Introduction of VoLTE

No: KT_1512_10
To: RJIL NPE
From: KT RF Part

KT Experts Group | **08-Mar-2016**
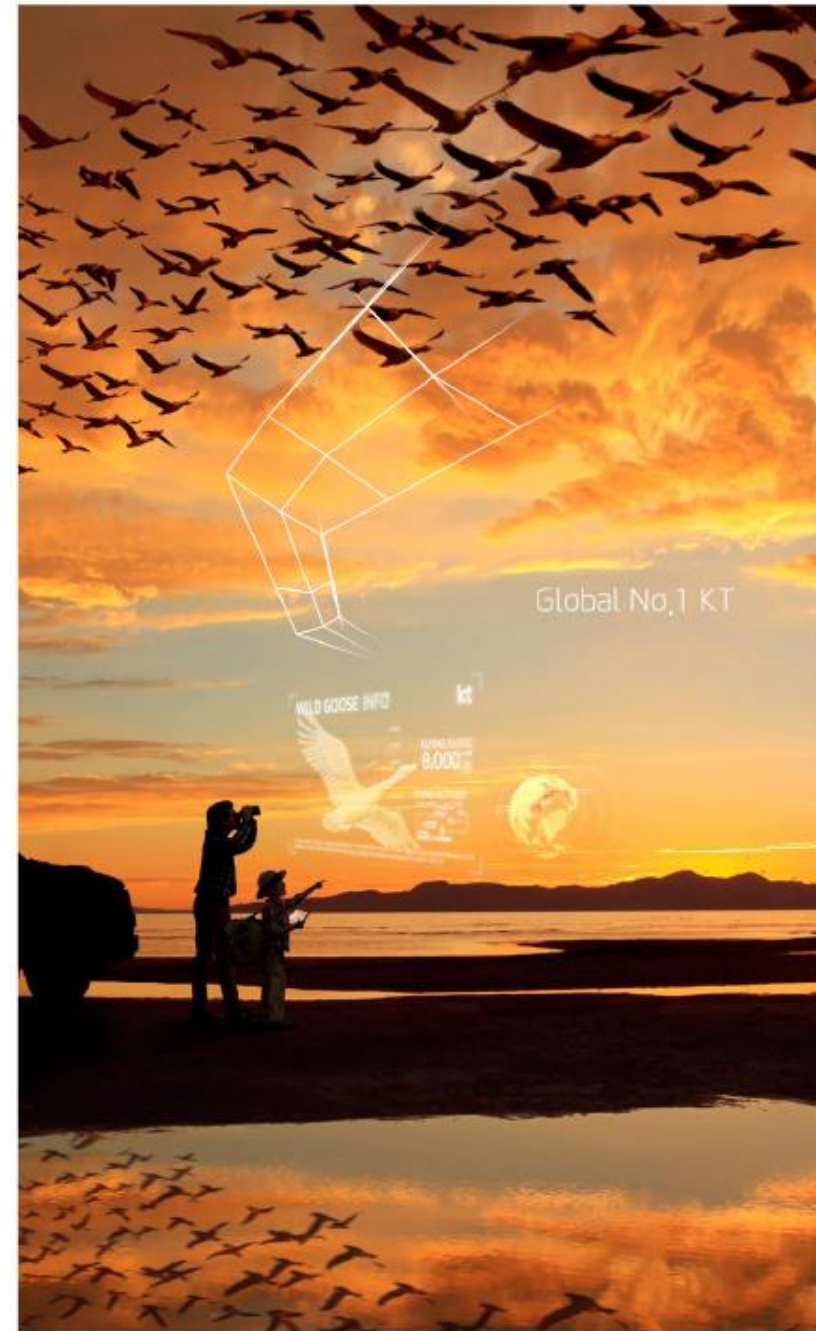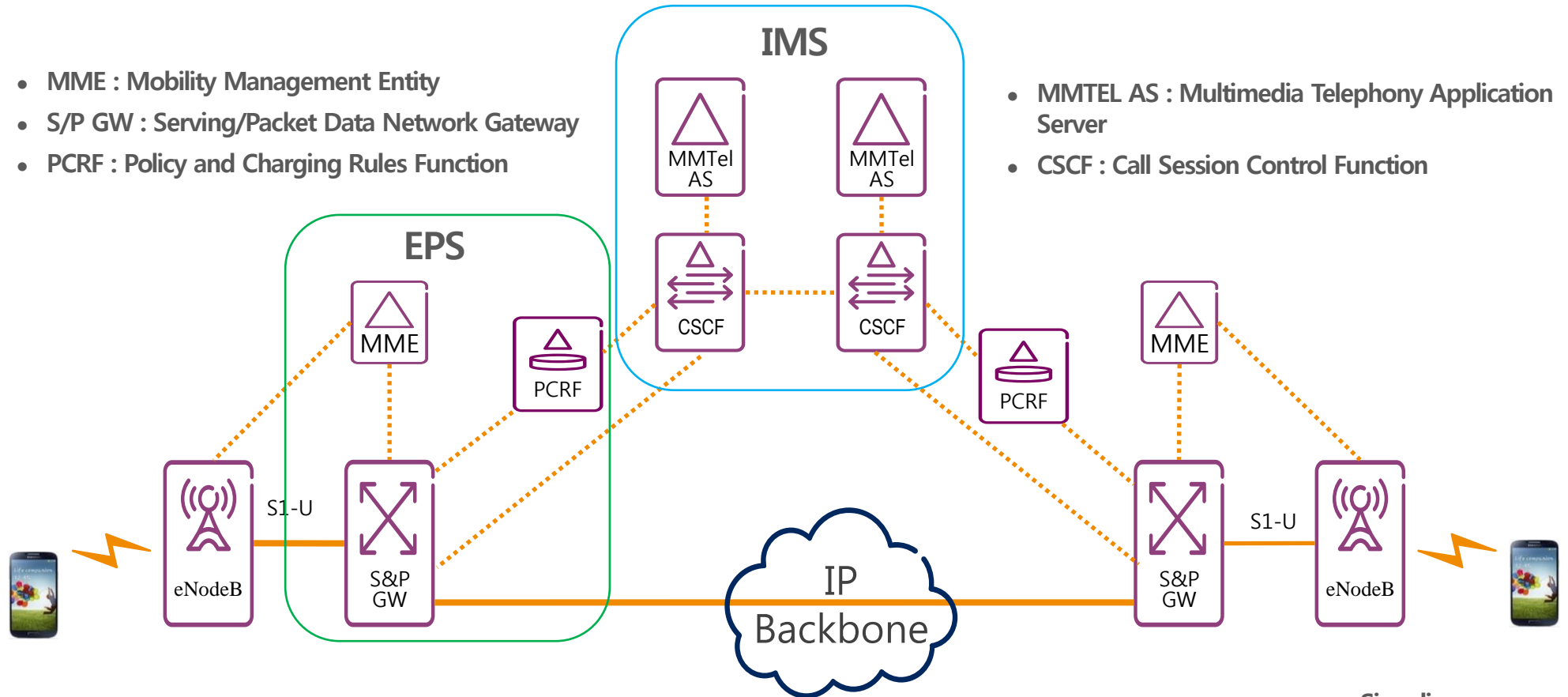
Global No.1 KT

Contents

VoLTE - Overview

Network Structure for VoLTE

- **MME : Mobility Management Entity**
- **S/P GW : Serving/Packet Data Network Gateway**
- **PCRF : Policy and Charging Rules Function**

- **MMTEL AS : Multimedia Telephony Application Server**
- **CSCF : Call Session Control Function**

IMS

MMTel AS

MMTel AS

CSCF

CSCF

EPS

MME

PCRF

PCRF

MME

S1-U

S1-U

eNodeB

S&P GW

S&P GW

eNodeB

IP Backbone

.... **Signaling pass**

──── **Traffic pass**

- **EPS : Evolved Packet System**
- **IMS : IP Multimedia Subsystem**

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01 **VoLTE - Overview**

Voice service on LTE network

☐ **SVLTE (Simultaneous Voice and LTE)**

  ✓ **Method : UE supports both LTE (data) and legacy networks (circuit service) simultaneously.**

  ✓ **Pros   : No interworking needed between LTE and legacy, Faster than CSFB, (Voice + LTE data) is possible**

  ✓ **Cons : High battery consumption (Using both modems simultaneously), Limited supplier for mobile**

  ✓ **Operator : CDMA2000 operators in Korea : LGU+ at first LTE launching**

☐ **CSFB (Circuit Switch Fall-Back)**

  ✓ **Method : UE falls back to a legacy network for voice service**

  ✓ **Pros : Low battery consumption, Simple UE structure (cost down)**

  ✓ **Cons : Interworking needed between LTE and legacy, Delay for switching system, (Voice + LTE data) is impossible (3G data only)**

 ✓ **Operator : Most of WCDMA operators, it's a 3GPP standard. (in Korea : KT/SKT)**

☐ **VoLTE (Voice Over LTE)**

  ✓ **Method : Supports Voice call on LTE network**

  ✓ **Pros : Low battery consumption, Simple UE structure (cost down), Faster than CSFB, (Voice + LTE data) is possible**

  ✓ **Cons : Requires IMS system, Complex core network, Requires National Wide network coverage**

  ✓ **Operator : Most of LTE operators are preparing**

  ➢ **SRVCC (Single Radio Voice Call Continuity) : Technology for transferring VoLTE call to the legacy (3G/2G) CS network while the call is in progress to . It is specified 3GPP REL.10**

