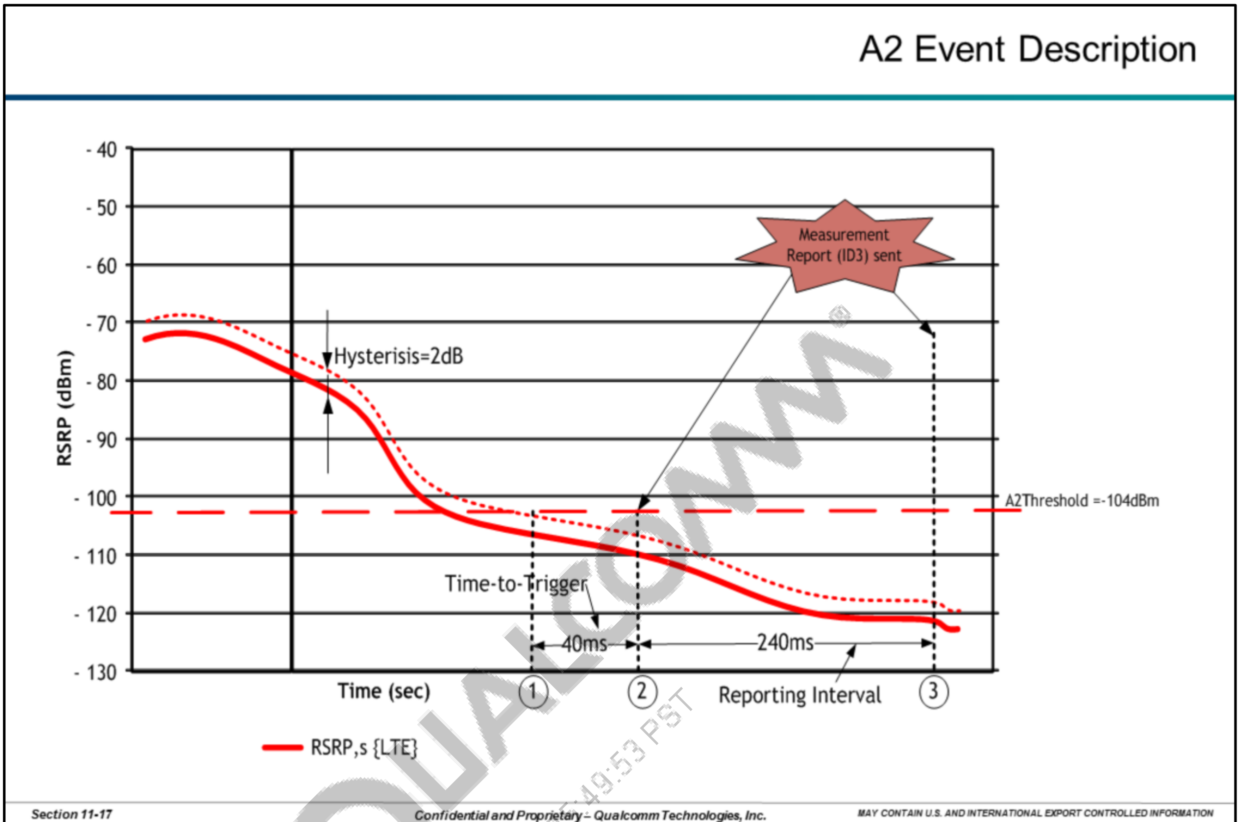
- SRVCC→UTRAN with PS Handover: Data bearers/non-voice bearers occur in parallel and are established during the handover.



PS to CS Voice Delay due to IRAT SRVCC HO

This slide shows the delay incurred due to IRAT SRVCC handover to CS domain.

In this particular case, PS to CS Voice Call Continuity is maintained with a small User Plane interruption of ~230ms.



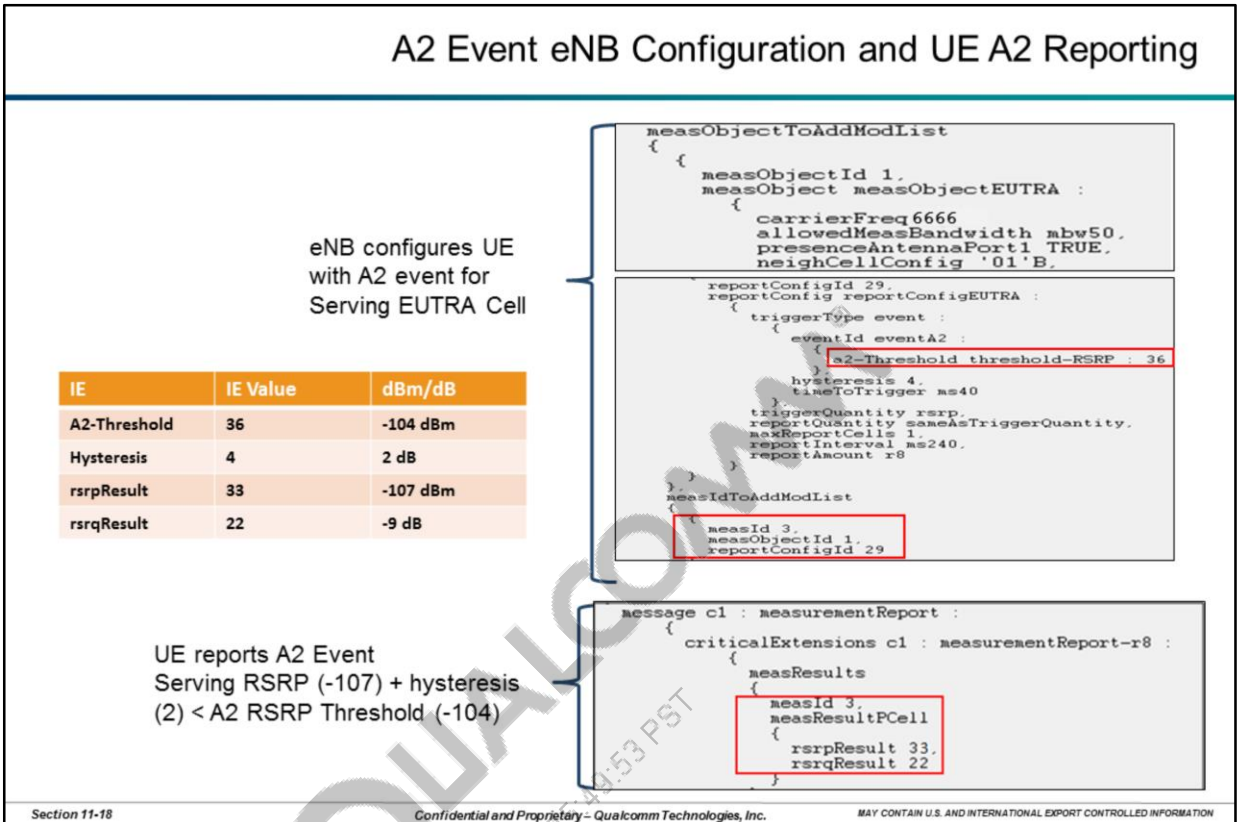
A2 Event Description

This slide describes the A2 Event with LTE Serving Cell RSRP variations noted at three different time instances on the Time Axis.

1. At Time instance 1, the LTE Serving Cell RSRP falls below the pre-defined A2 Threshold of -104dBm.
2. At Time instance 2, Measurement reporting by the UE is triggered after the Time-to-Trigger (TTT) expires.
3. At Time instance 3, Measurement Reporting Interval (240ms) expires.

Details on the IEs used for A2 Event Configuration and Reporting are mentioned in the next slide.

Upon reception of the A2 Measurement report, the network configures the UE with UTRAN channel measurements and measurement gap information. This is discussed in detail in upcoming slides.



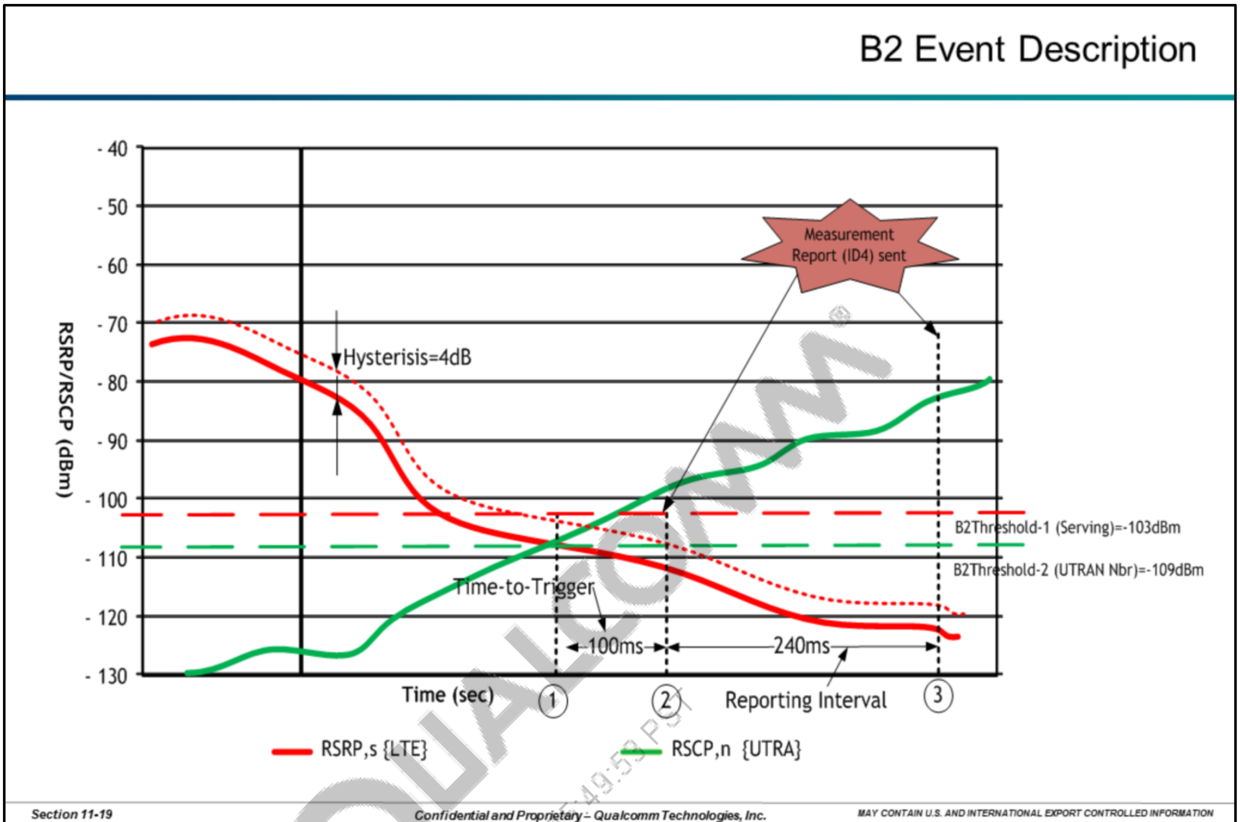
A2 Event eNB Configuration and UE A2 Reporting

Useful formulae :

RSRP (dBm) = IE value -140

RSRQ (dB) = [IE value – 40]/2

Hysteresis (dB) = IE value/2



B2 Event Description

This slide describes the B2 Event with EUTRA (LTE) Serving Cell RSRP and UTRA Neighbor Cell RSCP variations noted at three different time instances on the Time Axis.

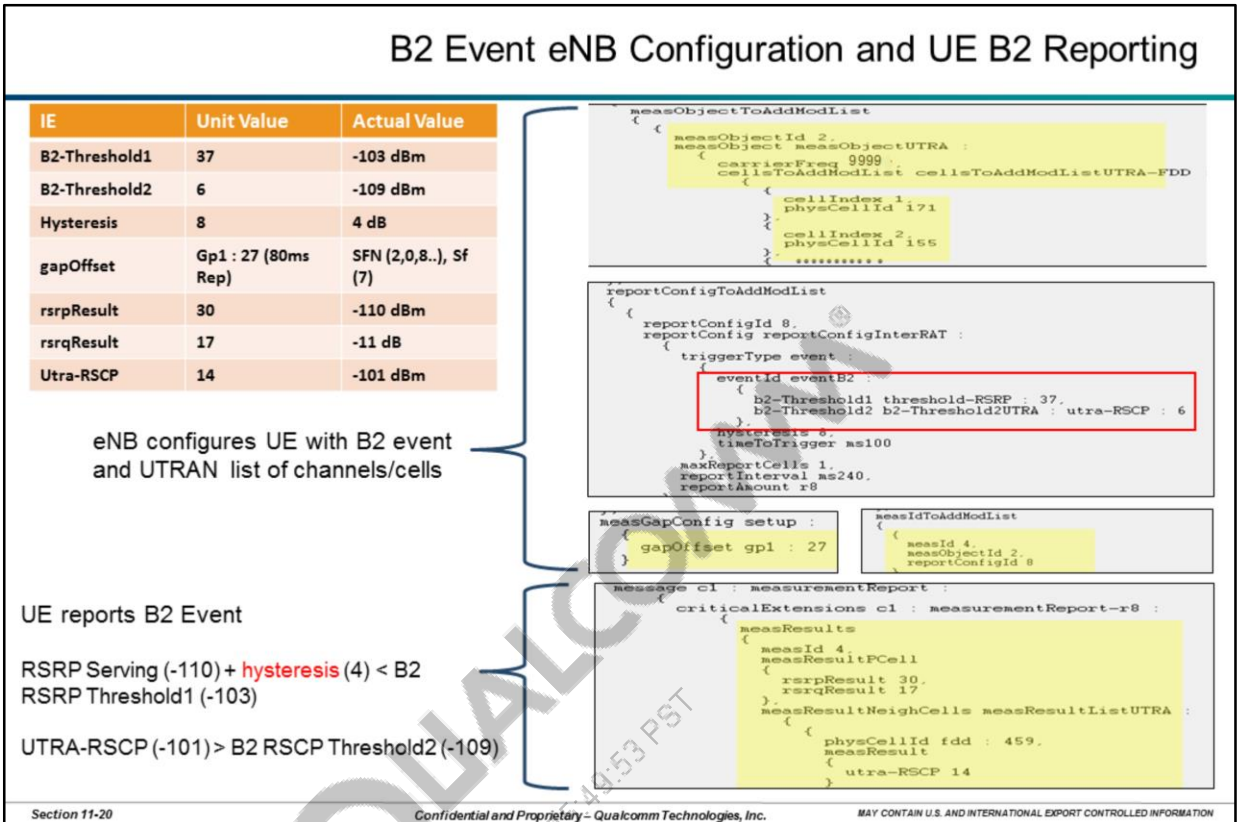
1. At Time instance 1, the EUTRA Serving Cell RSRP falls below the pre-defined B2 Threshold 1 of -103dBm and the UTRAN Neighbor Cell falls below the pre-defined B2 Threshold 2 of -109dBm.

2. At Time instance 2, Measurement reporting by the UE is triggered after the Time-to-Trigger (TTT) expires.

3. At Time instance 3, Measurement Reporting Interval (240ms) expires.

When the eNB receives the B2 Measurement report, it initiates the SRVCC procedure.

Details on the IEs used for B2 Event Configuration and Reporting are mentioned in the next slide.



