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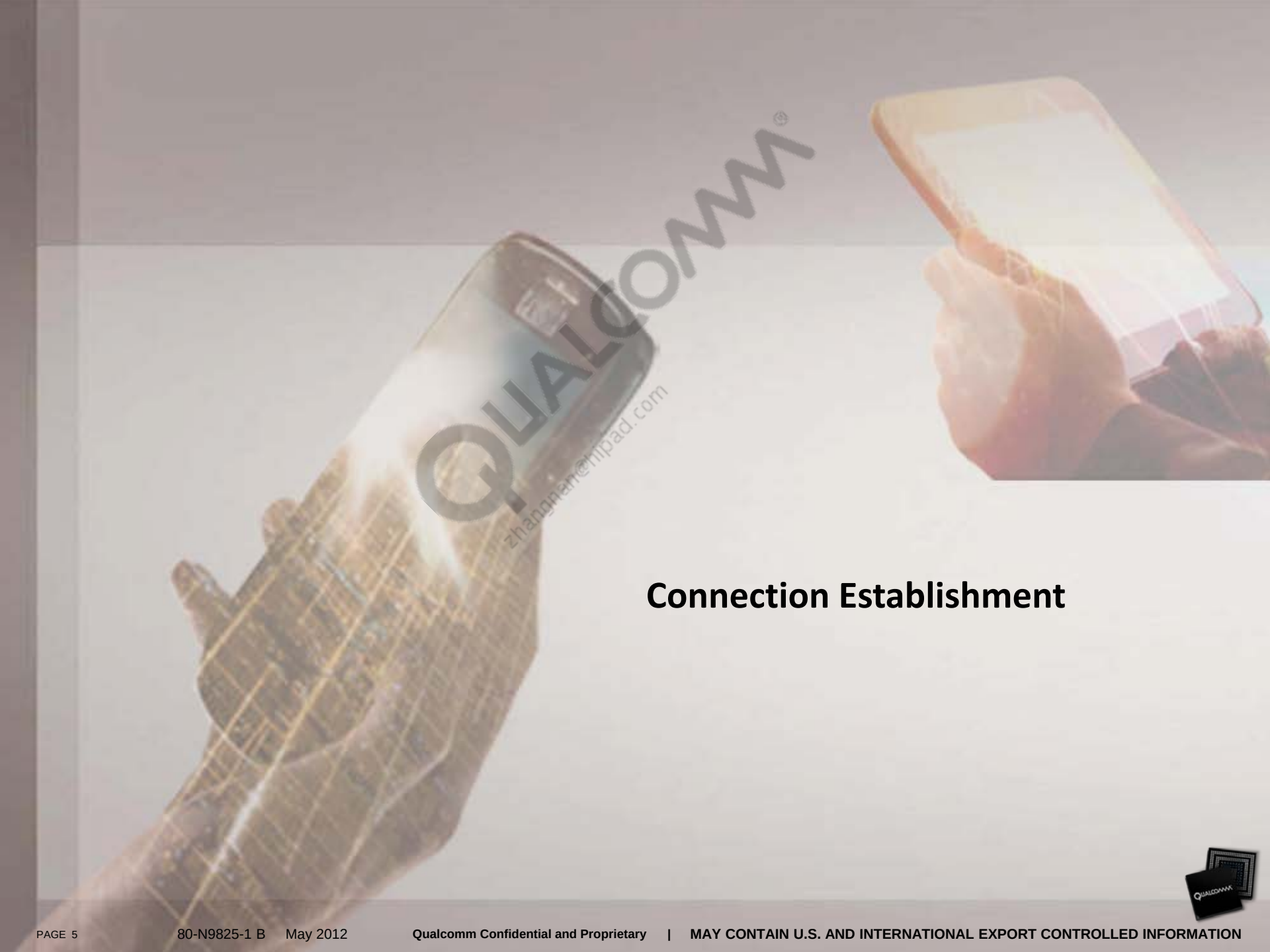
Revision History

Version	Date	Description
A	Feb 2012	Initial release
B	May 2012	Added QXDM Professional® analysis snapshots