01 VoLTE – Overview

QOS based bearers

- **The SIP Bearer is constructed as a default bearer on IMS APN in attach procedure.**
- **The Voice bearer is constructed as a dedicated bearer on IMS specific APN in voice activation phase.**
- **Bearer for data is constructed as default bearer on other APN in attach procedure.**
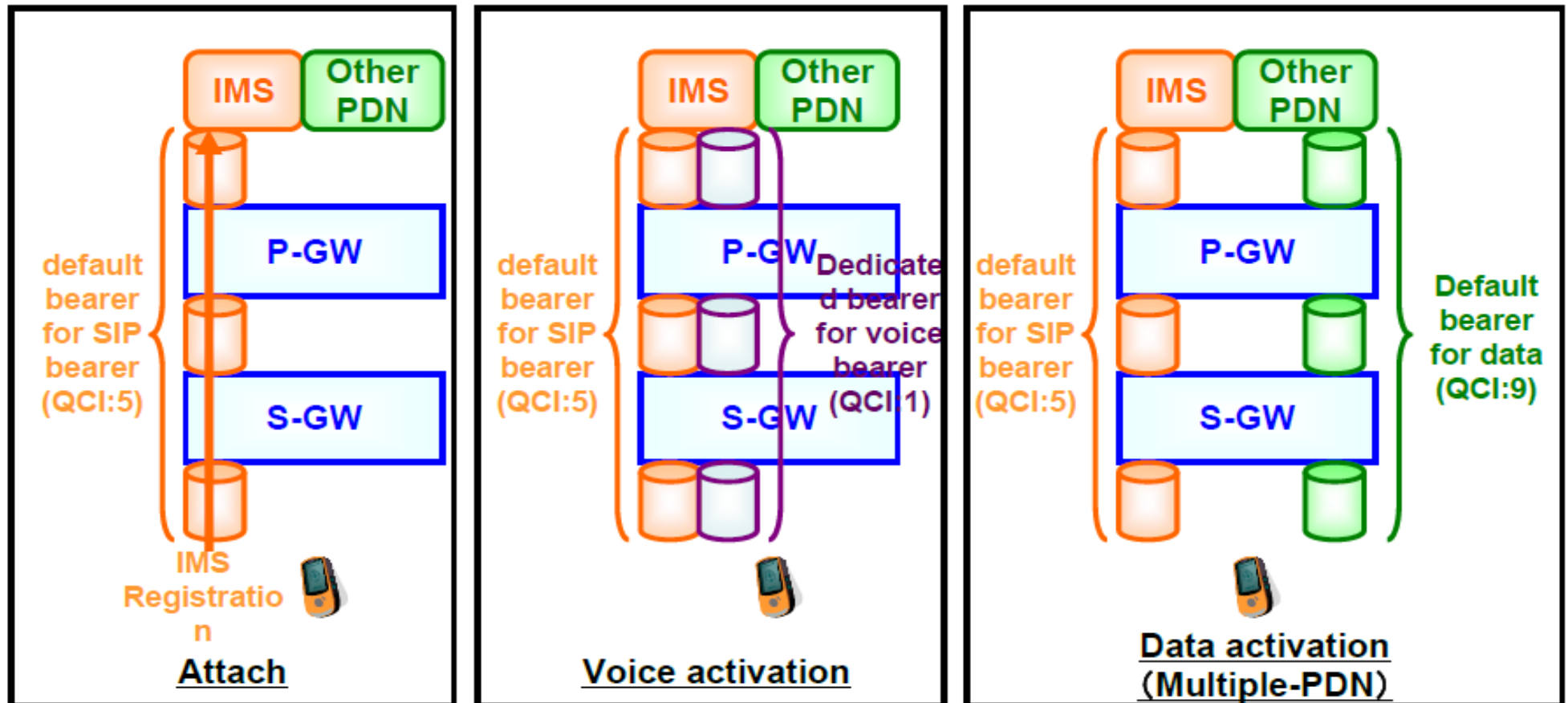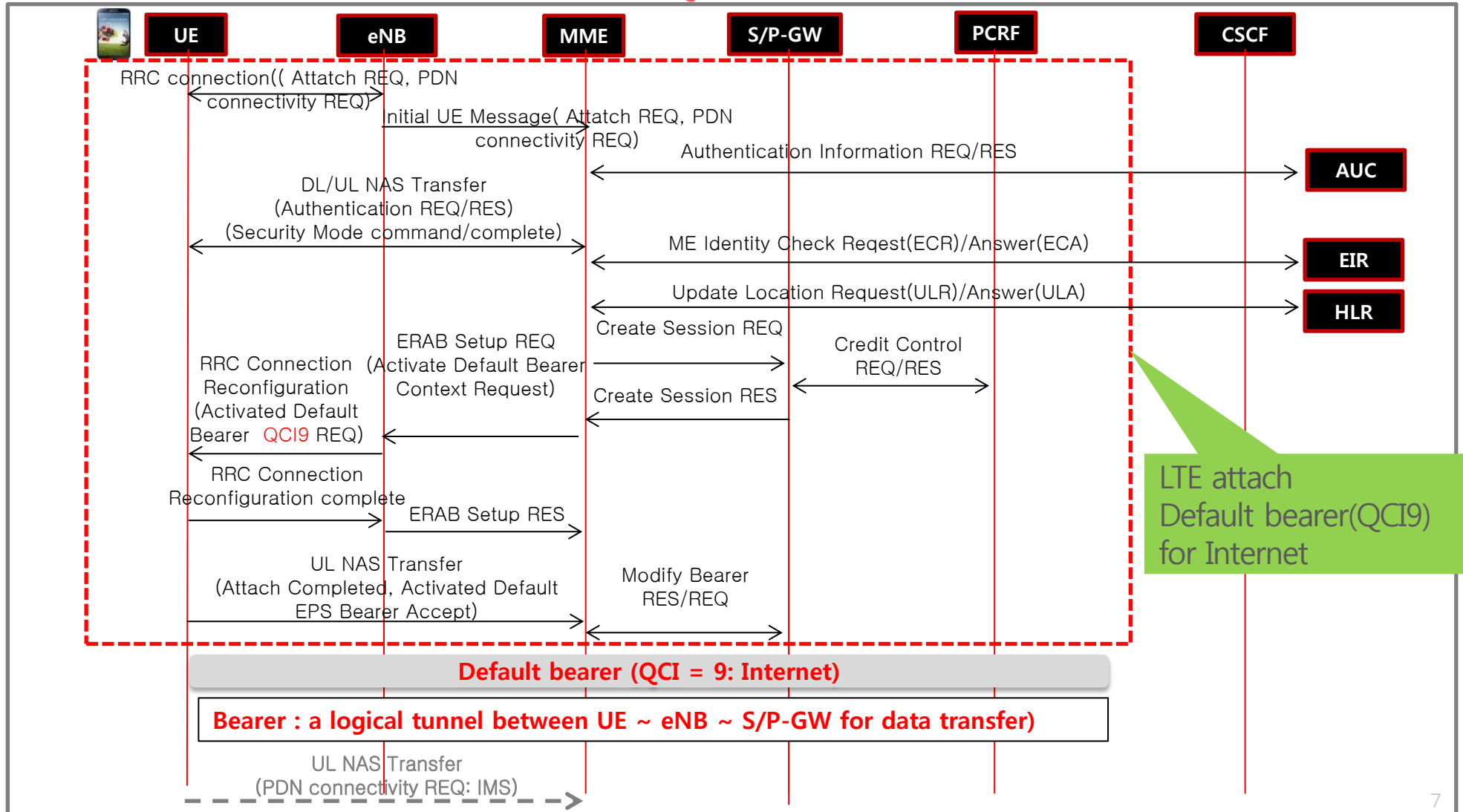
VoLTE - Overview

QCI (QoS Class Identifier)

QCI	Resource type	Priority	Packet Delay Budget(ms)	Packet error Loss Rate	services	remark
1	GBR	2	100	10^{-2}	Conversation Voice	VoLTE RTP
2	GBR	4	150	10^{-3}	Conversation Video (live streaming)	PSVT
3	GBR	3	50	10^{-3}	Real-time Gaming	
4	GBR	5	300	10^{-6}	Non-conversation Video (buffered streaming)	
5	Non-GBR	1	100	10^{-6}	IMS signaling	RJIL,KT IMS
6	Non-GBR	6	300	10^{-6}	Video (buffering streaming)	KT default bearer for data
7	Non-GBR	7	100	10^{-3}	Voice, Video (live streaming), interacting gaming	
8	Non-GBR	8	300	10^{-6}	TCP-based (WWW, email, FTP) ;privileged subscriber	
9	Non-GBR	9	300	10^{-6}	TCP-based (WWW, email, FTP) ;non-privileged subscriber	RJIL default bearer for data

> PSVT : Packet Switched Video Telephony service

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VoLTE – Call Flow

Attach and allocation Default bearer QCI9

Default bearer (QCI = 9: Internet)

Bearer : a logical tunnel between UE ~ eNB ~ S/P-GW for data transfer)

VoLTE – Call Flow

Attach and allocation Default bearer QCI5

| UE | eNB | MME | S/P-GW | PCRF | CSCF |

UL NAS Transfer
(PDN connectivity REQ: IMS)

Create Session REQ

Credit Control
REQ/RES

RRC Connection
Reconfiguration
(Activate Default
Bearer Context
Request /QCI5)

ERAB Set up REQ
(Activate Default Bearer
Context Request)