B2 Event eNB Configuration and UE B2 Reporting

Useful formulae :

RSRP (dBm) = IE value -140

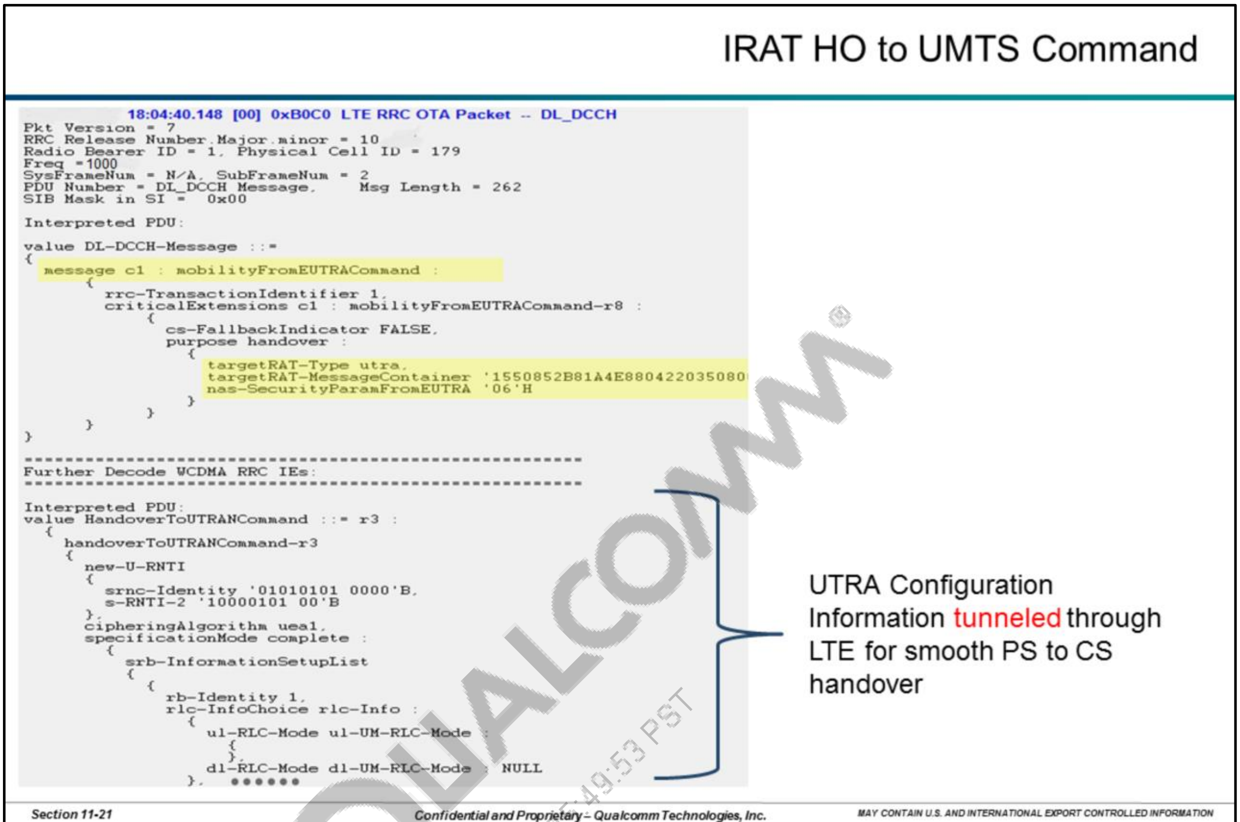
RSRQ (dB) = [IE value – 40]/2

Hysteresis (dB) = IE value/2

RSCP (dBm) = IE value – 116

gapOffset : (SFN Mod T = FLOOR [GPOff IE value/10], sf = GPOff IE value mod 10)

Gp0 = 40 ms period, gp1 = 80 ms period


IRAT HO to UMTS Command
18:04:40.148 [00] 0xB0C0 LTE RRC OTA Packet -- DL_DCCH
Pkt Version = 7
RRC Release Number.Major.minor = 10
Radio Bearer ID = 1, Physical Cell ID = 179
Freq =1000
SysFrameNum = N/A, SubFrameNum = 2
PDU Number = DL_DCCH Message, Msg Length = 262
SIB Mask in SI = 0x00
Interpreted PDU:
value DL-DCCH-Message ::=
{
message c1 : mobilityFromEUTRACommand :
{
rrc-TransactionIdentifier 1,
criticalExtensions c1 : mobilityFromEUTRACommand-r8 :
{
cs-FallbackIndicator FALSE,
purpose handover :
{
targetRAT-Type utra,
targetRAT-MessageContainer '1550852B81A4E880422035080
nas-SecurityParamFromEUTRA '06'H
}
}
}
}
Further Decode WCDMA RRC IEs:
Interpreted PDU:
value HandoverToUTRANCommand ::= r3 :
{
handoverToUTRANCommand-r3
{
new-U-RNTI
{
srnc-Identity '01010101 0000'B,
s-RNTI-2 '10000101 00'B
},
cipheringAlgorithm uea1,
specificationMode complete :
{
srb-InformationSetupList
{
{
rb-Identity 1,
rlc-InfoChoice rlc-Info :
{
ul-RLC-Mode ul-UM-RLC-Mode :
{
},
dl-RLC-Mode dl-UM-RLC-Mode : NULL
}, ●●●●●●
UTRA Configuration Information tunneled through LTE for smooth PS to CS handover
Section 11-21
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Notes

Analysis Example: PS to CS Voice Call Switch

Log Analysis Procedure: PS to CS Voice Call Switch

Open File: 11-01-SRVCC

Notes

ATTACH Procedure: Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	Attach Request	0xB0ED	18:01:50.929	UE advertises SRVCC support
2	RRC Connection Request	0xB0C0	18:01:50.929	establishmentCause mo-Signalling
3	UE Capability Inquiry	0xB0C0	18:01:51.719	ue-CapabilityRequest set to 'EUTRA"
4	UE Capability Information	0xB0C0	18:01:51.720	FGI bits are properly set for SRVCC support
5	Attach Accept	0xB0EC	18:01:51.764	Activate default EPS bearer context request; IP addresses; IMS VoPS set to '1'
6	RRC Connection Release	0xB0C0	18:02:06.501	

Notes

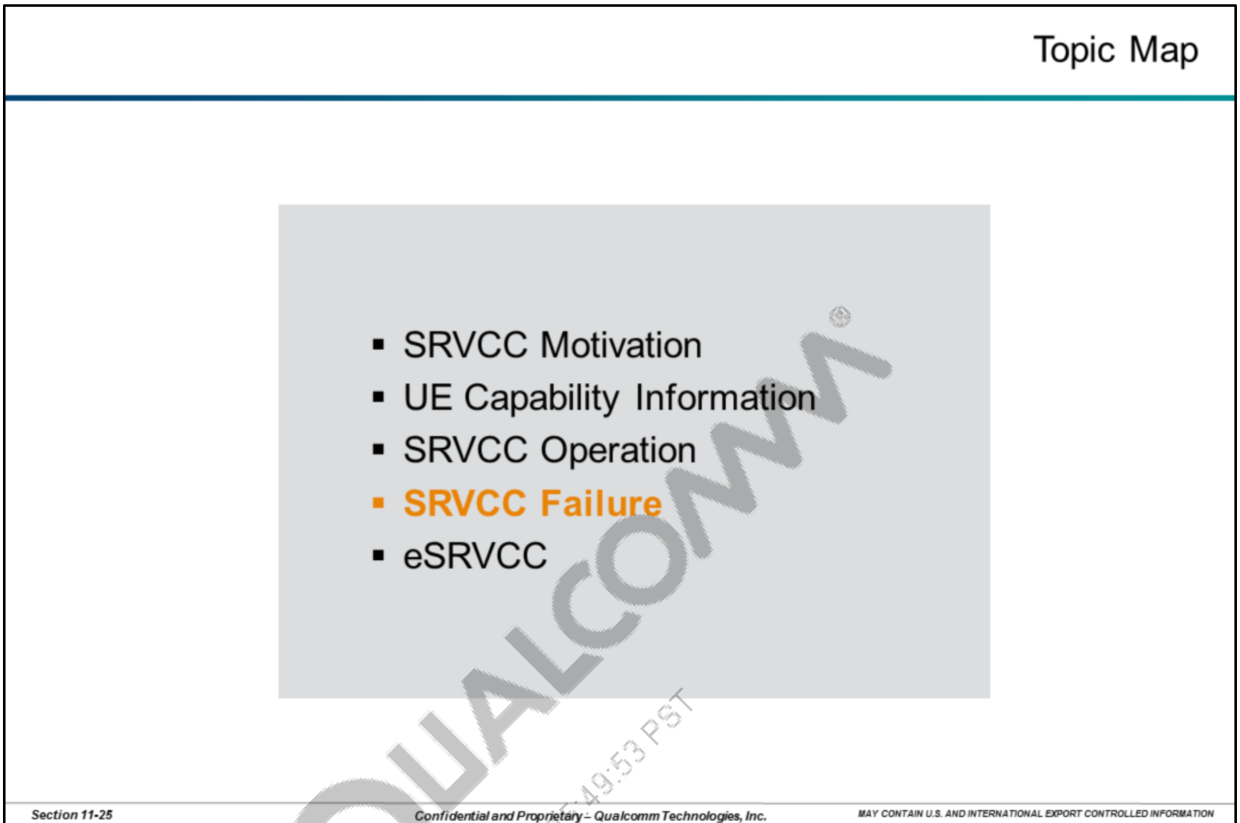
SRVCC : PS to CS Voice Call Continuity - Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	IMS SIP Message	0x156E	18:02:09.821	UE sends IMS_SIP_INVITE to set up PS Voice Call
2	NAS EMM Outgoing Message	0xB0ED	18:02:09.823	Service Request to set up PS Voice Call
3	RRC Connection Request	0xB0C0	18:02:09.824	Establishment Cause: mo-Data
4	NAS ESM Incoming Message	0xB0E2	18:02:13.328	eNB commands UE to activate dedicated EPS bearer context request. QCI set to 1 and GBR rates are set
5	NAS ESM Outgoing Message	0xB0E2	18:02:13.333	UE activates dedicated EPS bearer context request
6	RRC Connection Reconfiguration	0xB0C0	18:04:38.796	A2 Event configuration
7	RRC Measurement Report	0xB0C0	18:04:39.805	A2 Event Measurement Report
8	RRC Connection Reconfiguration	0xB0C0	18:04:39.825	B2 Event and measurement gap configuration (UTRA Channel/Cell Info)
9	RRC Measurement Report	0xB0C0	18:04:40.138	B2 Event Measurement Report
10	MobilityFrom EUTRACommand	0xB0C0	18:04:40.148	IRAT HO Command to UTRAN
11	UL_DCCH HO to UTRAN complete	0x412F	18:04:41.260	IRAT HO to UTRAN complete
12	UMTS NAS MM State	0x7131	18:04:41.263	CS Voice Call Active
13	OMTS OTA UE	0x713A	18:04:41.273	RoutingAreaUpdate Request

Analysis Summary

The arrival of messages during logging could impact the order in which time stamps are shown.

If needed while analyzing a log file in the browser, use the menu "Edit" + "Find on this Page" (Ctrl+F) to find a specific timestamp.


Topic Map
SRVCC Motivation
UE Capability Information
SRVCC Operation
SRVCC Failure
eSRVCC
Section 11-25
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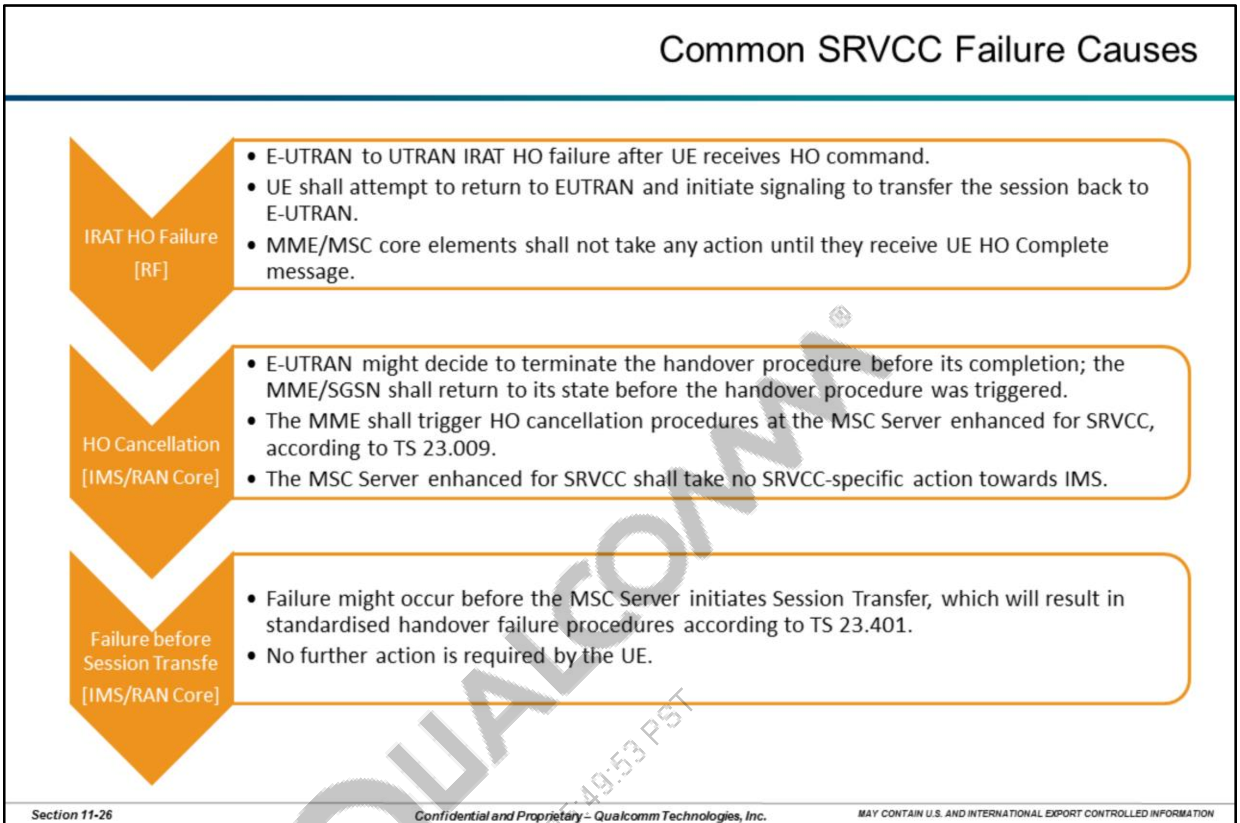
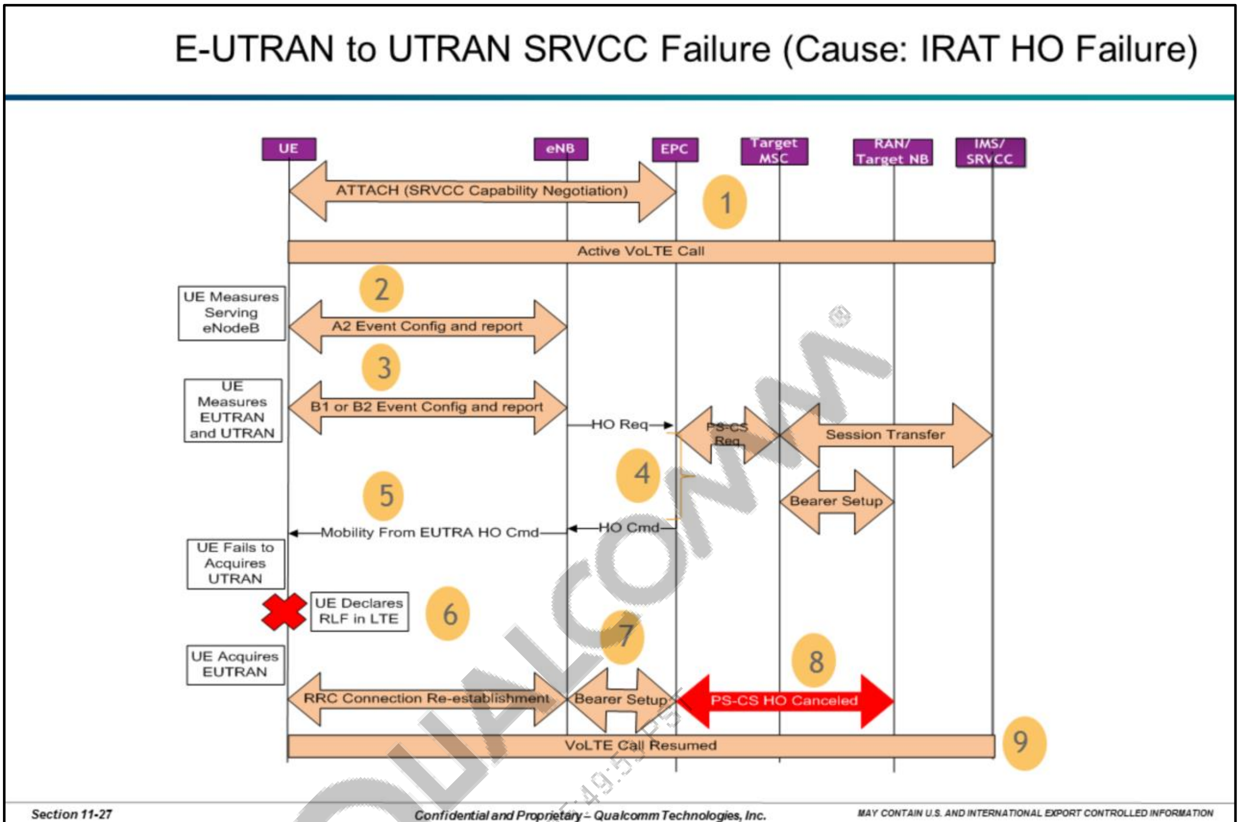
Notes



Reference

See TS 23.216 for further details.



E-UTRAN to UTRAN SRVCC Call Flow

For a VoLTE call, the UE initiates an IMS multimedia session and uses only PS media flow. The request is forwarded to S-CSCF and the session is anchored at SCC AS to enable Session Transfer. The call flow steps are:

1. SRVCC capability negotiation during attach, UE capability Inquiry, and UE establishes PS VoIP call.

   SRVCC STN (Session Transfer Number) along with other information are downloaded to MME from HSS during the E-UTRAN attach procedure, and these are used by MSC for enabling PS-CS service continuity of IMS multimedia sessions.

2. UE measures the Serving Cell and reports an A2 event as the Serving Cell falls below a certain threshold.

3. Network configures UE with UTRAN channel measurements and measurement gap information. UE reports B2 event to eNB as E-UTRAN Serving Cell falls below a certain threshold and UTRAN Cell becomes better than another threshold.