Create Session RES

RRC Connection
Reconfiguration complete

E-RAB Set up Response

UL NAS Transport
(Activate Default EPS Bearer Accept)

Modify Bearer
RES/REQ

Default bearer(QCI5)
for IMS

Default bearer & Session(QCI = 5: IMS)

Bearer and Session ~ eNB ~ S/P-GW for IMS)

SIP : REGISER

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VoLTE – Call Flow

Attach to register IMS
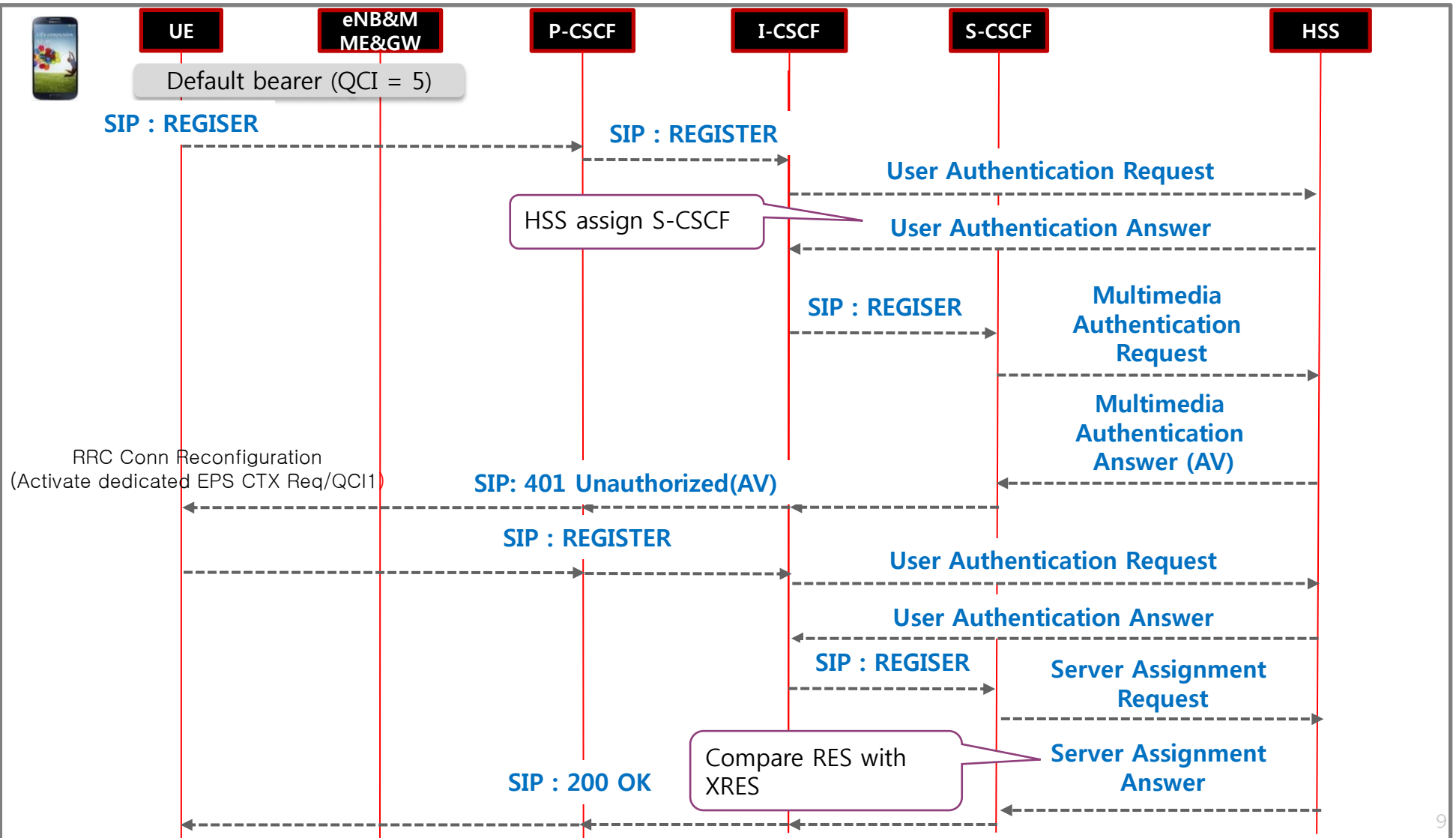
VoLTE – Call Flow

Mobile Origination

Default bearer (QCI =5) for SIP

SIP : INVITE

SIP : INVITE(SDP OFFER)

SIP : 100Trying

SIP : 183 Progress(SDP Answer)

RRC Conn Reconfiguration (Activate dedicated EPS CTX Req/QCI1)

ERAB REQ(Activate dedicated EPS CTX Req)

Create Bearer REQ

Re-Auth REQ

AA-REQ

RRC Conn Reconfiguration complete

ERAB response

UL NAS Transfer (Activate dedicated EPS bearer Ctx Accept)

Create Bearer RES

SIP : PRACK

Re-Auth RES

AA-RES

PRACK와 dedicated bear 의미 없음(NSN은 update 을 sendrece로 설정해서 정됨을 알려주고 RTP 송

Dedicated bearer (QCI = 1) for VoLTE

UPDATE

SIP :180 Ringing

SIP : 200 OK

Conversation state through Dedicated bearer using RTP

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RRC connection setup

Initial UE(Service REQ)

RRC Conn Reconfiguration (SRB2, DRB1/2)

Initial Context Setup REQ

Initial Context Setup RES

UE   eNB   MME   S/P-GW   PCRF   CSCF

02   VoLTE – Call Flow

Mobile Termination
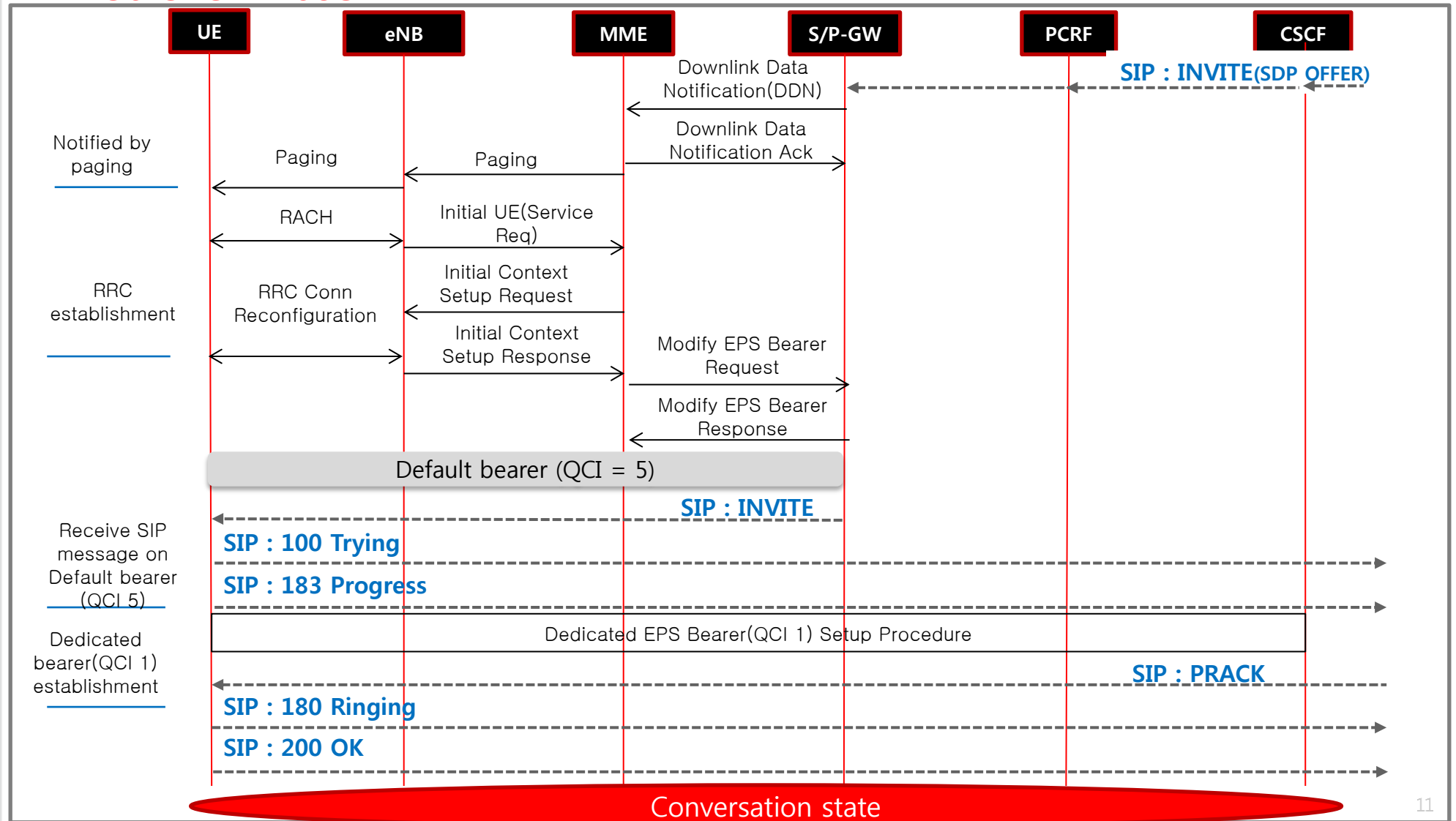
03 **Protocol - SIP** Method (Request / Respond)