4. E-UTRAN indicates to MME that this is an SRVCC handover.

   - MME sends a PS-CS request to UTRAN MSC enhanced with SRVCC capabilities along with IMSI, SRVCC STN, and other information.
   - The MSC initiates the SRVCC handover preparations and also initiates the SRVCC session transfer with IMS domain to maintain Voice call continuity. MSC then sends a PS-CS response to MME once preparations are complete on CS side.

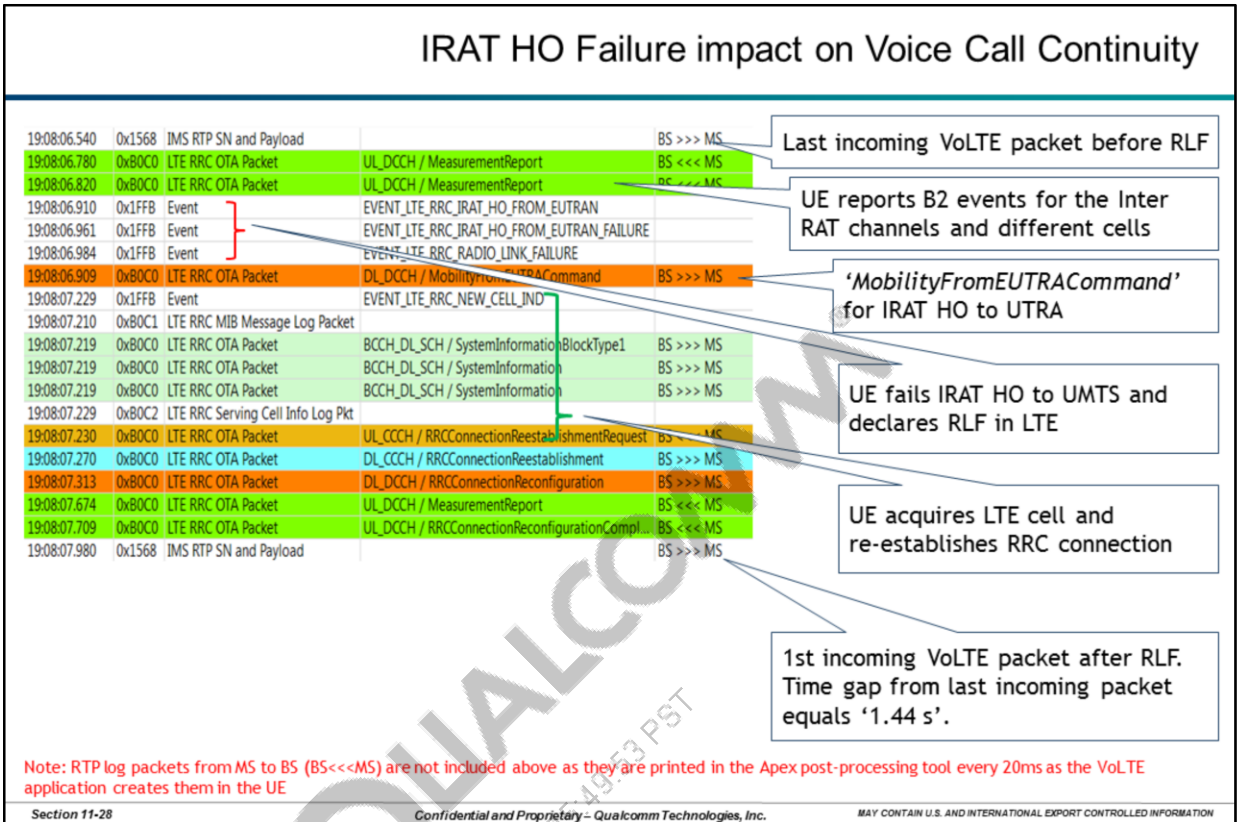
5. eNB sends E-UTRAN to UTRAN IRAT HO command to UE.

6. UE fails to acquires UTRAN and declares a Radio Link Failure.

7. UE attempts to return to E-UTRAN and execute RLF recovery procedure by acquiring an LTE cell, sending RRC Re-establishment request and sets up the required bearers.

8. PS-CS HO is canceled including the bearer setups. MME/MSC discover the UE has transferred back to E-UTRAN due to failure to acquire UMTS.

9. Once bearers are set up and the VoLTE session is transferred back to E-UTRAN, the VoLTE call can resume.


IRAT HO Failure impact on Voice Call Continuity
19:08:06.540 0x1568 IMS RTP SN and Payload BS >>> MS
19:08:06.780 0xB0C0 LTE RRC OTA Packet UL_DCCH / MeasurementReport BS <<< MS
19:08:06.820 0xB0C0 LTE RRC OTA Packet UL_DCCH / MeasurementReport
19:08:06.910 0x1FFB Event EVENT_LTE_RRC_IRAT_HO_FROM_EUTRAN
19:08:06.961 0x1FFB Event EVENT_LTE_RRC_IRAT_HO_FROM_EUTRAN_FAILURE
19:08:06.984 0x1FFB Event EVENT_LTE_RRC_RADIO_LINK_FAILURE
19:08:06.909 0xB0C0 LTE RRC OTA Packet DL_DCCH / Mobility EUTRACommand BS >>> MS
19:08:07.229 0x1FFB Event EVENT_LTE_RRC_NEW_CELL_IND
19:08:07.210 0xB0C1 LTE RRC MIB Message Log Packet
19:08:07.219 0xB0C0 LTE RRC OTA Packet BCCH_DL_SCH / SystemInformationBlockType1 BS >>> MS
19:08:07.219 0xB0C0 LTE RRC OTA Packet BCCH_DL_SCH / SystemInformation BS >>> MS
19:08:07.219 0xB0C0 LTE RRC OTA Packet BCCH_DL_SCH / SystemInformation BS >>> MS
19:08:07.229 0xB0C2 LTE RRC Serving Cell Info Log Pkt
19:08:07.230 0xB0C0 LTE RRC OTA Packet UL_CCCH / RRCConnectionReestablishmentRequest
19:08:07.270 0xB0C0 LTE RRC OTA Packet DL_CCCH / RRCConnectionReestablishment BS >>> MS
19:08:07.313 0xB0C0 LTE RRC OTA Packet DL_DCCH / RRCConnectionReconfiguration BS >>> MS
19:08:07.674 0xB0C0 LTE RRC OTA Packet UL_DCCH / MeasurementReport BS <<< MS
19:08:07.709 0xB0C0 LTE RRC OTA Packet UL_DCCH / RRCConnectionReconfigurationCompl... BS <<< MS
19:08:07.980 0x1568 IMS RTP SN and Payload BS >>> MS
Last incoming VoLTE packet before RLF
UE reports B2 events for the Inter RAT channels and different cells
'MobilityFromEUTRACommand' for IRAT HO to UTRA
UE fails IRAT HO to UMTS and declares RLF in LTE
UE acquires LTE cell and re-establishes RRC connection
1st incoming VoLTE packet after RLF. Time gap from last incoming packet equals '1.44 s'.
Note: RTP log packets from MS to BS (BS<<<MS) are not included above as they are printed in the Apex post-processing tool every 20ms as the VoLTE application creates them in the UE
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Notes

Key Considerations for IRAT HO

- It is important to ensure sufficient UMTS coverage at LTE coverage boundaries to mitigate IRAT HO failures.
- All thresholds (A2/B1/B2) related to IRAT HO should be configured optimally to prevent too late or too early handovers.
- UMTS inter-frequency handover stats can be examined to understand potential SRVCC failures due to IRAT HO failures.
- RTP timeout timer configuration is critical in mitigating VoLTE call drops.

Notes

Detailed Sequence of LTE Events

```
Selected Duration: 00:00:00.074 (0.07 sec)

19:08:06.910 [00] 0x1FFB Event -- EVENT_LTE_RRC_IRAT_HO_FROM_EUTRAN
19:08:06.910 Event  0 : EVENT_LTE_RRC_IRAT_HO_FROM_EUTRAN (ID=1615)  Payload = 0x00
        Payload String = RAT - Procedure = UTRA Handover

19:08:06.910 [00] 0x1FFB Event -- EVENT_LTE_RRC_STATE_CHANGE
19:08:06.910 Event  0 : EVENT_LTE_RRC_STATE_CHANGE (ID=1606)  Payload = 0x05
        Payload String = RRC State = Suspended

19:08:06.961 [00] 0x1FFB Event -- EVENT_LTE_RRC_IRAT_HO_FROM_EUTRAN_FAILURE
19:08:06.961 Event  0 : EVENT_LTE_RRC_IRAT_HO_FROM_EUTRAN_FAILURE (ID=1616)  Payload = 0x05
        Payload String = Status - Cause = Failed, Physical Channel Failure

19:08:06.984 [00] 0x1FFB Event -- EVENT_LTE_RRC_RADIO_LINK_FAILURE
19:08:06.984 Event  0 : EVENT_LTE_RRC_RADIO_LINK_FAILURE (ID=1608)  Payload = 0x01 00
        Payload String = Counter = 1

19:08:06.984 [00] 0x1FFB Event -- EVENT_LTE_RRC_RADIO_LINK_FAILURE_STAT
19:08:06.984 Event  0 : EVENT_LTE_RRC_RADIO_LINK_FAILURE_STAT (ID=1995)  Payload = 0x01 00 03 00 01 00
        Payload String = RLF Count since RRC Connected = 1, RLF Count since LTE Active = 3, RLF Cause = HO FAILURE

19:08:07.230 [00] 0xB0C0 LTE RRC OTA Packet -- UL_CCCH / RRCConnectionReestablishmentRequest
Pkt Version = 7
RRC Release Number.Major.minor = 10.7.1
Radio Bearer ID = 0, Physical Cell ID = 34
Freq = 932
SysFrameNum = N/A, SubFrameNum = 0
PDU Number = UL_CCCH Message,    Msg Length = 6
SIB Mask in SI =  0x00
```

- IRAT HO fails as UE is unable to acquire UMTS
- As per spec 36.331 UE returns to LTE, declares RLF and goes through RLF recovery or RRC Re-establishment process

Notes

Analysis Example: SRVCC Failure

Log Analysis Procedure: SRVCC Failure

Open File: 08-02-SRVCC_Failure

Notes

SRVCC Failure: IRAT HO Failure - Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	IMS RTP SN and payload	0x1568	19:08:06.540	Last packet sent from network to UE before RLF
2	MobilityFrom EUTRACommand	0xB0C0	19:08:06.909	IRAT HO Command to UTRAN
3	EVENT_LTE_RRC_IRAT_HO_FROM_EUTRAN_FAILURE	0X1FFB	19:08:06.961	HO Failure
4	EVENT_LTE_RRC_RADIO_LINK_FAILURE	0x1FFB	19:08:06.984	RLF Declared
5	EVENT_LTE_RRC_NEW_CELL_IND	0x1FFB	19:08:07.229	UE acquires new cell in LTE
6	RRCConnectionReestablishmentRequest	0cB0C0	19:08:07.230	UE reestablishes RRC Connection
7	IMS RTP SN and payload	0x1568	19:08:07.980	First packet sent from network to UE after RLF

Analysis Summary

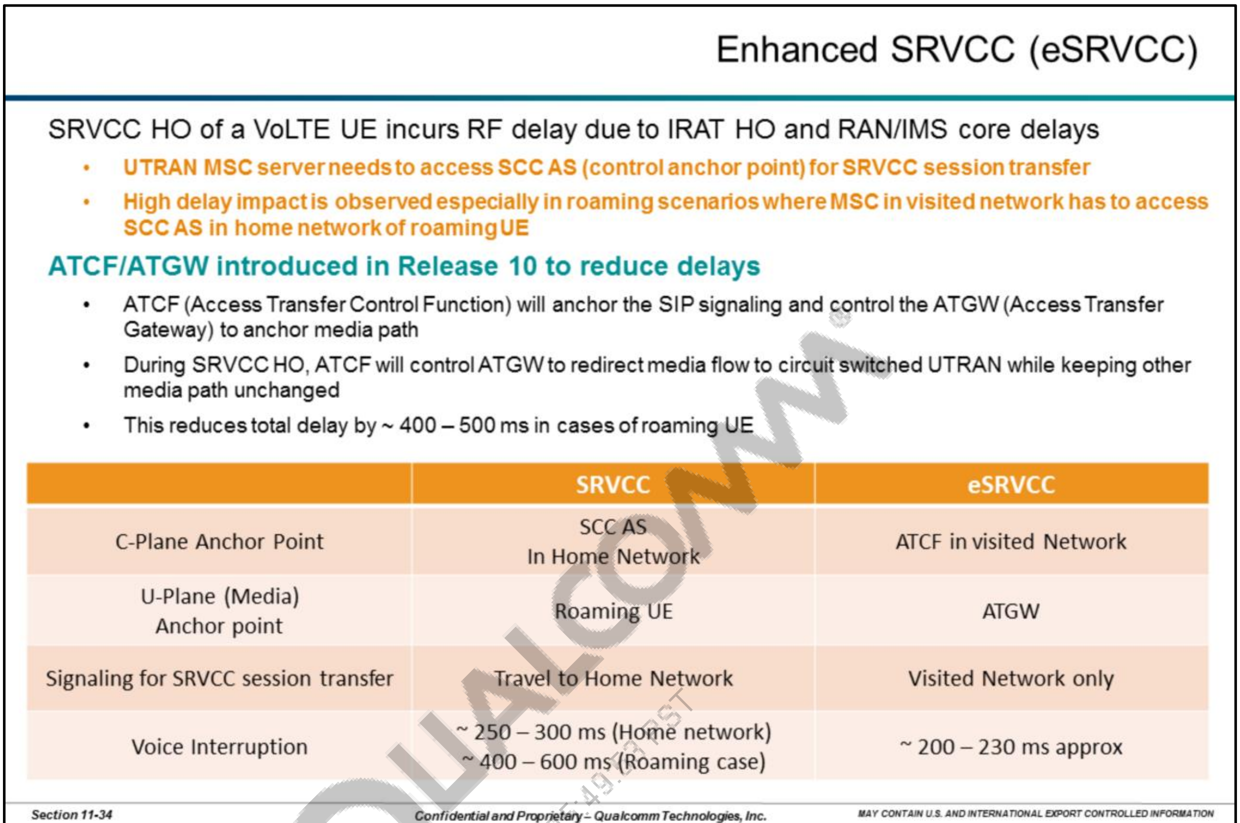
The arrival of messages during logging could impact the order in which time stamps are shown.

If needed while analyzing a log file in the browser, use the menu “Edit” + “Find on this Page” (Ctrl+F) to find a specific timestamp.

Topic Map

- SRVCC Motivation
- UE Capability Information
- SRVCC Operation
- SRVCC Failure
- **eSRVCC**

Notes

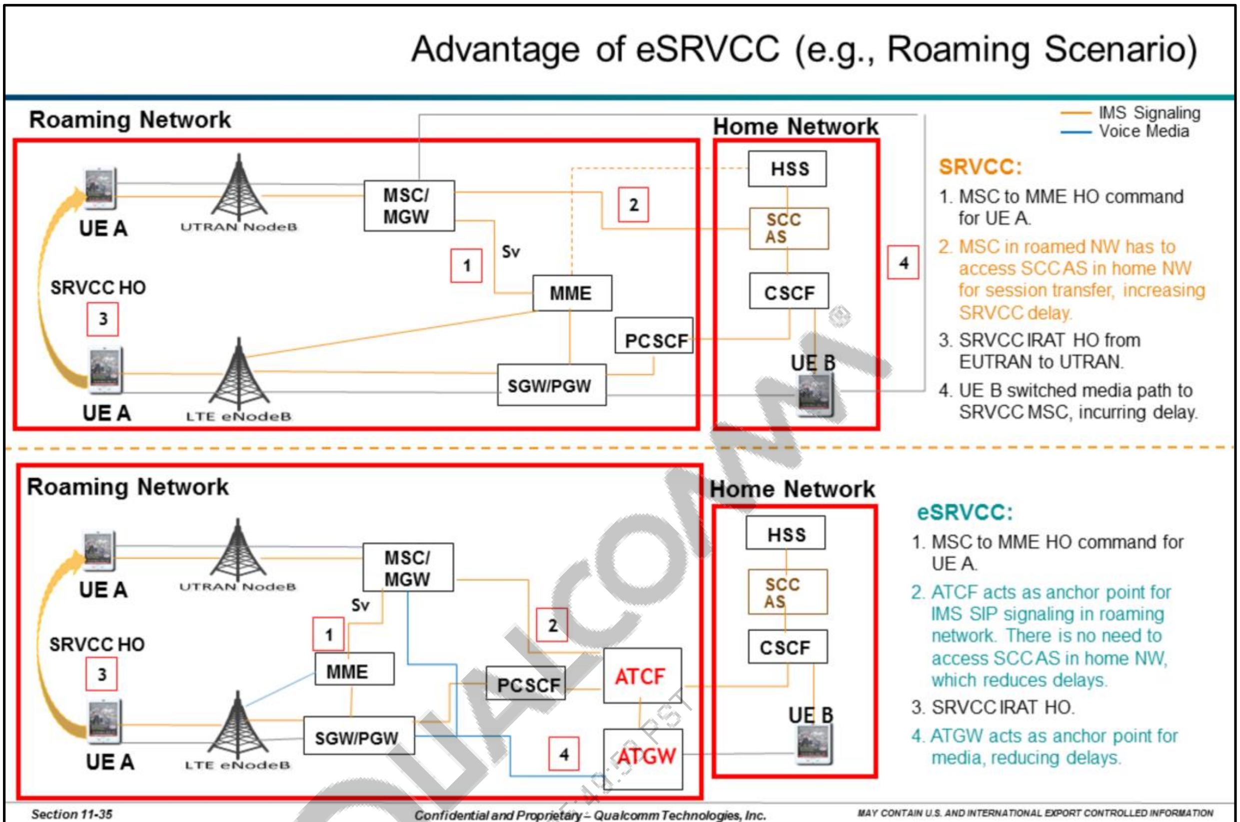


Enhanced SRVCC

IMS sessions from and to a UE are anchored at the SCC AS in the home IMS and may also be anchored at the ATCF in the serving (visited if roaming) network to provide Service Continuity for the user during transition between two Access Networks.