SIP Method	Description	Definition
INVITE	Indicate that a client being invited to participate in a call session	RFC 3261
ACK	Confirms that the client has received a final response to and INVITE request	RFC 3261
BYE	Terminates a call; can be sent by either the caller or the called party	RFC 3261
CANCEL	Cancels any pending request	RFC 3261
OPTION	Queries the capabilities of servers	RFC 3261
REGISTER	Registers the address listed in the To header field with a SIP server	RFC 3261
PRACK	Provisional acknowledgement	RFC 3262
SUBSCRIBE	Subscribes an event to the Server	RFC 3265
NOTIFY	Notifies the subscriber of a new Event	RFC 3265
PUBLISH	Publishes an event to the Server	RFC 3903
INFO	Sends mid-session information that does not modify the session state	RFC 6086
REFER	Asks recipient to issue a SIP request (call transfer)	RFC 3515
MESSAGE	Transports instant messages using SIP	RFC 3428
UPDATE	Modifies the State of a session without changing the state of the dialog	RFC 3911

03 Protocol - RTP

☐ RTP (Real-time Transport Protocol)

- ✓ **RTP was developed by the Audio-Video Transport Working Group of the (IETF) in 1996.**
- ✓ **RTP is designed for end-to-end, real-time, transfer of streaming media such as telephony, videoconference, TV and Push-to-talk services.**
- ✓ **RTP can be used with several protocols such as SIP, Jingle, RTSP, H.225, H.245 and etc. (These protocols transfer signals and RTP transfer Traffic.)**

☐ RTP payload types for VoLTE

Media type	Subtype	Rate(Hz)	IETF	3GPP	Notes
Audio	AMR	8000	RFC4867	26.071	Mandatory
Audio	AMR-WB	16000	RFC4867,3267	26.171	Mandatory
Audio	EVRCB	8000	RFC4788	C.S0055	for CDMA
Audio	EVRCWB	8000	RFC5188	C.S0055	for CDMA
Text	T140	1000	RFC4628		Mandatory
Video	H263	90000	RFC4628	26.235	Mandatory
Video	H264,MP4V-ES	90000	RFC6184,3016		options

☐ RTCP (Real-time Control Protocol)

- ✓ **The RTP specification describes two sub-protocols; RTP and RTCP (Real-time Transport Control Protocol).**
- ✓ **RTCP is used to monitor transmission statistics and Quality of Service (QoS) and aids synchronization of multiple streams.**

Protocol - SIP Response

SIP Response	Codes	Description
Information/Provisional	1XX	Request received and being processed
Successful	2XX	The action was successfully received, understood, and accepted
Redirection	3XX	Further action needs to be taken (typically by the sender) to complete the request
Client Failure	4XX	The request contains bad syntax or cannot be fulfilled at the server
Server Failure	5XX	The server failed to fulfill unapparent valid request
Global Failure	6XX	The request cannot be fulfilled at the server

Refer to Appendix. SIP codes.

Event Cases – Attach

Attach Failure due to no response for E-RAB Setup from eNB

Test Date	LDC Building 2nd floor 03-06-2015 11:34:53 - Reproduction test
Reason	MME doesn't receive E-RAB Setup response from eNB MME sends "deactivate EPS bearer context request (ESM 31)" to UE
Suggestion	Need eNB system trace to clarify eNB or Backhaul issue

Event Flow
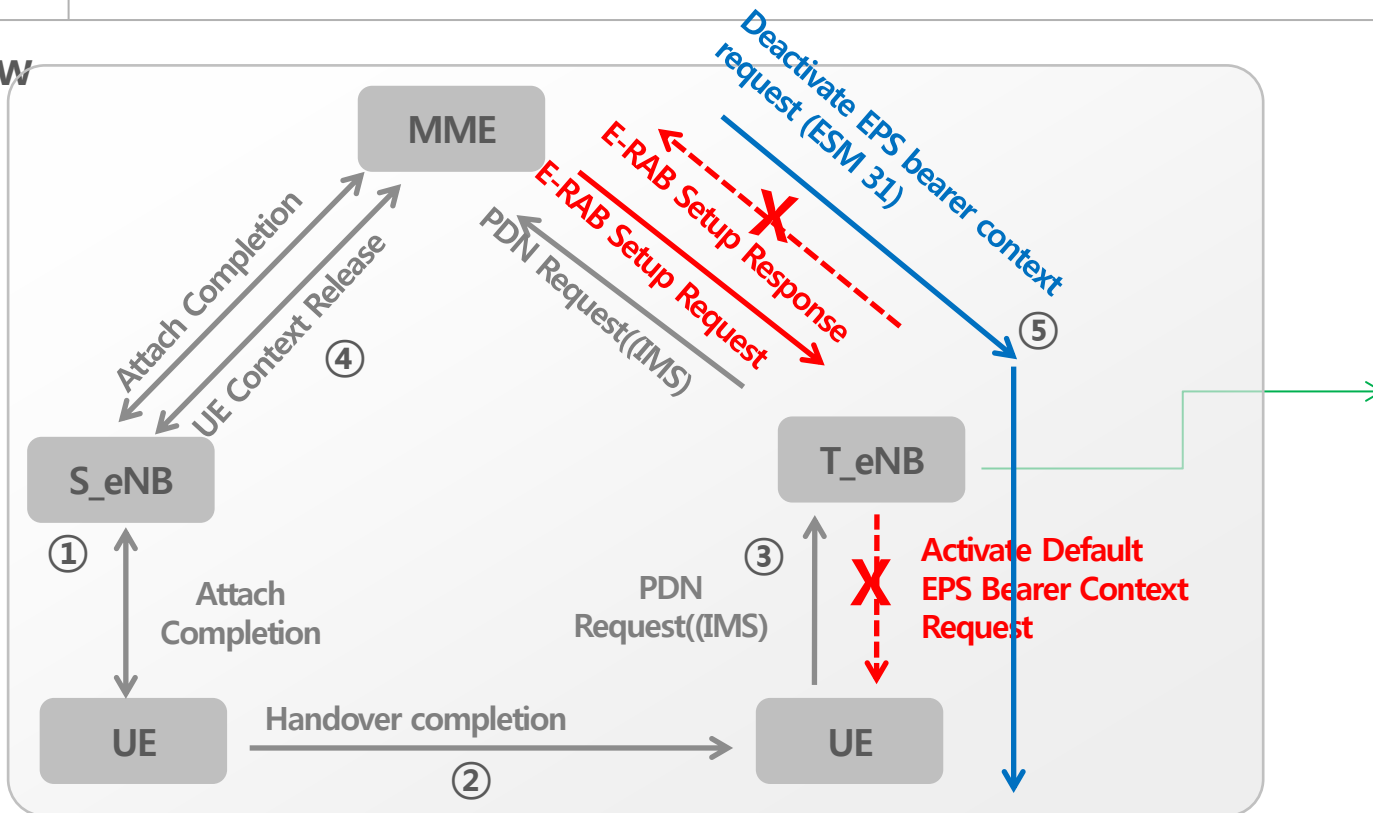
Event Cases – Attach

Due to poor RF condition, UE cannot receive RRC reconfiguration message including activate default EPS bearer context request

Cluster / Date	TN-DGGR-0100 08-05-2015 (20150508215858-RJS03-Cluster_VoS_C1_InProg_TN-VDGR0100_F4788193.dm)
Reason	eNB sends initial context setup failure (failure-in-radio-interface-procedure) to MME when RRC timer (2sec) expires
Suggestion	RF Issue

Event Cases - Attach

(UE-VRNS-0153)

W48	UE-VRNS-0153
Reason	No SIP signal(Register) for IMS form UE, after LTE attach procedure completed UE related issue

Total	No QCI5 Default Bearer	No SIP[Register] Message	Analyze in Progressing
50	33	8	9

Start Attach Procedure

Time gap : 12sec
No SIP(Register) message from UE & IMS send rrcConnectionRelease after 12sec
1. UE Problem : UE doesn't proceed register procedure

QCI9 Default Bearer Open

QCI5 Default Bearer Open

Event Cases – Attach

W47	KO-KLKT-0077
Reason	no procedure for 2nd Register UE, after 1st Register done. IMS stack in UE doesn't work properly

2015-11-03 12:54:50.005	LTE	EPS MM	Security protected NAS message	
2015-11-03 12:54:50.005	LTE	EPS MM	EMM information	
2015-11-03 12:54:50.802	LTE	EPS SM	PDN connectivity request	
2015-11-03 12:54:50.802	LTE	EPS MM	Security protected NAS message	
2015-11-03 12:54:50.802	LTE	UL-DCCH [Lte]	ulInformationTransfer	Security protected NAS message
2015-11-03 12:54:50.909	LTE	DL-DCCH [Lte]	rrcConnectionReconfiguration	Security protected NAS message
2015-11-03 12:54:50.909	LTE	UL-DCCH [Lte]	rrcConnectionReconfigurationComplete	
2015-11-03 12:54:50.909	LTE	EPS MM	Security protected NAS message	
2015-11-03 12:54:50.909	LTE	EPS SM	Activate default EPS bearer context request	
2015-11-03 12:54:50.909	LTE	[0xB0E4] LTE NAS ESM bearer Co		
2015-11-03 12:54:50.909	LTE	[0xB0E5] LTE NAS ESM bearer co		
2015-11-03 12:54:50.909	LTE	[0xB0E5] LTE NAS ESM bearer co		
2015-11-03 12:54:50.909	LTE	[0xB0E4] LTE NAS ESM bearer Co		
2015-11-03 12:54:50.909	LTE	EPS SM	Activate default EPS bearer context accept	