Release 8/9

- SRVCC call is anchored at the SCC AS, causing a total delay of 200 – 250 ms for regular SRVCC in the home network.
- For a roaming scenario, an additional delay of 400 – 500 ms is incurred because the SCC AS in the home network has to be contacted for SRVCC session transfer.
- Delay includes voice interruption on SRVCC UE during handover and the additional delay for media/signaling path switch for remote UE during SRVCC handover.



Advantage of eSRVSS

eSRVCC introduces the ATCF and ATGW. Located in the roaming VoLTE network, the ATCF anchors IMS signaling and the ATGW anchors media.

- The ATCF is inserted in the IMS signaling path during the IMS registration procedure.
- During IMS registration, the ATCF provides an STN-SR or session transfer number (pointing to itself) and forwards it to the SCC-AS.
- The SCC-AS is upgraded in the eSRVCC to update the HSS with the ATCF STN-SR.
- The HSS is upgraded to use this updated STN-SR and forward it to the MME.
- The roaming network's ATCF and the home network's SCC-AS act in cooperation to perform the actual eSRVCC voice call handover.

SRVCC Log Analysis – Questions

Fill the blanks using the log file:

1. What is the Physical Cell ID the UE is camped on? ____
   Frequency? __________________
2. Mcc/mnc: ________
3. What is the SRVCC IE in ATTACH and what is it set to? _________________
4. What is A2 threshold (dBm) in the log? ________________ Which MeasObjectID is it for (ID/CarrierFreq)? ____
5. What UTRA carrier frequencies are supported by the UE? (Hint: B2 event config) __________________
6. What B2 threshold is sent to UE for LTE? __ UTRA? _________________
7. What values does UE report for LTE and UTRA for B2 event? _____, When? ________
8. In mobilityFromEUTRACmd, is CSFB indicator set to TRUE or FALSE? ____________

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Notes

SRVCC Log Analysis – Answers

Fill the blanks using the log file:

1. What is the Physical Cell ID the UE is camped on? 179
   Frequency? 6666
2. Mcc/mnc: 211/111
3. What is the SRVCC IE in ATTACH and what is it set to? SRVCC to GERAN/UTRAN Capability
4. What is A2 threshold in the log (dBm)? -104 Which MeasObjectID is it for (ID/CarrierFreq)? 1/6666
5. What UTRA carrier frequencies are supported by the UE? 9999 and 1000
6. What B2 threshold is sent to UE for LTE? -103 dBm UTRA? -109 dBm
7. What values does UE report for LTE and UTRA for B2 event? -110 dBm and -101 dBm
8. In mobilityFromEUTRACmd, is CSFB indicator set to TRUE or FALSE? FALSE

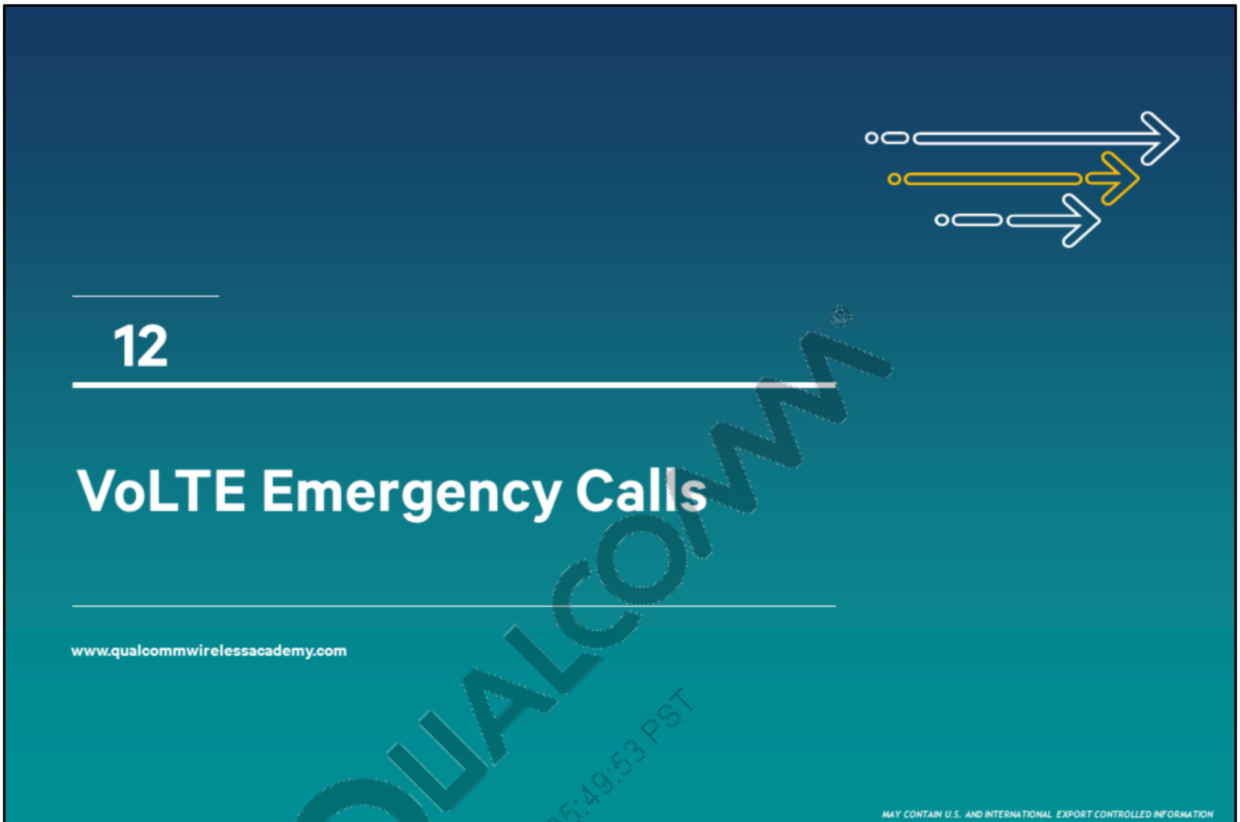
Notes

Specifications References

Specifications	Title
TS 23.216	Single Radio Voice Call Continuity (SRVCC)
TS 23.237	IP Multimedia Subsystem (IMS) Service Continuity; Stage 2

Specifications References

3GPP LTE specifications are available at www.3gpp.org.


12
VoLTE Emergency Calls
www.qualcommwirelessacademy.com
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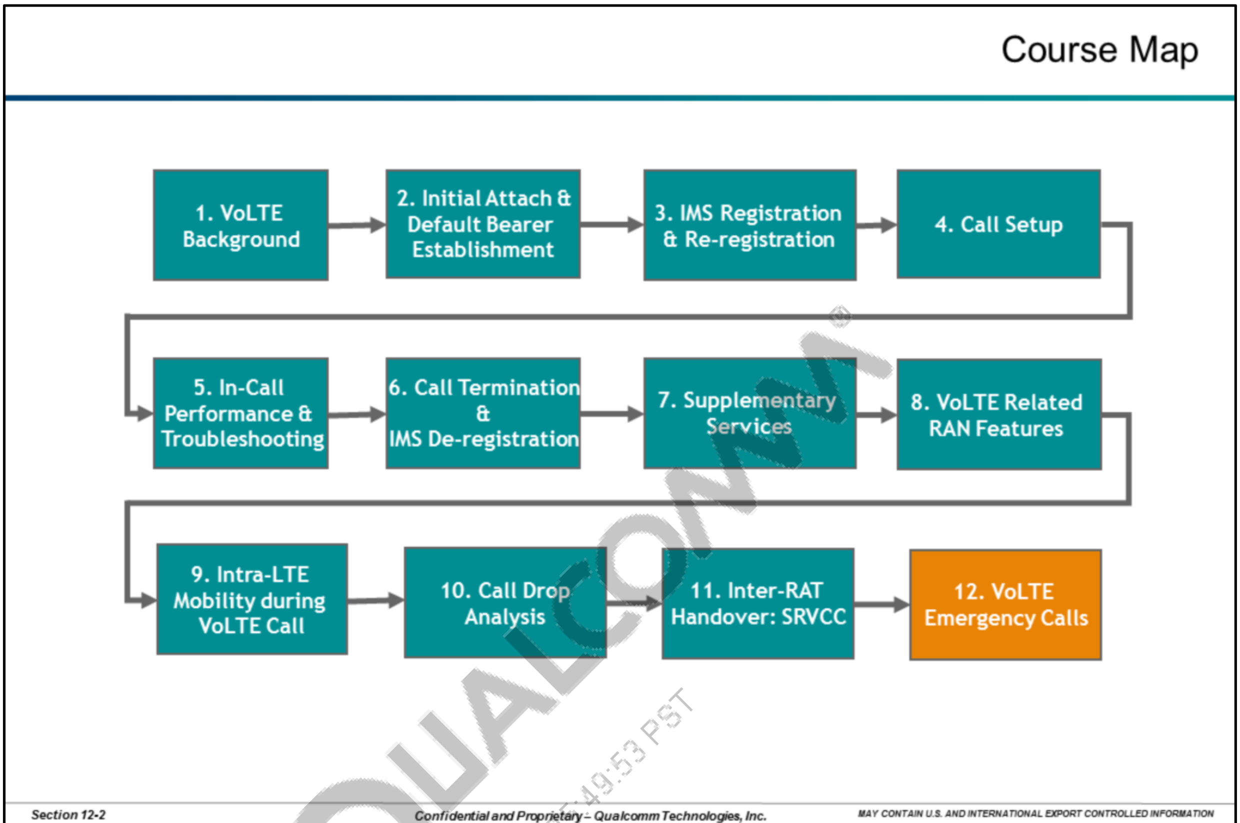
Course Map
1. VoLTE Background
2. Initial Attach & Default Bearer Establishment
3. IMS Registration & Re-registration
4. Call Setup
5. In-Call Performance & Troubleshooting
6. Call Termination & IMS De-registration
7. Supplementary Services
8. VoLTE Related RAN Features
9. Intra-LTE Mobility during VoLTE Call
10. Call Drop Analysis
11. Inter-RAT Handover: SRVCC
12. VoLTE Emergency Calls
Section 12-2
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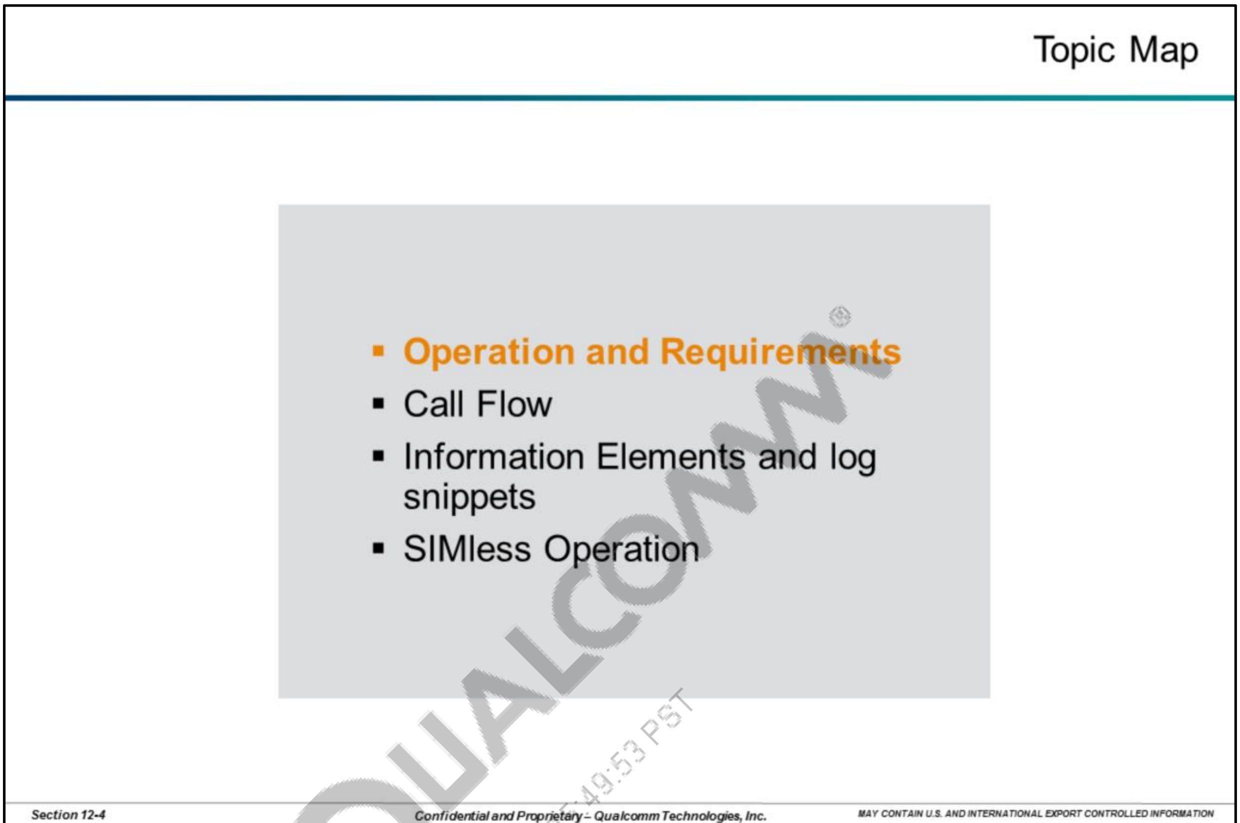
Notes

Objectives

- Describe the operation and requirements of IMS emergency calls.
- Describe an IMS emergency call flow.
- Identify information elements related to IMS emergency calls and show log snippets.
- For a UE with no SIM in limited service:
  - Describe IMS emergency call flow
  - Analyze an IMS emergency call log

Notes


Topic Map
▪ Operation and Requirements
▪ Call Flow
▪ Information Elements and log snippets
▪ SIMless Operation
Section 12-4
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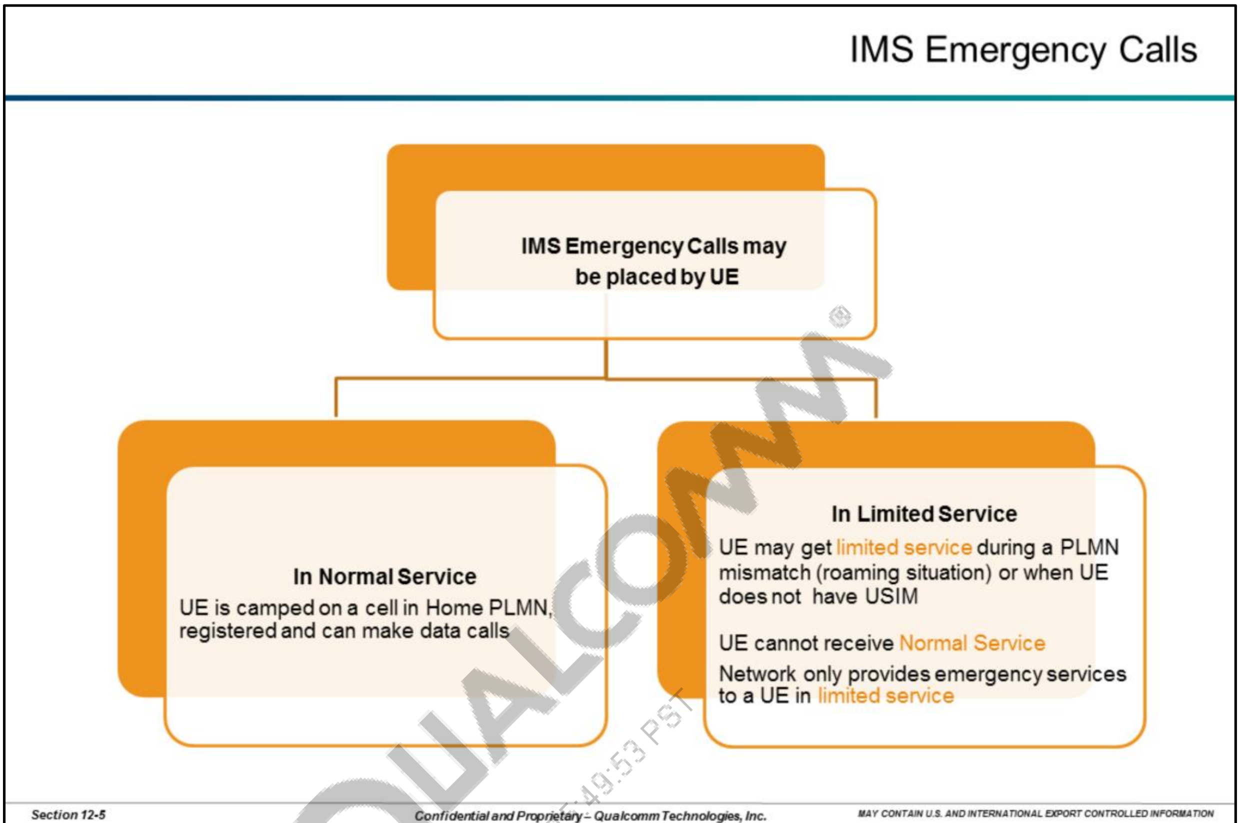
Notes