IP address and QoS to be used by IMS are allocated to UE

1. UE didn't send the 2nd Register as a response to 401 Unauthorized
2. It seems that IMS stack in UE doesn't work properly

2015-11-03 12:54:52.346	TCP Tx-SIP	TCP	25740, 60313, 5060, Seq:2025401588, Ack:214281898
2015-11-03 12:54:52.346	TCP Tx-SIP	TCP	25741, 60313, 5060, Seq:2025401588, Ack:214281898, REGISTER sip:ims.mnc873.mcc40
2015-11-03 12:54:52.410	TCP Rx-SIP	TCP	17443, 5060, 60313, Seq:214281898, Ack:2025402615
2015-11-03 12:54:52.494	TCP Rx-SIP	TCP	17444, 5060, 60313, Seq:214281898, Ack:2025402615, SIP/2.0 401 Unauthorized
2015-11-03 12:54:52.494	TCP Tx-SIP	TCP	25742, 60313, 5060, Seq:2025402615, Ack:214283128
2015-11-03 12:54:52.594	TCP Tx-SIP	TCP	25743, 60313, 5060, Seq:2025402615, Ack:214283128
2015-11-03 12:55:02.267	TCP Tx-ETC	TCP	39366, 53395, 15600, Seq:1328928166, Ack:0
2015-11-03 12:55:02.353	TCP Rx-ETC	TCP	31600, 15600, 53395, Seq:1959046023, Ack:1328928167
2015-11-03 12:55:02.353	TCP Tx-ETC	TCP	39367, 53395, 15600, Seq:1328928167, Ack:1959046024
2015-11-03 12:55:02.353	TCP Tx-ETC	TCP	39368, 53395, 15600, Seq:1328928167, Ack:1959046024
2015-11-03 12:55:02.353	TCP Tx-ETC	TCP	39369, 53395, 15600, Seq:1328928183, Ack:1959046024
2015-11-03 12:55:02.467	TCP Tx-ETC	TCP	39370, 53395, 15600, Seq:1328928204, Ack:1959046024
2015-11-03 12:55:02.467	TCP Tx-ETC	TCP	39371, 53395, 15600, Seq:1328928420, Ack:1959046024
2015-11-03 12:55:02.467	TCP Tx-ETC	TCP	39372, 53395, 15600, Seq:1328928457, Ack:1959046024

Event Cases – Attach

In case of X2HO collision during activating IMS default bearer

Test Date	GJ-AMBD-0049, 2015-05-20 17:46:00, CLOT VoS Test(C2)
Reason	Failure to create IMS APN default bearer due to Handover-trigger in eNB

Event Flow

UE	eNB	MME	SAE-GW

Attach Procedure Completion

PDN Connectivity Request(IMS)

Create session Request/response

E-RAB Setup Request
(Activate default EPS bearer context request)

E-RAB Setup Response
(X2-Handover-Triggered)

Delete session Request/response

Deactivate EPS bearer context (ESM cause 31)

ESM Status(Message not Compatible with the protocol)

T-eNB

Path Switch Req/Ack

PDN Connectivity Request(IMS)

04. Event Cases – Call setup

VoLTE call setup fail by receiving 503 service unavailable due to RF condition

Test Date	MP-GWLR-0717 2015-06-28 16:23:49 CLOT VoS Test(C2)
Reason	If there is no SIB1 message after completely receiving MIB then UE declares RLF by complementation

SIB1 read fail by Qualcomm implementation

Activate dedicated EPS bearer setup complete is not sent due to RLF
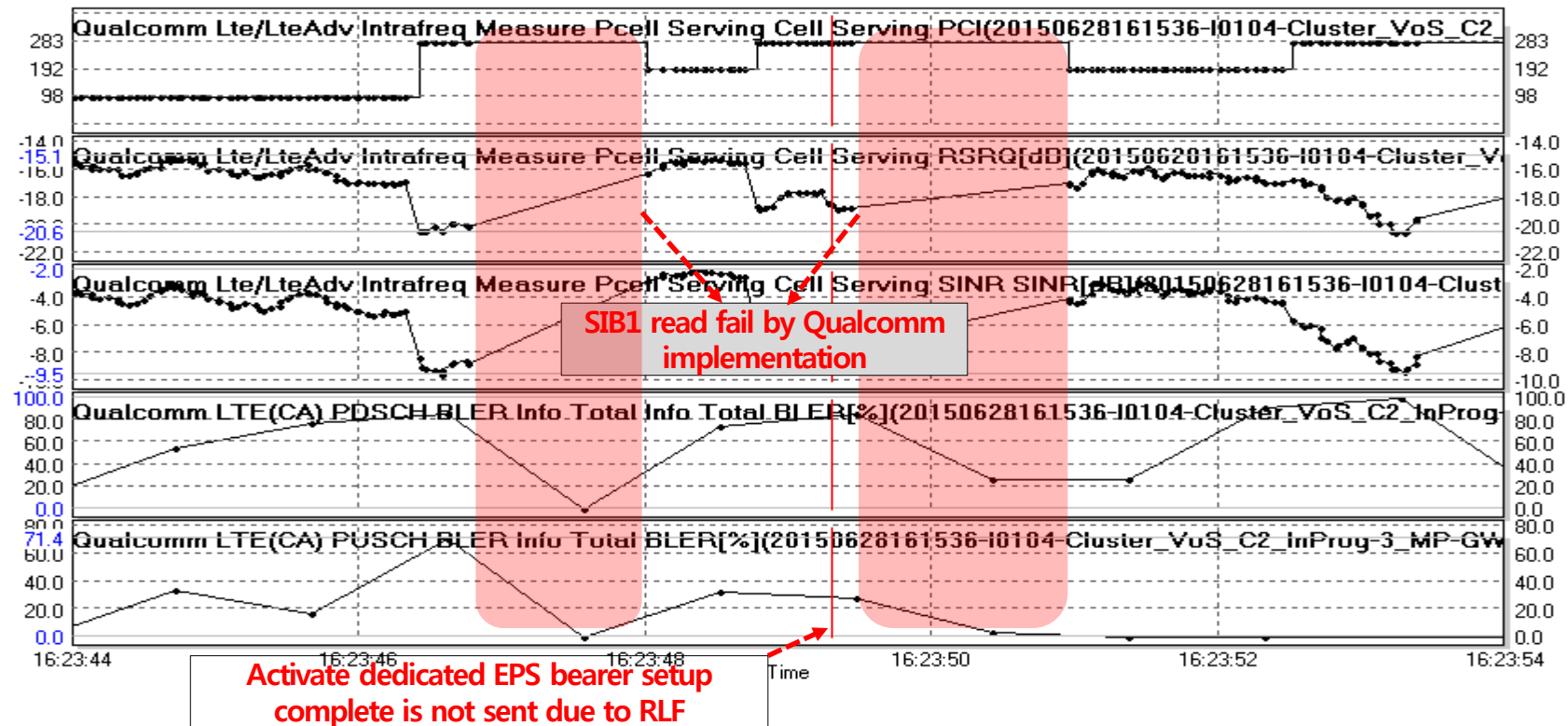
Event Cases – Call setup

W47	HR-MHNG-0205
Reason	UE does not retransmit " INVITE", after no 100Trying from IMS UE related issue

▷ **Due to low attach success counts(85 call), despite only 1 call failure, KPI was failed.**

- **RF condition: Good, RSRP -78.54 dBm, SINR 11.53 dB**

- **Issue: There is no '100 trying' from IMS, then UE does not retransmit "INVITE", until timer expires.**

  - **UE should retransmit "INVITE" before timer is expired, if there is no "100 trying" from IMS**

  - **not able to analyze further because Tektronix log data doesn't exist**

- **Result: one abnormal case occurred, No relation with RF condition**
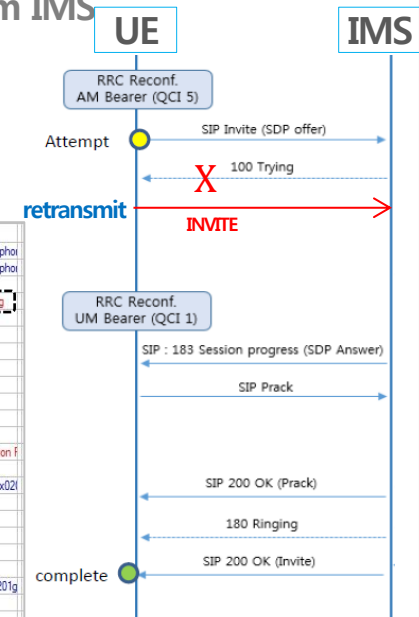
Abnormal case