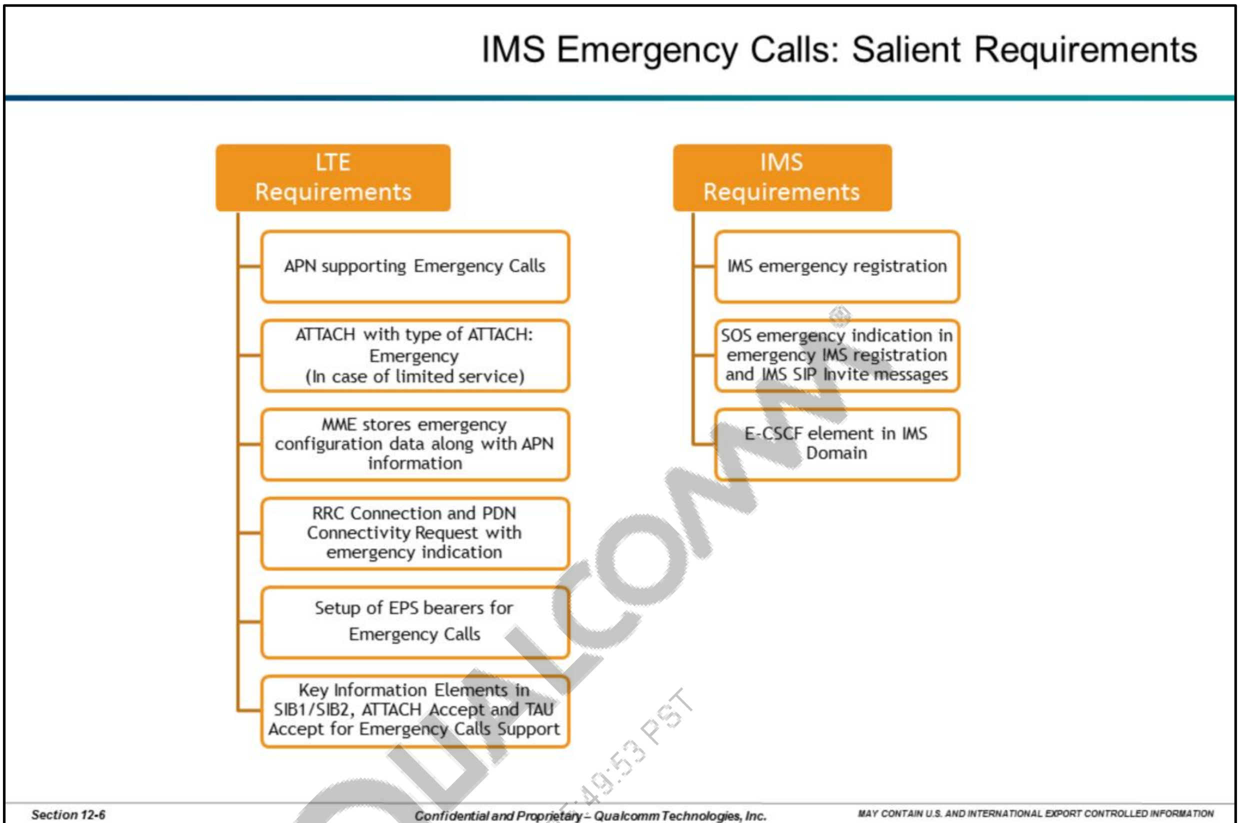
IMS Emergency Calls

Additional points mentioned below are requirements for VoLTE calls but not a requirement for emergency calls:

- UE subscription in HSS
- UE with USIM
- ATTACH and IMS registration
- Authentication/Security procedures during emergency Attach
- QoS parameters and static gateway address information stored in MME
- NOTE : IMS Emergency Calls can also happen without IMS emergency registration in certain specific scenarios

Limited service: Limited service is declared when the network is unable to provide normal service to a UE such as when the UE has no SIM or when there is no cell available from the HPLMN/EHPLMN (subscribed network), as in roaming situations. The network shall provide only emergency bearer services.

During **Normal service**, the UE initiates a new PDN Connectivity Request to attach to the network for getting emergency bearer services. In limited service mode, the UE has to conduct an emergency attach, which shall be treated as an emergency bearer establishment request.


IMS Emergency Calls: Salient Requirements
LTE Requirements
APN supporting Emergency Calls
ATTACH with type of ATTACH: Emergency (In case of limited service)
MME stores emergency configuration data along with APN information
RRC Connection and PDN Connectivity Request with emergency indication
Setup of EPS bearers for Emergency Calls
Key Information Elements in SIB1/SIB2, ATTACH Accept and TAU Accept for Emergency Calls Support
IMS Requirements
IMS emergency registration
SOS emergency indication in emergency IMS registration and IMS SIP Invite messages
E-CSCF element in IMS Domain
Section 12-6
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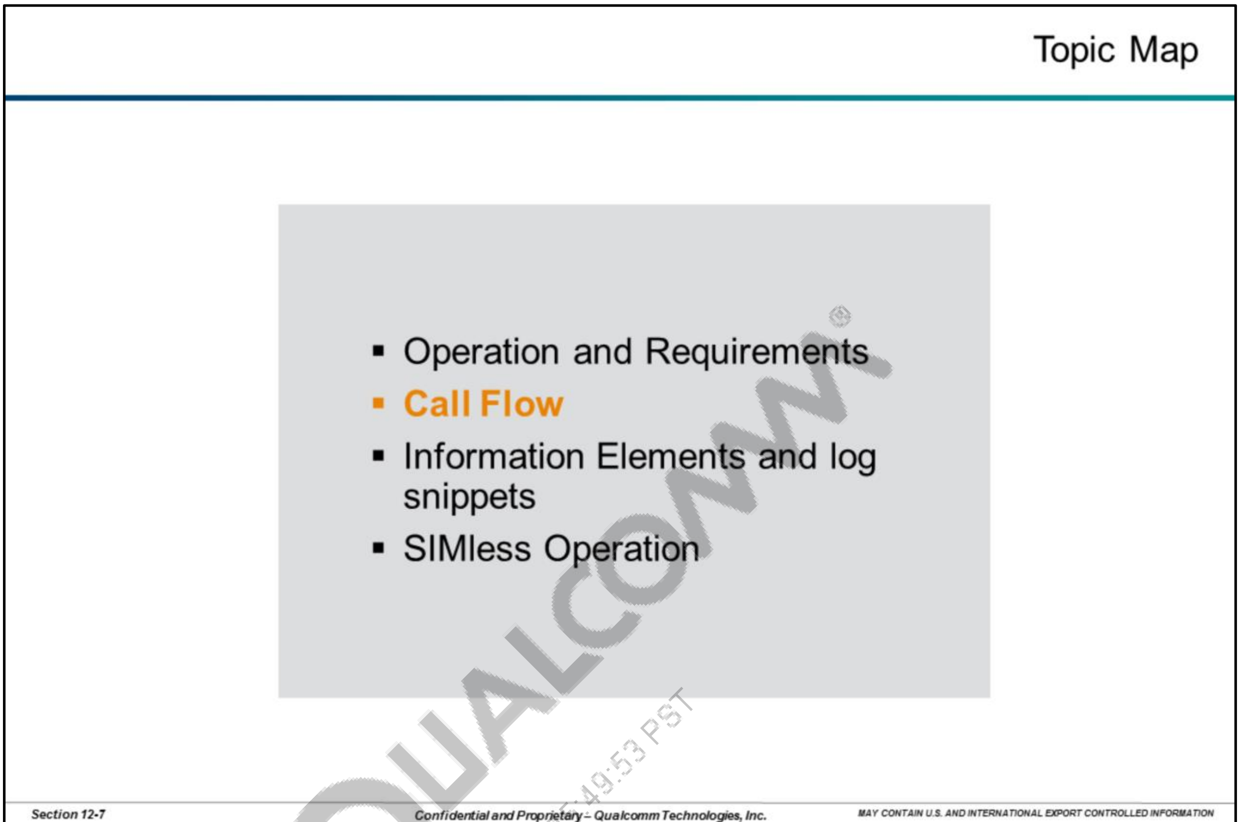
Notes


Topic Map
Operation and Requirements
Call Flow
Information Elements and log snippets
SIMless Operation
Section 12-7
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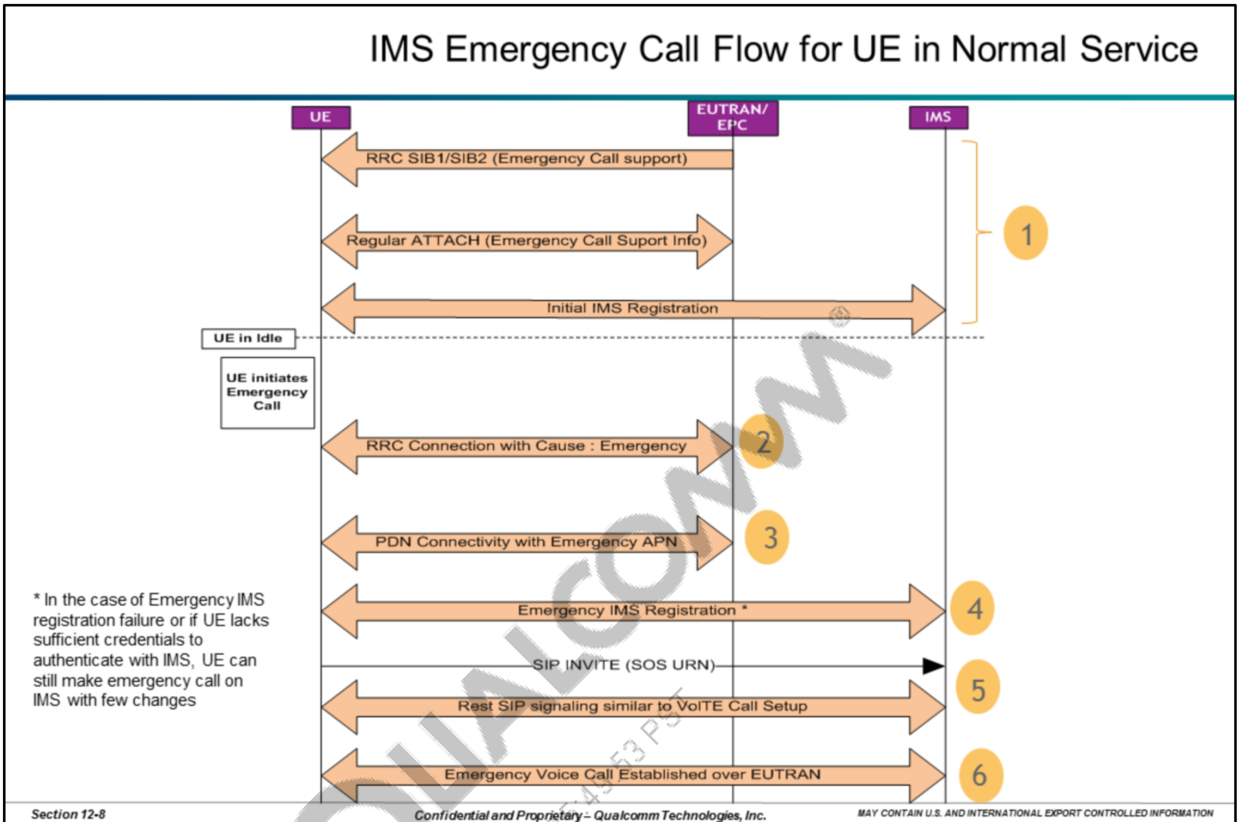
Notes



IMS Emergency Call Flow for UE in Normal Service

Call Flow Steps:

1. Network informs UE of IMS emergency call support through SIB1/SIB2 and Attach Accept (Regular Attach Procedure). UE registers with IMS domain.

2. UE detects requirement for Emergency Calls and sets up RRC connection with cause ‘emergency.’

3. UE requests PDN connectivity with emergency indication. MME selects emergency APN based on emergency configuration data and required EPS bearers are set up.

4. UE performs emergency IMS registration with value SOS in Contact header field to indicate this is an emergency registration.

5. UE sends out SIP INVITE message and includes an ‘emergency service URN (Uniform Resource Name) with a top-level service type of SOS ’. UE shall translate any user-indicated emergency number to an emergency URN. For further details refer to RFC 5031 and TS 22.101.

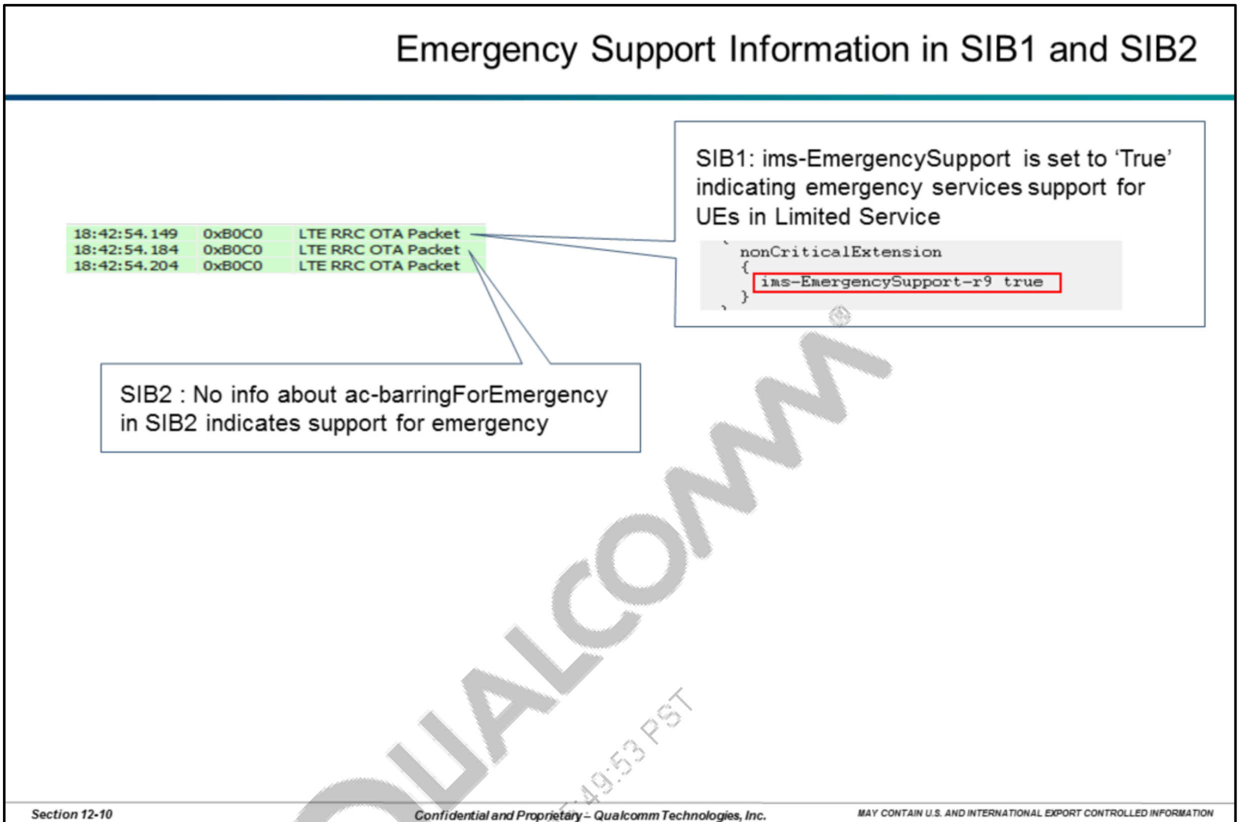
6. Emergency voice call is set up after the necessary SIP signaling is complete.

Note: UE can still make emergency calls without emergency IMS registration with few changes. Additionally, emergency calls are first attempted on LTE if there is PS voice preference and VoLTE is available. In case of failure, UE shall fall back to 3G for making an emergency call.

Topic Map

- Operation and Requirements
- Call Flow
- **Information Elements and log snippets**
- SIMless Operation

Notes


Emergency Support Information in SIB1 and SIB2
18:42:54.149 0xB0C0 LTE RRC OTA Packet
18:42:54.184 0xB0C0 LTE RRC OTA Packet
18:42:54.204 0xB0C0 LTE RRC OTA Packet
SIB1: ims-EmergencySupport is set to 'True' indicating emergency services support for UEs in Limited Service
nonCriticalExtension
{
ims-EmergencySupport-r9 true
}
SIB2 : No info about ac-barringForEmergency in SIB2 indicates support for emergency
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Notes

LTE Emergency Support Information (RRC and NAS)

Msg Type	Information element	Description
SIB1 (RRC)	Ims-EmergencySupport	The SIB1 emergency support indicator informs UEs that if set to 'True' then emergency services are supported by the cell even for UEs in Limited Service ('False' or absence indicates no IMS emergency support for UEs in Limited Service.)
SIB2 (RRC)	ac-barringForemergency	This indicates whether emergency services are allowed for UEs with certain access class
ATTACH ACCEPT/ TAU ACCEPT (NAS)	EMC_BS Indicator	The UEs that camp normally on a cell are informed that the MME/EPC supports emergency services and bearer setup over EUTRAN

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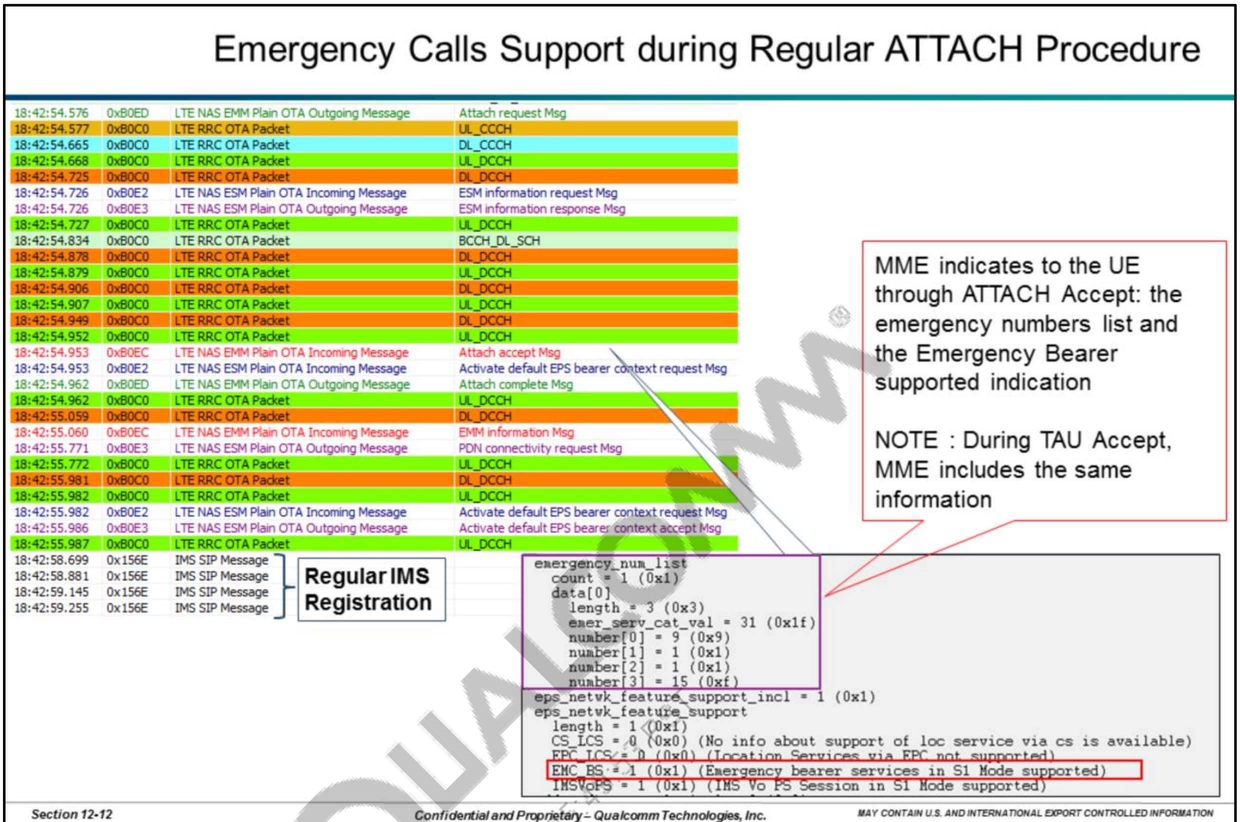
Notes


Emergency Calls Support during Regular ATTACH Procedure
18:42:54.576 0xB0ED LTE NAS EMM Plain OTA Outgoing Message Attach request Msg
18:42:54.577 0xB0C0 LTE RRC OTA Packet UL_CCCH
18:42:54.665 0xB0C0 LTE RRC OTA Packet DL_CCCH
18:42:54.668 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:42:54.725 0xB0C0 LTE RRC OTA Packet DL_DCCH
18:42:54.726 0xB0E2 LTE NAS ESM Plain OTA Incoming Message ESM information request Msg
18:42:54.726 0xB0E3 LTE NAS ESM Plain OTA Outgoing Message ESM information response Msg
18:42:54.727 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:42:54.834 0xB0C0 LTE RRC OTA Packet BCCH_DL_SCH
18:42:54.878 0xB0C0 LTE RRC OTA Packet DL_DCCH
18:42:54.879 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:42:54.906 0xB0C0 LTE RRC OTA Packet DL_DCCH
18:42:54.907 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:42:54.949 0xB0C0 LTE RRC OTA Packet DL_DCCH
18:42:54.952 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:42:54.953 0xB0EC LTE NAS EMM Plain OTA Incoming Message Attach accept Msg
18:42:54.953 0xB0E2 LTE NAS ESM Plain OTA Incoming Message Activate default EPS bearer context request Msg
18:42:54.962 0xB0ED LTE NAS EMM Plain OTA Outgoing Message Attach complete Msg
18:42:54.962 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:42:55.059 0xB0C0 LTE RRC OTA Packet DL_DCCH
18:42:55.060 0xB0EC LTE NAS EMM Plain OTA Incoming Message EMM information Msg
18:42:55.771 0xB0E3 LTE NAS ESM Plain OTA Outgoing Message PDN connectivity request Msg
18:42:55.772 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:42:55.981 0xB0C0 LTE RRC OTA Packet DL_DCCH
18:42:55.982 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:42:55.982 0xB0E2 LTE NAS ESM Plain OTA Incoming Message Activate default EPS bearer context request Msg
18:42:55.986 0xB0E3 LTE NAS ESM Plain OTA Outgoing Message Activate default EPS bearer context accept Msg
18:42:55.987 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:42:58.699 0x156E IMS SIP Message
18:42:58.881 0x156E IMS SIP Message
18:42:59.145 0x156E IMS SIP Message
18:42:59.255 0x156E IMS SIP Message
Regular IMS Registration
MME indicates to the UE through ATTACH Accept: the emergency numbers list and the Emergency Bearer supported indication
NOTE : During TAU Accept, MME includes the same information
emergency_num_list
count = 1 (0x1)
data[0]
length = 3 (0x3)
emer_serv_cat_val = 31 (0x1f)
number[0] = 9 (0x9)
number[1] = 1 (0x1)
number[2] = 1 (0x1)
number[3] = 15 (0xf)
eps_netwk_feature_support_incl = 1 (0x1)
eps_netwk_feature_support
length = 1 (0x1)
CS_LCS = 0 (0x0) (No info about support of loc service via cs is available)
EPC_LCS = 0 (0x0) (Location Services via EPC not supported)
EMC_BS = 1 (0x1) (Emergency bearer services in S1 Mode supported)
IMSVoPS = 1 (0x1) (IMS Vo PS Session in S1 Mode supported)
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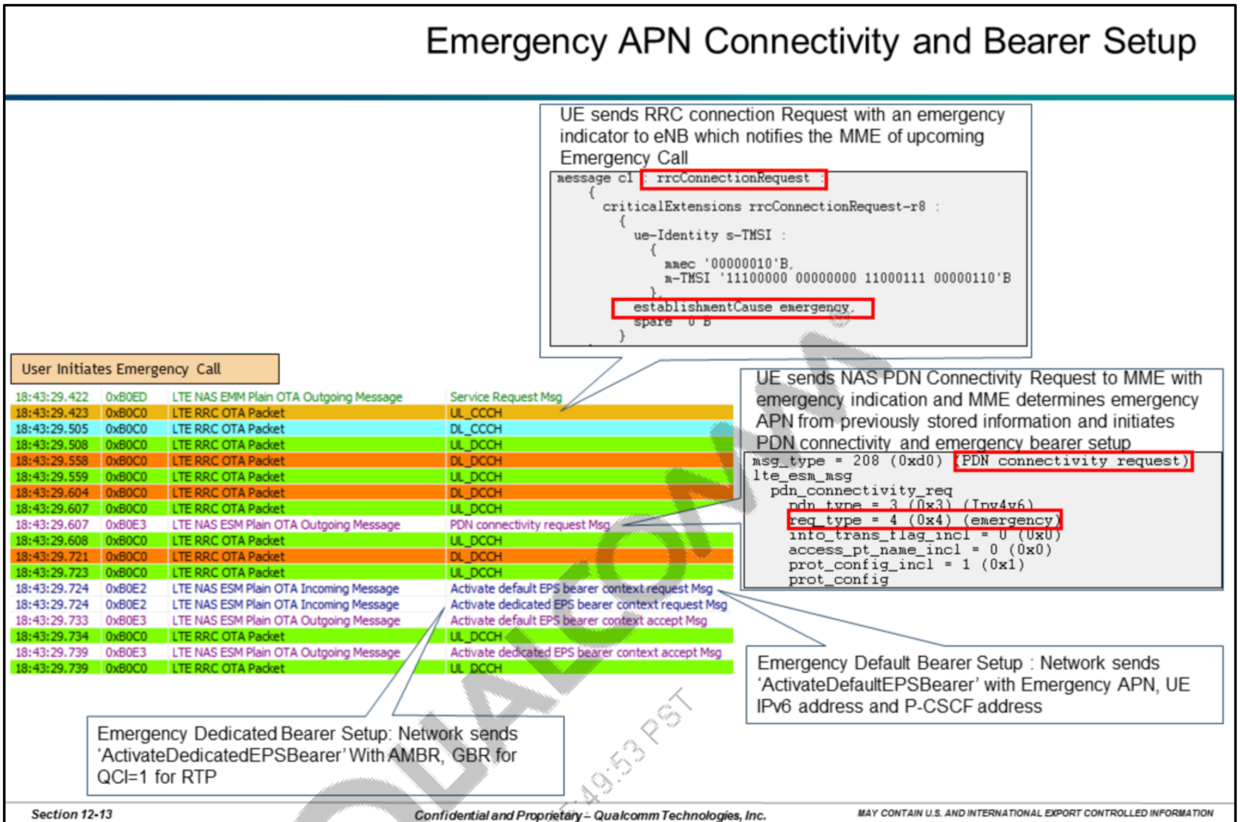
Notes


Emergency APN Connectivity and Bearer Setup
UE sends RRC connection Request with an emergency indicator to eNB which notifies the MME of upcoming Emergency Call
message c1 : rrcConnectionRequest :
criticalExtensions rrcConnectionRequest-r8 :
ue-Identity s-TMSI :
mmec '00000010'B,
m-TMSI '11100000 00000000 11000111 00000110'B
establishmentCause emergency,
spare '0'B
User Initiates Emergency Call
18:43:29.422 0xB0ED LTE NAS EMM Plain OTA Outgoing Message Service Request Msg
18:43:29.423 0xB0C0 LTE RRC OTA Packet UL_CCCH
18:43:29.505 0xB0C0 LTE RRC OTA Packet DL_CCCH
18:43:29.508 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:43:29.558 0xB0C0 LTE RRC OTA Packet DL_DCCH
18:43:29.559 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:43:29.604 0xB0C0 LTE RRC OTA Packet DL_DCCH
18:43:29.607 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:43:29.607 0xB0E3 LTE NAS ESM Plain OTA Outgoing Message PDN connectivity request Msg
18:43:29.608 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:43:29.721 0xB0C0 LTE RRC OTA Packet DL_DCCH
18:43:29.723 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:43:29.724 0xB0E2 LTE NAS ESM Plain OTA Incoming Message Activate default EPS bearer context request Msg
18:43:29.724 0xB0E2 LTE NAS ESM Plain OTA Incoming Message Activate dedicated EPS bearer context request Msg
18:43:29.733 0xB0E3 LTE NAS ESM Plain OTA Outgoing Message Activate default EPS bearer context accept Msg
18:43:29.734 0xB0C0 LTE RRC OTA Packet UL_DCCH
18:43:29.739 0xB0E3 LTE NAS ESM Plain OTA Outgoing Message Activate dedicated EPS bearer context accept Msg
18:43:29.739 0xB0C0 LTE RRC OTA Packet UL_DCCH
UE sends NAS PDN Connectivity Request to MME with emergency indication and MME determines emergency APN from previously stored information and initiates PDN connectivity and emergency bearer setup
msg_type = 208 (0xd0) (PDN connectivity request)
lte_esm_msg
pdn_connectivity_req
pdn_type = 3 (0x3) (Ipv4v6)
req_type = 4 (0x4) (emergency)
info_trans_flag_incl = 0 (0x0)
access_pt_name_incl = 0 (0x0)
prot_config_incl = 1 (0x1)
prot_config
Emergency Default Bearer Setup : Network sends 'ActivateDefaultEPSBearer' with Emergency APN, UE IPv6 address and P-CSCF address
Emergency Dedicated Bearer Setup: Network sends 'ActivateDedicatedEPSBearer' With AMBR, GBR for QCI=1 for RTP
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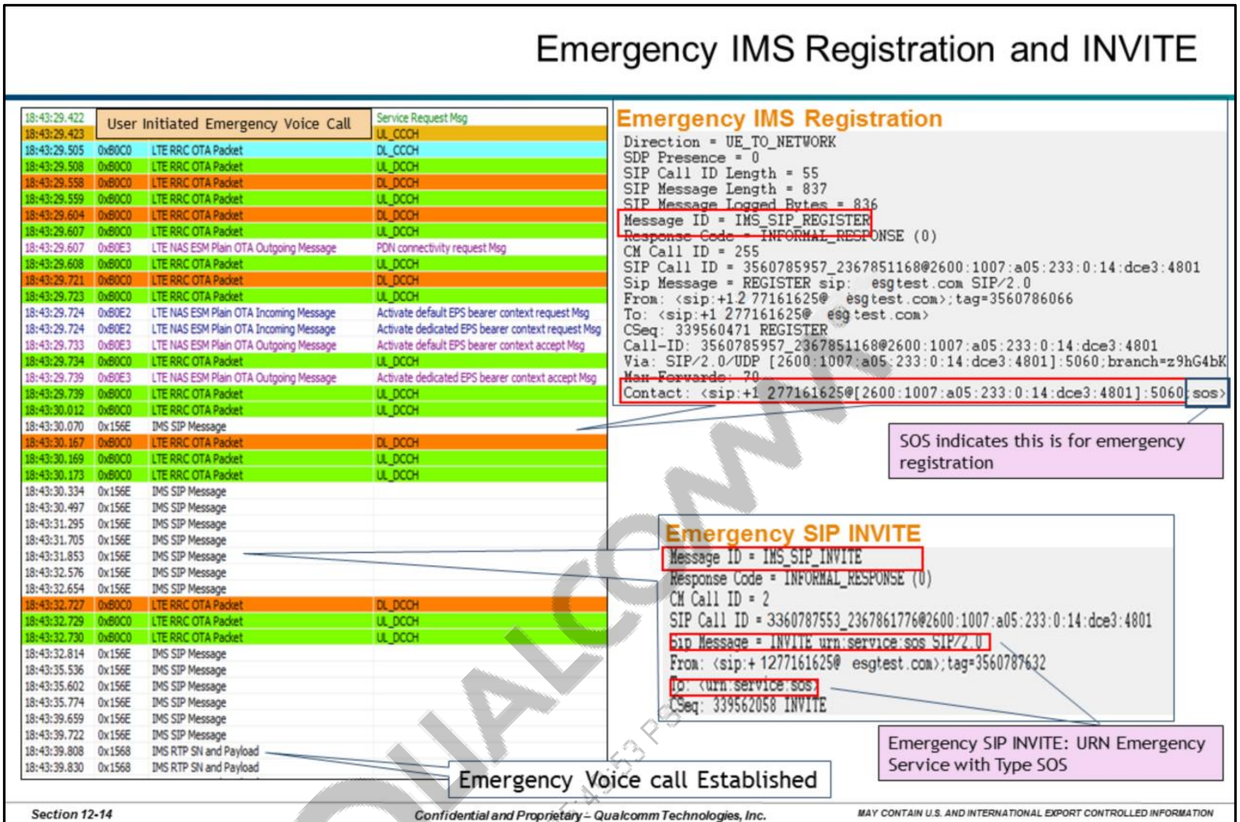
Notes



Emergency IMS Registration and INVITE

Emergency IMS Registration

- IMS emergency registration is a special registration that relates to binding a public user identity to a contact address used for an emergency.
- UE includes a reg-type SIP URI parameter with a value of **sos** in the Contact header field indicating this is emergency registration.