2015-11-13 16:01:07.50:	Tx Voice Call	Call Setup Status	Intent.ACTION_CALL
2015-11-13 16:01:07.914	TCP Tx-SIP	TCP	18060, 45422, 5060, Seq:1042729266, Ack:1378043782, INVITE tel:55555;pho
2015-11-13 16:01:07.914	TCP Tx-SIP	TCP	18061, 45422, 5060, Seq:1042730634, Ack:1378043782, INVITE tel:55555;pho
2015-11-13 16:01:08.112	TCP Rx-SIP	TCP	38795, 5060, 45422, Seq:1378043782, Ack:1042730634
2015-11-13 16:01:08.429	TCP Tx-SIP	TCP	18062, 45422, 5060, Seq:1042730634, Ack:1378043782, 00
2015-11-13 16:01:09.165	TCP Tx-SIP	TCP	
2015-11-13 16:01:10.532	TCP Tx-SIP	TCP	
2015-11-13 16:01:11.749	TCP Rx-SIP	TCP	
2015-11-13 16:01:11.749	TCP Tx-SIP	TCP	18065, 45422, 5060, Seq:1042731098, Ack:1378043783
2015-11-13 16:01:11.794	TCP Rx-SIP	TCP	0, 5060, 45422, Seq:1378043782, Ack:0
2015-11-13 16:01:11.794	TCP Rx-SIP	TCP	0, 5060, 45422, Seq:1378043782, Ack:0
2015-11-13 16:01:11.794	TCP Rx-SIP	TCP	0, 5060, 45422, Seq:1378043782, Ack:0
2015-11-13 16:01:11.794	TCP Rx-SIP	TCP	0, 5060, 45422, Seq:1378043782, Ack:0
2015-11-13 16:01:11.794	TCP Rx-SIP	TCP	0, 5060, 45422, Seq:1378043783, Ack:0

UE does not get 100 Trying from IMS
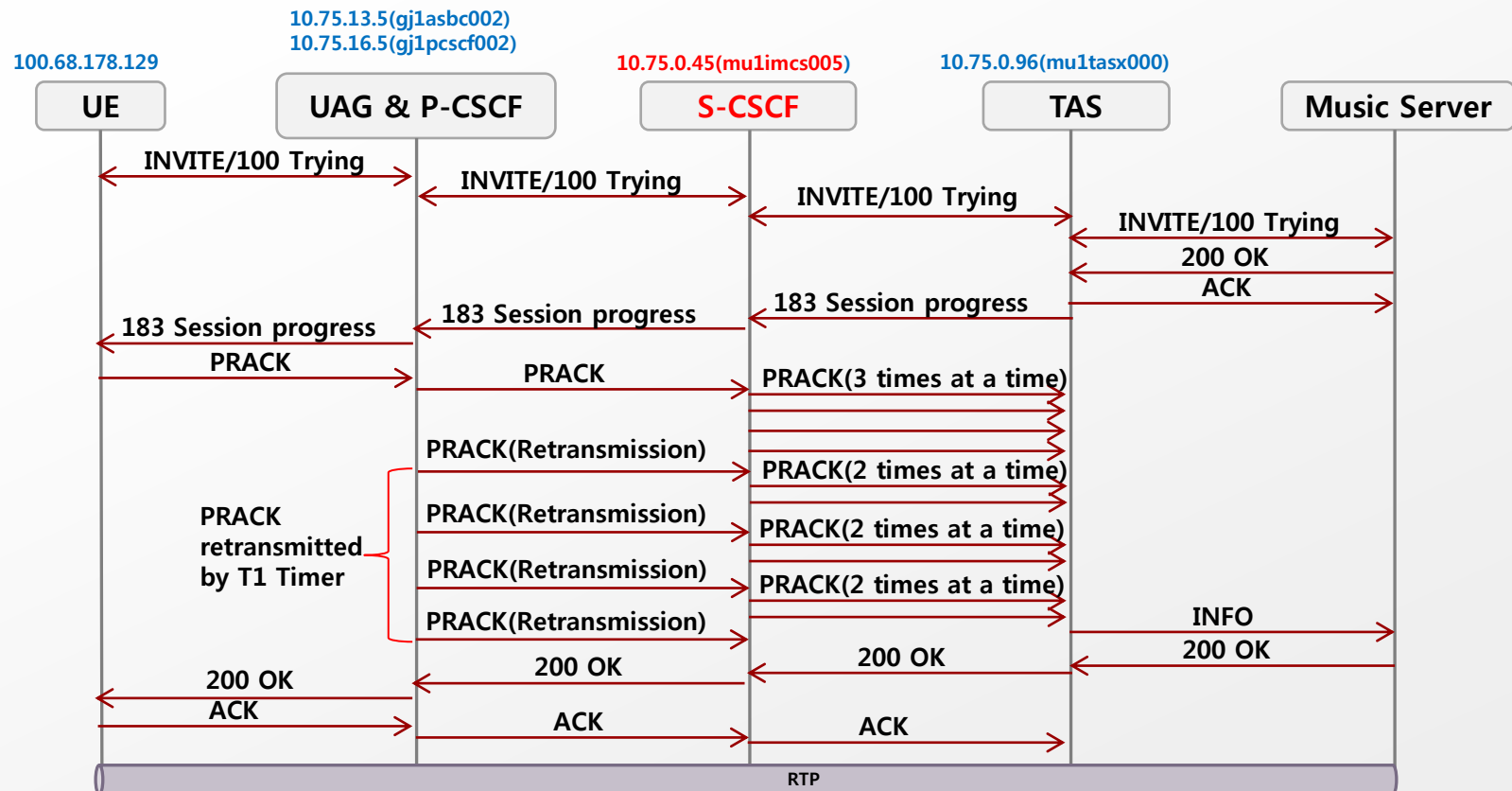
UE does not retransmit "INVITE"

Normal case

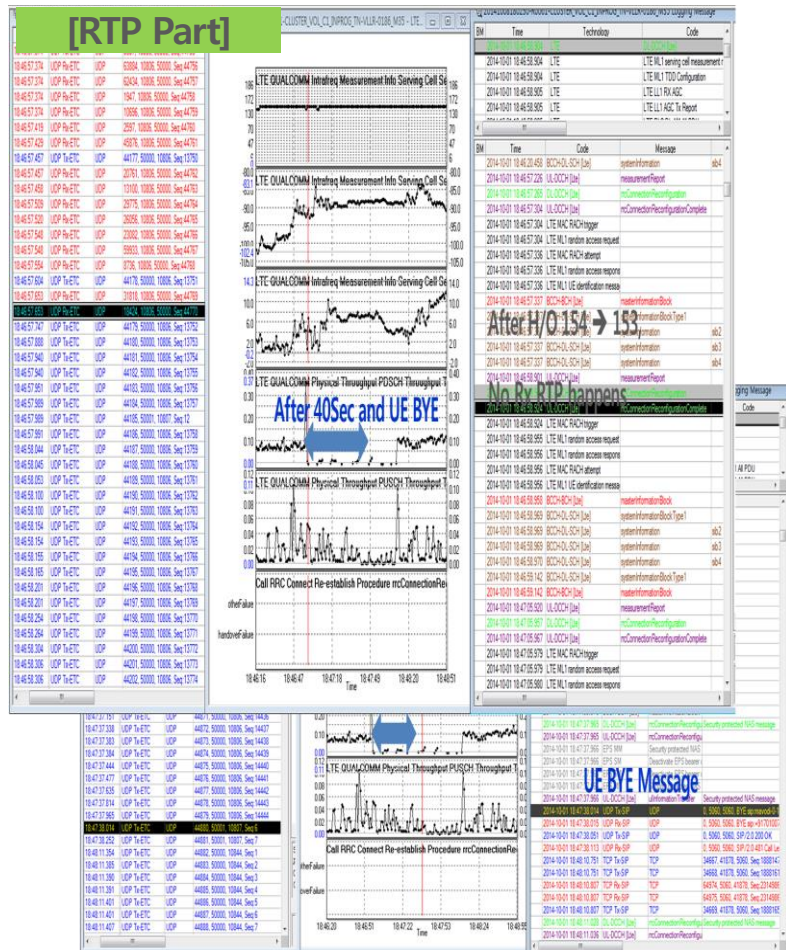| 2015-11-13 16:04:39.39:	Tx Voice Call	Call Setup Status	Intent.ACTION_CALL
2015-11-13 16:04:40.517	TCP Tx-SIP	TCP	64980, 60548, 5060, Seq:3183853442, Ack:3608402396, INVITE tel:55555;pho
2015-11-13 16:04:40.517	TCP Tx-SIP	TCP	64981, 60548, 5060, Seq:3183854810, Ack:3608402396, INVITE tel:55555;pho
2015-11-13 16:04:40.578	TCP Rx-SIP	TCP	30445, 5060, 60548, Seq:3608402396, Ack:3183855278
2015-11-13 16:04:40.588	TCP Rx-SIP	TCP	30446, 5060, 60548, Seq:3608402396, Ack:3183855278, SIP/2.0 100 Trying
2015-11-13 16:04:40.645	TCP Tx-SIP	TCP	64982, 60548, 5060, Seq:3183855278, Ack:3608402649
2015-11-13 16:04:40.833	LTE	DL-DCCH [Lte]	rrcConnectionReconfig Security protected NAS message
2015-11-13 16:04:40.843	LTE	EPS MM	Security protected NAS
2015-11-13 16:04:40.843	LTE	UL-DCCH [Lte]	rrcConnectionReconfig
2015-11-13 16:04:40.844	LTE	EPS SM	Activate dedicated EP
2015-11-13 16:04:40.844	LTE	EPS SM	Activate dedicated EP
2015-11-13 16:04:40.844	LTE	EPS MM	Security protected NAS
2015-11-13 16:04:40.844	LTE	UL-DCCH [Lte]	ulInformationTransfer Security protected NAS message
2015-11-13 16:04:40.891	TCP Rx-SIP	TCP	30447, 5060, 60548, Seq:3608402649, Ack:3183855278, SIP/2.0 183 Session
2015-11-13 16:04:40.891	TCP Tx-SIP	TCP	64983, 60548, 5060, Seq:3183855278, Ack:3608404001
2015-11-13 16:04:40.962	TCP Tx-SIP	TCP	64984, 60548, 5060, Seq:3183855278, Ack:3608404001, PRACK sip:hr1pcfx02(
2015-11-13 16:04:41.083	TCP Rx-SIP	TCP	30448, 5060, 60548, Seq:3608404001, Ack:3183856264
2015-11-13 16:04:41.083	TCP Rx-SIP	TCP	30449, 5060, 60548, Seq:3608404001, Ack:3183856264, SIP/2.0 200 OK
2015-11-13 16:04:41.093	TCP Tx-SIP	TCP	64985, 60548, 5060, Seq:3183856264, Ack:3608404393
2015-11-13 16:04:41.126	TCP Rx-SIP	TCP	30450, 5060, 60548, Seq:3608404393, Ack:3183856264, SIP/2.0 200 OK
2015-11-13 16:04:41.127	TCP Tx-SIP	TCP	64986, 60548, 5060, Seq:3183856264, Ack:3608405389
2015-11-13 16:04:41.176	TCP Tx-SIP	TCP	64987, 60548, 5060, Seq:3183856264, Ack:3608405389, ACK sip:hr1pcfx0201g
2015-11-13 16:04:41.243	TCP Rx-SIP	TCP	30451, 5060, 60548, Seq:3608405389, Ack:3183857150
2015-11-13 16:04:43.72(	Tx Voice Call	Call Connected	First RTP
2015-11-13 16:04:43.72(	Tx Voice Call	Traffic Start	
2015-11-13 16:04:53.75(	Tx Voice Call	Success	

UE / IMS

RRC Reconf. AM Bearer (QCI 5)

Attempt — SIP Invite (SDP offer)

X — 100 Trying

retransmit — **INVITE**

RRC Reconf. UM Bearer (QCI 1)

SIP : 183 Session progress (SDP Answer)

SIP Prack

SIP 200 OK (Prack)

180 Ringing

SIP 200 OK (Invite)

complete

04. Event Cases – Call setup

200OK for PRACK is delayed

Test Date	GJ-GDGR-0632 15-05-2016 17:55:27 ~ 17:55:50
Reason	S-CSCF didn't send PRACK normally to TAS during 8 sec, so 200OK for PRACK is delayed IMC had problem between 12th~ 20th May, that problem is resolved by removing its routing table.

Event Case – NO_RTP

[RTP Part]

[SIP Part]

15min 40sec (Invite – Bye)

< 50sec NO_RTP Bye Case >

15min 50sec (Invite – Bye)

< 50sec NO_RTP Bye Case >

< NO_RTP DM Message >

➤ **Refer to [kt_1411_11] RJIL VoLTE Call Drop Analysis & [kt_1411_11-01] NO RTP Issues for VoLTE Session2**

Appendix#1 - IMS function Blocks

- P-CSCF (Proxy CSCF) : initial contact point of UE, SIP proxy between UE and IMS core
- S-CSCF (Serving CSCF) : provide session setup, session tear-down, session control, routing function
- I-CSCF (Interrogating CSCF) : I-CSCF is the contact point within an operator's network for all connections destined to a user of that network
- TAS (Telephony Application Server) : TAS provide supporting for a minimum set of mandatory Multimedia Telephony services
- MRF (Media Resource Function) : provide media plane processing independent of application types (eg transcoding, multiparty conference, network announcements/tone etc.
- IBCF/TrGW (Interconnection Border Control Function/Transaction Gateway) : interconnection point to other PMNs.
- IMS-ALG/IMS-AGW (IMS Application Level Gateway/IMS Access Gateway) : It provides functions for Gate Control & Local NAT, IP realm indication and availability, Remote NAT traversal support, Traffic Policing, QoS Packet Marking, IMS Media Plane Security, etc.
- MGCF/IMS-MGW (Media Gateway Control Function/IMS Media Gateway) : interconnecting point to circuit-switched network
- BGCF (Breakout Gateway Control Function) : determining the next hop for routing SIP message (select proper MGCF for CS domain)
- SEG (Security Gateway) : originate and terminate secure associations between eNB and EPS bye IPsec
- ENUM (E.164 Number Mapping) : translate E.164 number to SIP URIs using DNS to enable message routing of IMS sessions
- Diameter Agent : enabling the seamless communication and control of information between network elements within LTE or IMS networks and across network borders

Appendix#2 - SIP code list

100 Trying
180 Ringing
181 Call Forwarding
182 Queued
183 Session Progress
199 Early Dialog Terminated

200 OK
202 Accepted
204 No Notification

300 Multiple Choices
301 Moved Permanently
302 Moved Temporarily
305 Use Proxy
380 Alternative Service

400 Bad Request
401 Unauthorized
402 Payment Requirement
403 Forbidden
404 Not Found
405 Bad Method
406 Not Acceptable

407 Proxy Authentication Required
408 Request Timeout
410 Gone
412 Conditional Request Failed
413 Request Entity Too Large
414 Request-URI Too Long
415 Unsupported Content
417 Unknown Resource-Priority
420 Bad Extensions
421 Extension Required
422 Session Interval Too Small
423 Interval Too Brief
424 Bad Location Information
428 Use Identity Header
429 Provide Referrer Identity
430 Flow Failed
433 Anonymity Disallowed
436 Bad Identity-Info
437 Unsupported Certificate
438 Invalid Identity Header
439 First Hop Lacks outbound Support
440 Max-Breadth Exceed

469 Bad Info Package
470 Consent Needed
480 Temporally Unavailable
481 Call/Transaction Does Not Exist
482 Loop detected
493 Undecipherable
494 security Agreement Required
483 Too Many Hops
484 Address Incomplete
485 Ambiguous
486 Busy Here
487 Request Terminated
488 Not Acceptable Here
489 Bad Event
491 Request Pending