Emergency IMS SIP INVITE

- UE sends out SIP INVITE message and includes an ‘emergency service URN with a top-level service type of SOS’. URN stands for ‘Uniform Resource name’. UE shall translate any user-indicated emergency number to an emergency URN. For further details refer to RFC 5031 and TS 22.101.
- UE includes same emergency service URN in TO header field.

Analysis Example: Emergency PDN and Emergency Call Establishment

Log Analysis Procedure: Emergency PDN Connectivity and Emergency Call Establishment

Open File: 12-01-Emergency_Calls

Notes

ATTACH Procedure: Log Walk-Through

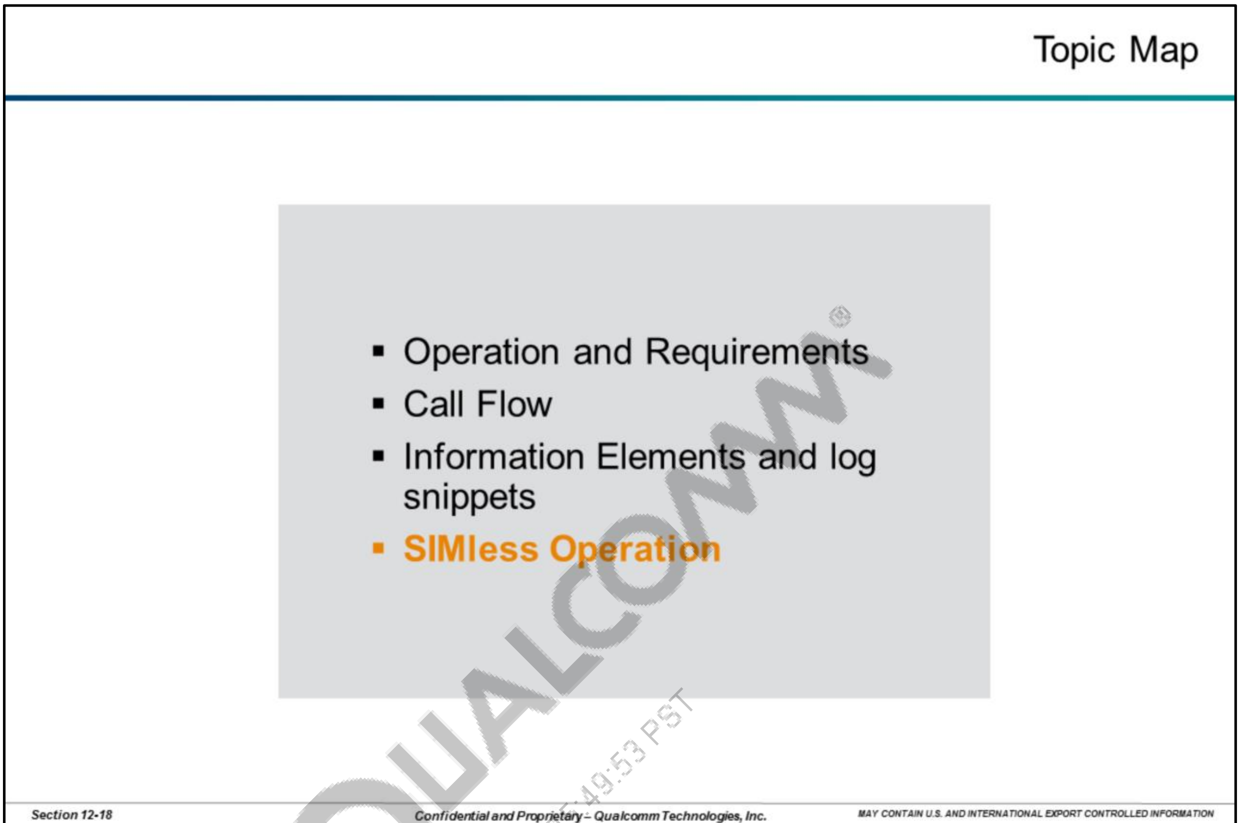
Step	Look for	Log Packet	Time Stamp	Verify
1	SIB1	OxB0C0	18:42:54.149	ims-emergencysupport is set to TRUE
2	Attach Request	0xB0ED	18:42:54.576	
3	Attach Accept	0xB0ED	18:42:54.953	EMC_BS=1 (emergency bearer services supported)

Notes

Emergency Voice Call Setup: Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	RRC Connection Request	0xB0C0	18:43:29.423	Establishment Cause: emergency
2	NAS EMM Outgoing Message	0xB0ED	18:43:29.607	PDN Connectivity Request for emergency APN
4	NAS ESM Incoming Message	0xB0E2	18:43:29.724	eNB commands UE to activate default EPS bearer context request. QCI set to 1 and GBR rates are set.
5	NAS ESM Incoming Message	0xB0E2	18:43:29.724	eNB commands UE to activate dedicated EPS bearer context request. QCI set to 1 and GBR rates are set.
6	IMS SIP Registration Message	0x156E	18:43:30.070	Emergency Registration
7	IMS SIP INVITE Message	0x156E	18:43:31.705	Emergency service URN included with service type SOS
8	IMS RTP SN and Payload	0x1568	18:43:39.808	First RTP packet on emergency voice call. Sequence number = 0

Notes


Topic Map
Operation and Requirements
Call Flow
Information Elements and log snippets
SIMless Operation
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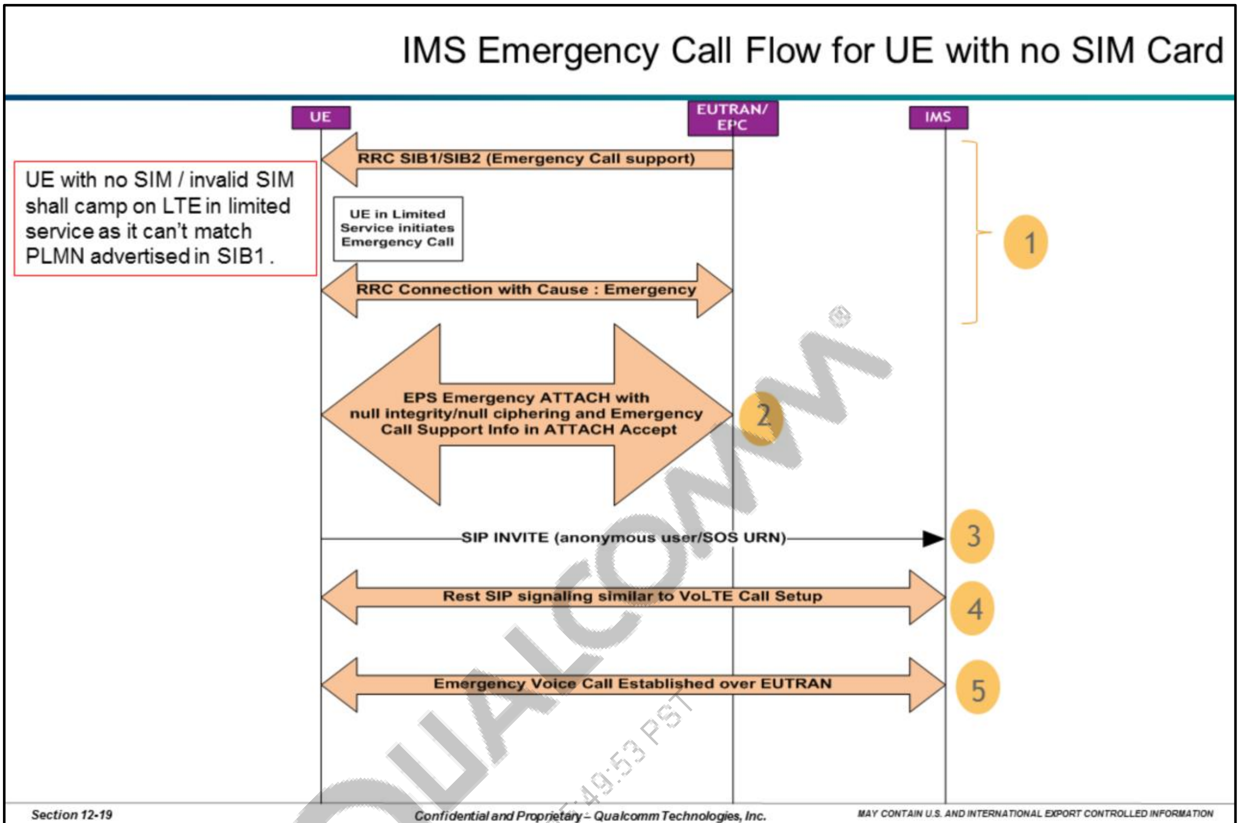
Notes



IMS Emergency Call Flow for UE with no SIM Card Call Flow Steps

1. Network informs UE of IMS emergency call support through SIB1/SIB2.
   a) SIMless UE is in Limited Service and UE detects requirement for Emergency Calls and sets up RRC connection with cause 'emergency'.
2. UE sends ATTACH Request with ATTACH Type as "EPS Emergency ATTACH".
   a) MME selects emergency APN based on emergency configuration data, and required Emergency EPS bearers are set up.
   b) Since UE is SIMless, UE might not have IMSI and has to include IMEI in EPS mobile identity IE.
   c) Null integrity and null ciphering algorithm used during emergency ATTACH.
   d) Attach Accept contains emergency call support information.
3. UE establishes SIP session by sending SIP INVITE and includes both the "anonymous user" and "emergency service" indications which is 'sos' in the emergency session establishment request to the P-CSCF. When P-CSCF accepts the "anonymous user" emergency session establishment, it forwards this request to an appropriate E-CSCF although no security association between UE and P-CSCF is established.

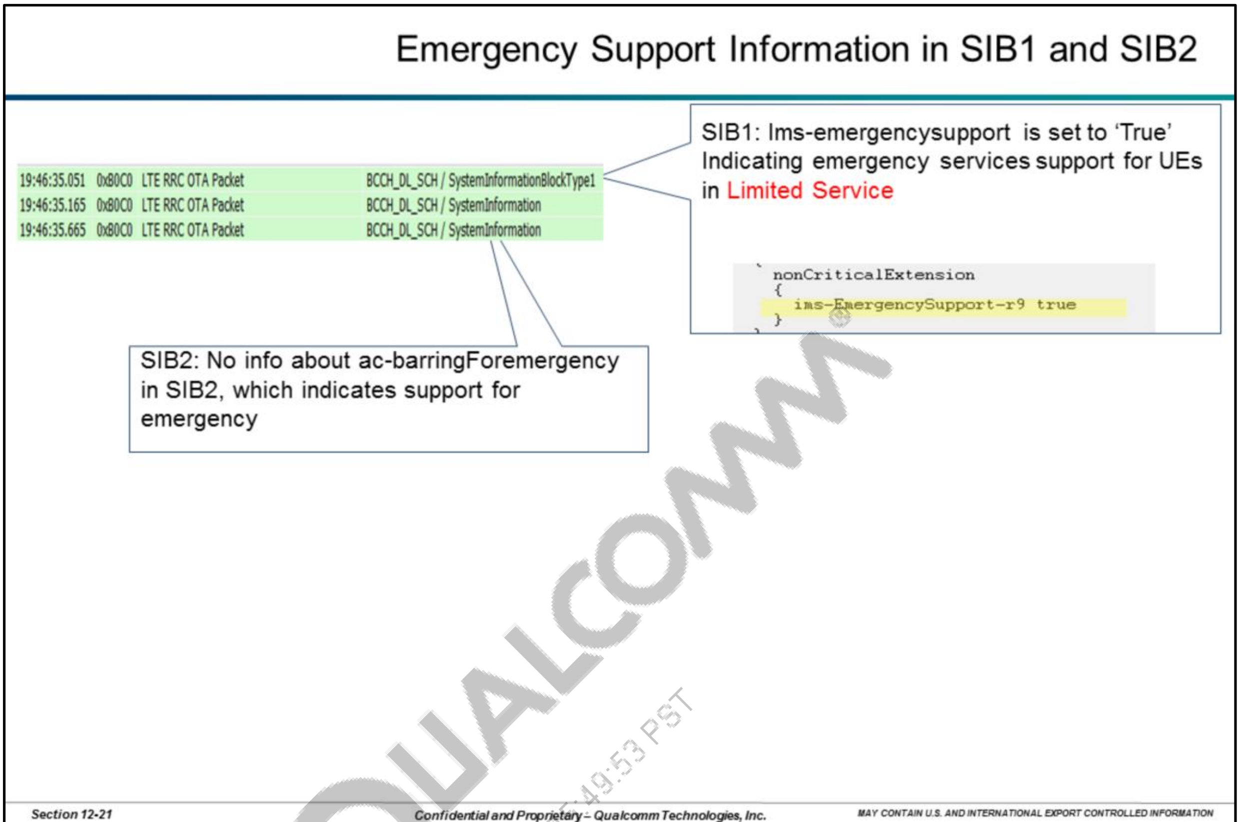
4&5. Emergency voice call is set up after the necessary SIP signaling is complete.

Note: UE will make emergency calls without emergency IMS registration with few changes since without SIM IMS authentications may fail. Additionally emergency calls are first attempted on LTE if there is PS voice preference and VolTE is available. In case of failure, UE shall fall back to 3G for making emergency call.

IMS Emergency Call (UE with and without SIM)

	UE with valid SIM	UE with no or invalid SIM
Type of Service on cell camping	Normal service	Limited service
LTE ATTACH / registration	Required	No ATTACH
IMS registration	Required	No IMS Registration
Emergency APN	PDN connectivity sent after IMS emergency call initiation	Emergency ATTACH request sent after IMS emergency call initiation
Emergency SIP INVITE	‘Valid User number’ in ‘From’ field	‘anonymous user’ in ‘From’ Field

Notes


Emergency Support Information in SIB1 and SIB2
19:46:35.051 0xB0C0 LTE RRC OTA Packet BCCH_DL_SCH / SystemInformationBlockType1
19:46:35.165 0xB0C0 LTE RRC OTA Packet BCCH_DL_SCH / SystemInformation
19:46:35.665 0xB0C0 LTE RRC OTA Packet BCCH_DL_SCH / SystemInformation
SIB1: Ims-emergencysupport is set to 'True' Indicating emergency services support for UEs in Limited Service
nonCriticalExtension
{
ims-EmergencySupport-r9 true
}
SIB2: No info about ac-barringForemergency in SIB2, which indicates support for emergency
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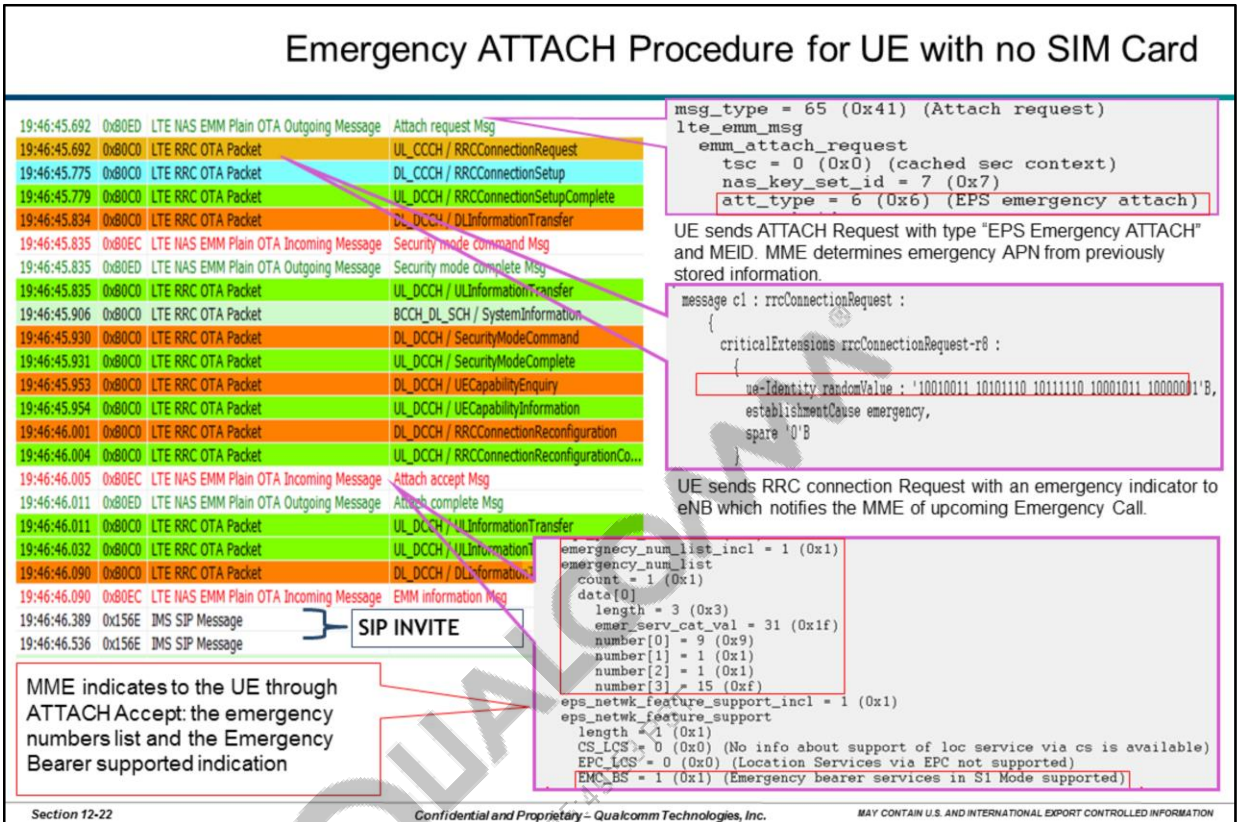
Notes