500 Server Error
501 Not Implemented
503 Unavailable
504 Timeout

600 Busy Everywhere
603 Decline
604 Doesn't Exist
606 Not Acceptable

Appendix#3

X2 handover
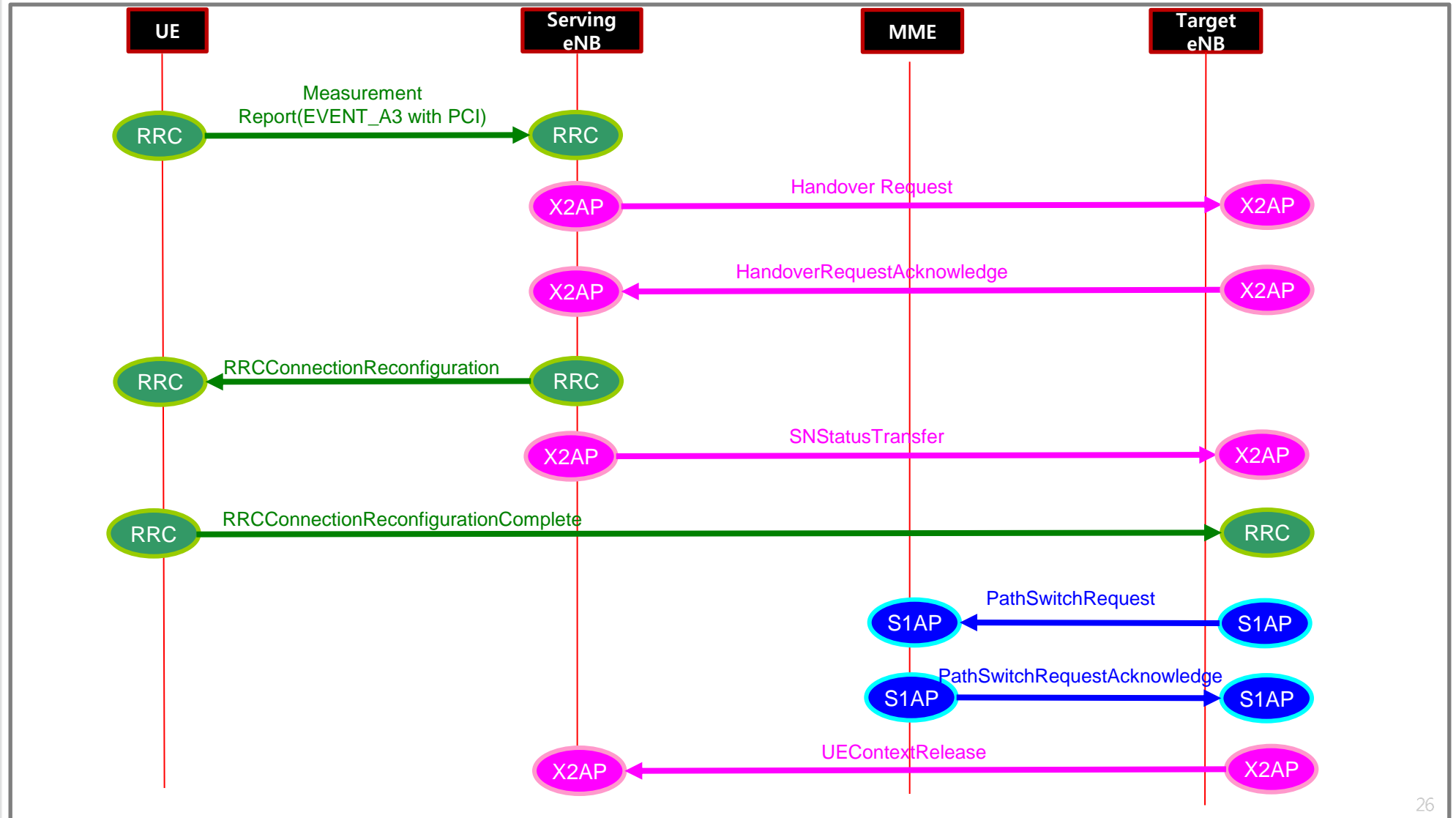
Appendix#4

S1 handover

RRC connection setup flow

UE ⟷ **EUTRAN**

Paging 또는 Random access procedure

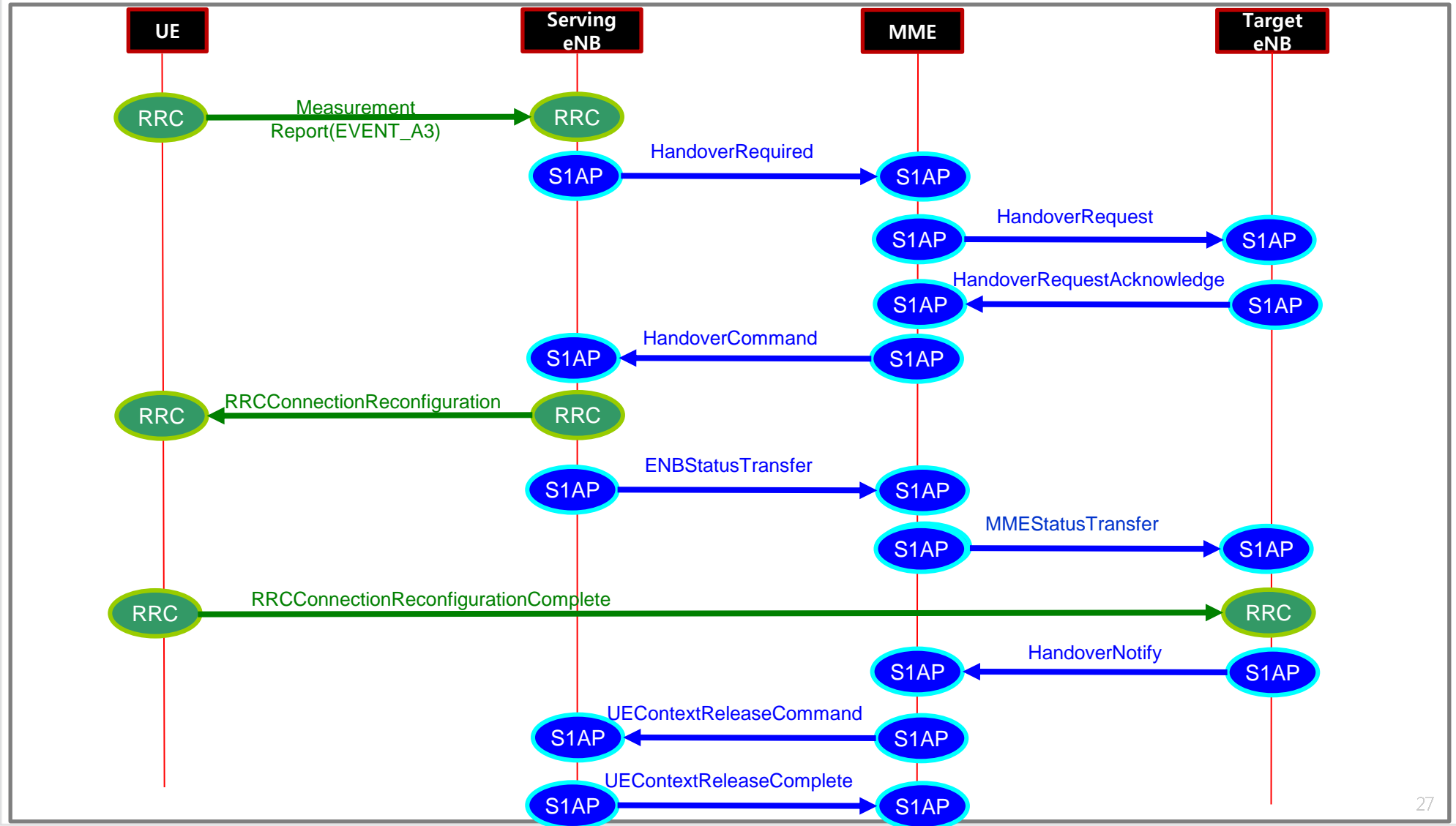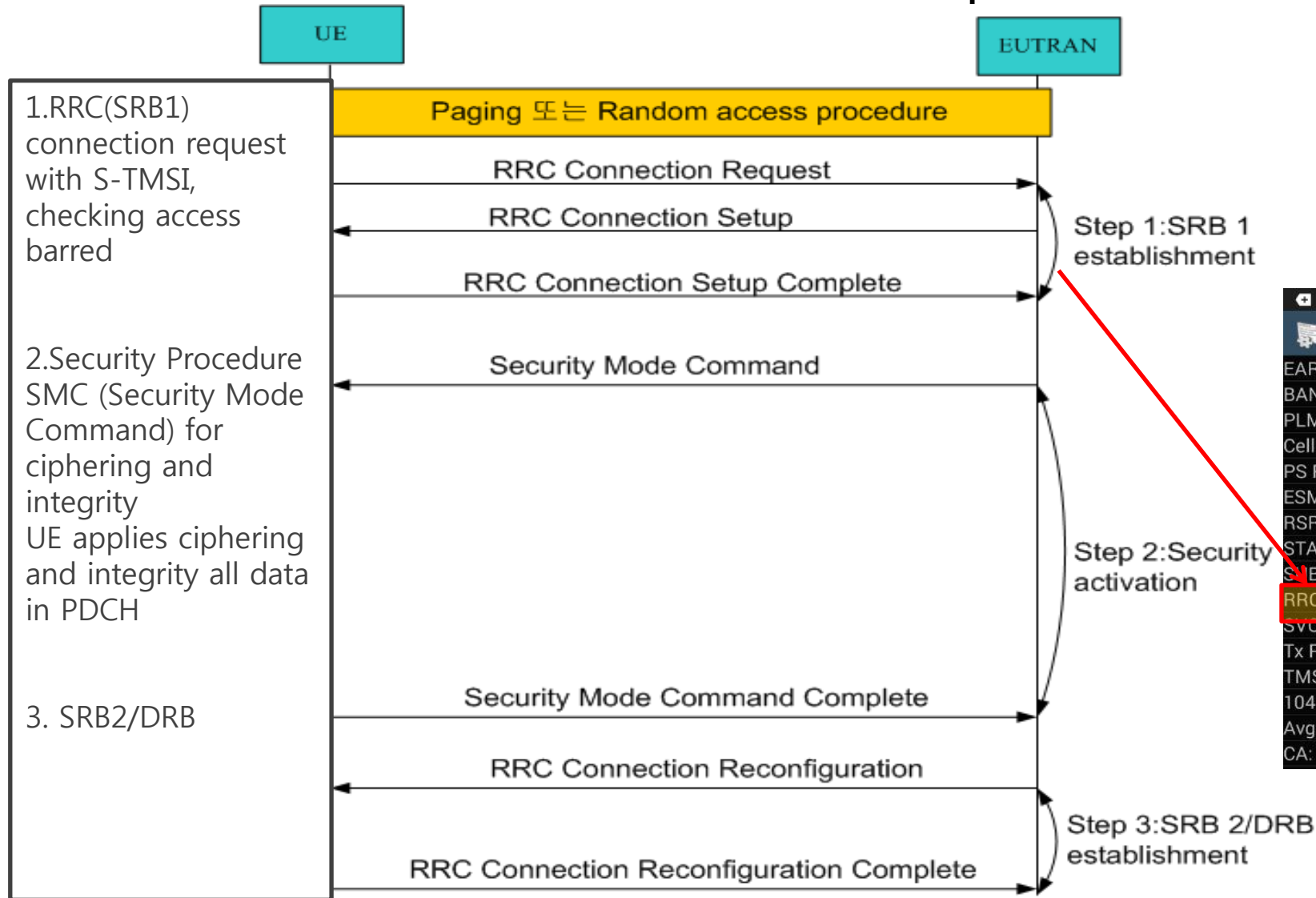| UE	EUTRAN	
1.RRC(SRB1) connection request with S-TMSI, checking access barred	RRC Connection Request →	
	← RRC Connection Setup	Step 1:SRB 1 establishment
	RRC Connection Setup Complete →	
2.Security Procedure SMC (Security Mode Command) for ciphering and integrity UE applies ciphering and integrity all data in PDCH	← Security Mode Command	Step 2:Security activation
	Security Mode Command Complete →	
3. SRB2/DRB	← RRC Connection Reconfiguration	Step 3:SRB 2/DRB establishment
	RRC Connection Reconfiguration Complete →	

ServiceMode

EARFCN(DL/UL): 1550/19550
BAND: 3 BW: 20 MHz
PLMN: 450 08 TAC: 136
Cell(PCI): 7-0-0-0-2674-0-0(330
PS REJECT: 0 CS REJECT: 0
ESM CAUSE: 0 L2W: --
RSRP:-76 RSRQ:-7 RSSI:-50
STATUS: SRV/REGISTRED
SRB STATUS: NORMAL
RRC: CONNECTED
SVC: CS_PS SINR: 23.80
Tx Pwr: -36 RI: -- DRX: --
TMSI : 192101196208
104.216.24.90 100.81.5.29
AvgRSRP -75 AvgRSRQ -7 ANT 4
CA: 0 S_PCI: -- S_freq: --

Thank you | kt