Emergency ATTACH Procedure for UE with no SIM Card
19:46:45.692 0xB0ED LTE NAS EMM Plain OTA Outgoing Message Attach request Msg
19:46:45.692 0xB0C0 LTE RRC OTA Packet UL_CCCH / RRCConnectionRequest
19:46:45.775 0xB0C0 LTE RRC OTA Packet DL_CCCH / RRCConnectionSetup
19:46:45.779 0xB0C0 LTE RRC OTA Packet UL_DCCH / RRCConnectionSetupComplete
19:46:45.834 0xB0C0 LTE RRC OTA Packet DL_DCCH / DLInformationTransfer
19:46:45.835 0xB0EC LTE NAS EMM Plain OTA Incoming Message Security mode command Msg
19:46:45.835 0xB0ED LTE NAS EMM Plain OTA Outgoing Message Security mode complete Msg
19:46:45.835 0xB0C0 LTE RRC OTA Packet UL_DCCH / ULInformationTransfer
19:46:45.906 0xB0C0 LTE RRC OTA Packet BCCH_DL_SCH / SystemInformation
19:46:45.930 0xB0C0 LTE RRC OTA Packet DL_DCCH / SecurityModeCommand
19:46:45.931 0xB0C0 LTE RRC OTA Packet UL_DCCH / SecurityModeComplete
19:46:45.953 0xB0C0 LTE RRC OTA Packet DL_DCCH / UECapabilityEnquiry
19:46:45.954 0xB0C0 LTE RRC OTA Packet UL_DCCH / UECapabilityInformation
19:46:46.001 0xB0C0 LTE RRC OTA Packet DL_DCCH / RRCConnectionReconfiguration
19:46:46.004 0xB0C0 LTE RRC OTA Packet UL_DCCH / RRCConnectionReconfigurationCo...
19:46:46.005 0xB0EC LTE NAS EMM Plain OTA Incoming Message Attach accept Msg
19:46:46.011 0xB0ED LTE NAS EMM Plain OTA Outgoing Message Attach complete Msg
19:46:46.011 0xB0C0 LTE RRC OTA Packet UL_DCCH / ULInformationTransfer
19:46:46.032 0xB0C0 LTE RRC OTA Packet UL_DCCH / ULInformation
19:46:46.090 0xB0C0 LTE RRC OTA Packet DL_DCCH / DLInformation
19:46:46.090 0xB0EC LTE NAS EMM Plain OTA Incoming Message EMM information Msg
19:46:46.389 0x156E IMS SIP Message
19:46:46.536 0x156E IMS SIP Message
SIP INVITE
msg_type = 65 (0x41) (Attach request)
lte_emm_msg
emm_attach_request
tsc = 0 (0x0) (cached sec context)
nas_key_set_id = 7 (0x7)
att_type = 6 (0x6) (EPS emergency attach)
UE sends ATTACH Request with type "EPS Emergency ATTACH" and MEID. MME determines emergency APN from previously stored information.
message c1 : rrcConnectionRequest :
{
criticalExtensions rrcConnectionRequest-r8 :
{
ue-Identity randomValue : '10010011 10101110 10111110 10001011 10000001'B,
establishmentCause emergency,
spare '0'B
}
UE sends RRC connection Request with an emergency indicator to eNB which notifies the MME of upcoming Emergency Call.
emergnecy_num_list_incl = 1 (0x1)
emergency_num_list
count = 1 (0x1)
data[0]
length = 3 (0x3)
emer_serv_cat_val = 31 (0x1f)
number[0] = 9 (0x9)
number[1] = 1 (0x1)
number[2] = 1 (0x1)
number[3] = 15 (0xf)
eps_netwk_feature_support_incl = 1 (0x1)
eps_netwk_feature_support
length = 1 (0x1)
CS_LCS = 0 (0x0) (No info about support of loc service via cs is available)
EPC_LCS = 0 (0x0) (Location Services via EPC not supported)
EMC_BS = 1 (0x1) (Emergency bearer services in S1 Mode supported)
MME indicates to the UE through ATTACH Accept: the emergency numbers list and the Emergency Bearer supported indication
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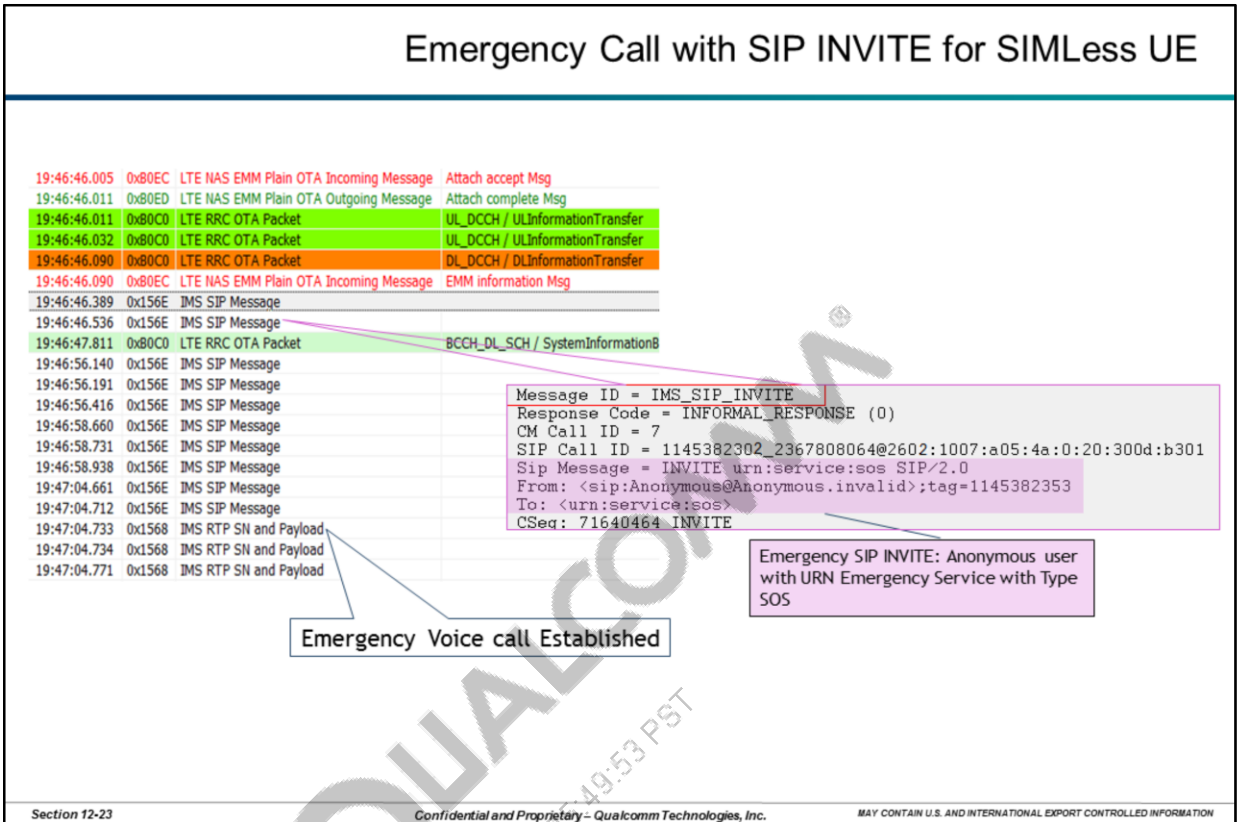
Notes


Emergency Call with SIP INVITE for SIMLess UE
19:46:46.005 0xB0EC LTE NAS EMM Plain OTA Incoming Message Attach accept Msg
19:46:46.011 0xB0ED LTE NAS EMM Plain OTA Outgoing Message Attach complete Msg
19:46:46.011 0xB0C0 LTE RRC OTA Packet UL_DCCH / ULInformationTransfer
19:46:46.032 0xB0C0 LTE RRC OTA Packet UL_DCCH / ULInformationTransfer
19:46:46.090 0xB0C0 LTE RRC OTA Packet DL_DCCH / DLInformationTransfer
19:46:46.090 0xB0EC LTE NAS EMM Plain OTA Incoming Message EMM information Msg
19:46:46.389 0x156E IMS SIP Message
19:46:46.536 0x156E IMS SIP Message
19:46:47.811 0xB0C0 LTE RRC OTA Packet BCCH_DL_SCH / SystemInformationB
19:46:56.140 0x156E IMS SIP Message
19:46:56.191 0x156E IMS SIP Message
19:46:56.416 0x156E IMS SIP Message
19:46:58.660 0x156E IMS SIP Message
19:46:58.731 0x156E IMS SIP Message
19:46:58.938 0x156E IMS SIP Message
19:47:04.661 0x156E IMS SIP Message
19:47:04.712 0x156E IMS SIP Message
19:47:04.733 0x1568 IMS RTP SN and Payload
19:47:04.734 0x1568 IMS RTP SN and Payload
19:47:04.771 0x1568 IMS RTP SN and Payload
Message ID = IMS_SIP_INVITE
Response Code = INFORMAL_RESPONSE (0)
CM Call ID = 7
SIP Call ID = 1145382302_2367808064@2602:1007:a05:4a:0:20:300d:b301
Sip Message = INVITE urn:service:sos SIP/2.0
From: <sip:Anonymous@Anonymous.invalid>;tag=1145382353
To: <urn:service:sos>
CSeq: 71640464 INVITE
Emergency SIP INVITE: Anonymous user with URN Emergency Service with Type SOS
Emergency Voice call Established
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Notes

Analysis Example: Emergency ATTACH and Emergency Calls Establishment for SIM-less UE

Log Analysis Procedure: Emergency ATTACH and Emergency Calls Establishment for SIM-less UE

Open File: 12-02-SIMless_Emergency_Calls

Notes

Emergency ATTACH/Call for SIMLess UE : Log Walk-Through

Step	Look for	Log Packet	Time Stamp	Verify
1	SIB1	OxB0C0	19:46:35.051	Ims-emergencysupport is set to TRUE
2	RRC Connection Request	0xB0C0	19:46:45.692	Establishment Cause: emergency
3	Attach Request	0xB0ED	19:46:45.692	Emergency ATTACH
4	Attach Accept	0xB0ED	19:46:46.005	EMC_BS=1 (emergency bearer services supported)
5	IMS SIP INVITE Message	0x156E	19:46:46.389	Emergency service URN included with service type SOS and user : anonymous
6	IMS RTP SN and Payload	0x1568	19:47:04.733	First RTP packet on emergency voice call. Sequence number = 0

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Notes

Emergency Log Analysis – Questions

Fill the blanks using the log file:

1. What is the Physical Cell ID the UE is camped on? ____
   Frequency? __________________
2. Mcc/mnc in ATTACH: _______
3. What is the Emergency IE in ATTACHACCEPT and what is it set to? ________________
4. What is establishmentCause for RRCConnection msg for the emergency call in the log? ________________ Time? ____
5. What is the emergency APN name from the log (Hint:Activate Default Bearer NAS msg)? ______________________
6. What are the EPS bearer IDs for emergency default and dedicated bearers? ________________
7. Does the 'sip message' portion in emergency SIP INVITE have an 'sos' term? _____, What's the value of 'max-forwards' in same SIP INVITE message? ________
8. Does the 'Contact' portion in emergency SIP INVITE have an 'sos' term? ___________

Notes

Emergency Log Analysis – Answers

Fill the blanks using the log file:

1. What is the Physical Cell ID the UE is camped on? **11**
   Frequency? **6666**
2. Mcc/mnc in ATTACH: **211/111**
3. What is the Emergency IE in ATTACHACCEPT and what is it set to? **EMC_BC and set to 1**
4. What is establishmentCause for RRCConnection msg for the emergency call in the log? **emergency**
   Time? **18:43:29.423**
5. What is the emergency APN name from the log (Hint:Activate Default Bearer NAS msg)?
   esgemergency
6. What are the EPS bearer IDs for emergency default and dedicated bearers? **7 and 8**
7. Does the 'sip message' portion in emergency SIP INVITE have an 'sos' term? **Yes** , What's the value of 'max-forwards' in same SIP INVITE message? **70**
8. Does the 'Contact' portion in emergency SIP INVITE have an 'sos' term? **No**

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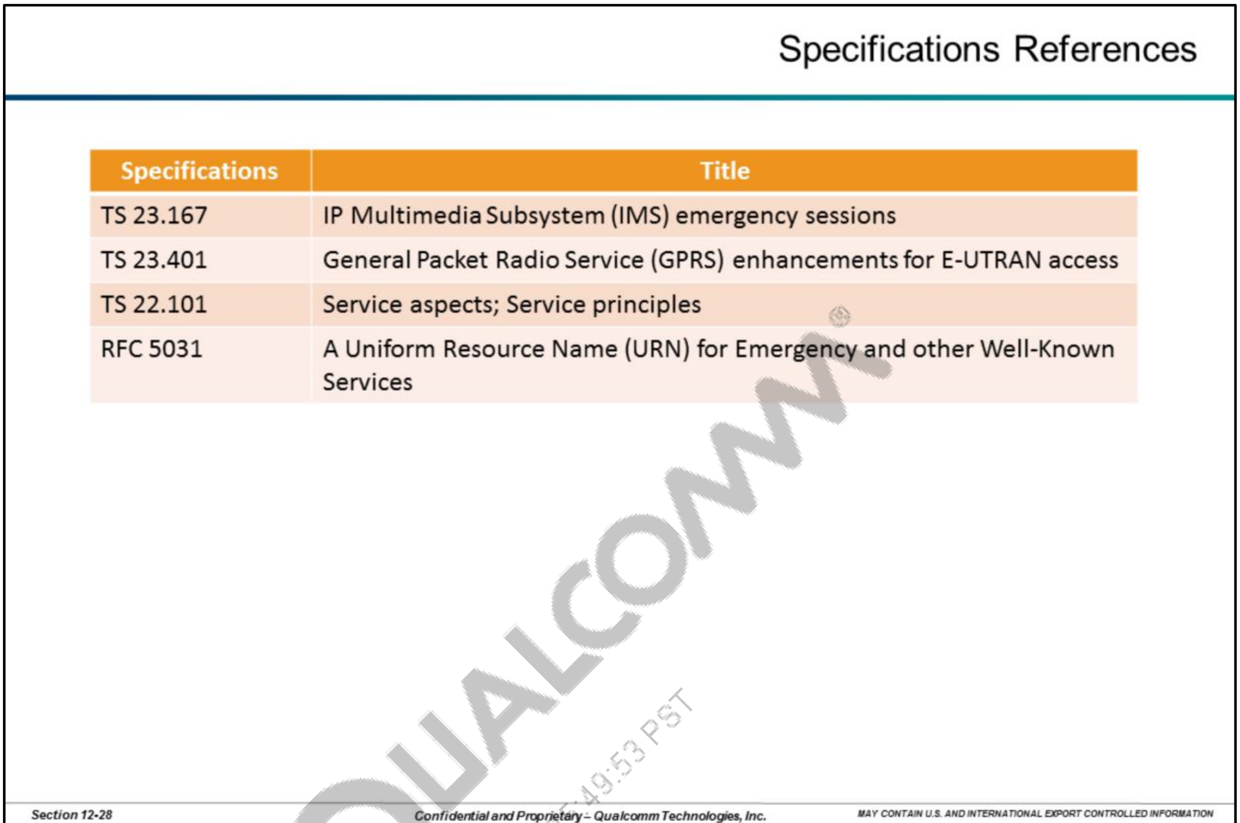
Notes



Specifications References

Specifications	Title
TS 23.167	IP Multimedia Subsystem (IMS) emergency sessions
TS 23.401	General Packet Radio Service (GPRS) enhancements for E-UTRAN access
TS 22.101	Service aspects; Service principles
RFC 5031	A Uniform Resource Name (URN) for Emergency and other Well-Known Services

Specifications References

3GPP LTE specifications available at www.3gpp.org

IETF RFCs available at www.ietf.org