Contents



Connection Establishment

SRB1 Establishment

- After RRC Connection Setup, UE has Signaling radio bearer 1(SRB) established.

```
2011 Dec 9 10:22:39.297 [00] 0xB0C0 LTE RRC OTA Packet -- DL_CCCH
Pkt Version = 2
RRC Release Number.Major.minor = 9.3.0
Radio Bearer ID = 0, Physical Cell ID = 1
Freq = 5230
SysFrameNum = 474, SubFrameNum = 7
PDU Number = DL_CCCH Message,   Msg Length = 17

Interpreted PDU:

value DL-CCCH-Message ::=
{
  message c1 : rrcConnectionSetup :
      {
        rrc-TransactionIdentifier 0,
        criticalExtensions c1 : rrcConnectionSetup-r8 :
            {
              radioResourceConfigDedicated
              {
                srb-ToAddModList
                {
                  {
                    srb-Identity 1,
                    rlc-Config defaultValue : NULL,
                    logicalChannelConfig defaultValue : NULL
                  }
                },
```

SRB1 Establishment (cont.)

- SRB1 is mapped to Radio Bearers (RBs) above 32.
- RBs below 32 are for DRBs.
- Logical Channel (LCID) and RB ID are the same for the UL and DL.

```
2011 Dec 9 10:22:39.300 [00] 0xB081 LTE RLC DL Config Log packet
Version = 1
Number of SubPackets = 1
Subpacket ID = 64
SubPacket - ( RLCDL Configuration )
   Version = 1
   SubPacket Size = 48 bytes
   Reason = Configuration
   Number of released RB = 0
   Number of added/modified RB = 1
   ----------------------
   |RB Cfg Idx|Action    |
   ----------------------
   |        33|       ADD|

   Number of active RB = 1
   ------------------------------------------------------------------------------
   |           |      |      |      |RB  |      |T          |           |T Status  |
   |           |RB    |      |      |Cfg |RB    |Reordering|           |Prohibit  |
   |RLCDL CFG  |mode  |LC ID|RB ID|Idx |Type  |(ms)       |SN Length  |(ms)      |
   ------------------------------------------------------------------------------
   | RLCDL CFG|   AM|    1|    1|  33|  SRB|        35|         10|    0     |
```

DRB Establishment

- After the RRC reconfiguration procedure, the UE has both SRBs and Data Radio Bearer (DRBs) established.

```
2011 Dec 9 10:22:42.230 [00] 0xB0C0 LTE RRC OTA Packet -- DL_DCCH
Pkt Version = 2
RRC Release Number.Major.minor = 9.3.0
Radio Bearer ID = 1, Physical Cell ID = 1
Freq = 5230
SysFrameNum = N/A, SubFrameNum = 0
PDU Number = DL_DCCH Message,    Msg Length = 103

Interpreted PDU:

value DL-DCCH-Message ::=
{
  message c1 : rrcConnectionReconfiguration :
      {
        rrc-TransactionIdentifier 0,
        criticalExtensions c1 : rrcConnectionReconfiguration-r8 :
            {
              dedicatedInfoNASList
              {
                '27F0C7859802074201E0060000F1100001002A5204C101090C0B565A57494E5445524
              },
              radioResourceConfigDedicated
              {
                srb-ToAddModList
                {
                  {
                    srb-Identity 2,
                    rlc-Config defaultValue : NULL,
                    logicalChannelConfig defaultValue : NULL
                  }
                },
                drb-ToAddModList
                {
                  {
                    eps-BearerIdentity 5,
                    drb-Identity 1,
```

DRB Establishment (cont.)

- LC ID 1 is mapped to RB ID 1 of type SRB.
- LC ID 3 is mapped to RB ID 2 of type DRB.

```
2011 Dec 9 10:22:42.233 [00] 0xB081 LTE RLC DL Config Log packet
Version = 1
Number of SubPackets = 1
Subpacket ID = 64
SubPacket - ( RLCDL Configuration )
   Version = 1
   SubPacket Size = 68 bytes
   Reason = Configuration
   Number of released RB = 0
   Number of added/modified RB = 2
   ----------------------
   |RB Cfg Idx|Action    |
   ----------------------
   |         34|       ADD|
   |          1|       ADD|

   Number of active RB = 3
   ------------------------------------------------------------------------------
   |           |      |      |      |RB    |      |T          |           |T Status  |
   |           |RB    |      |      |Cfg   |RB    |Reordering |           |Prohibit  |
   |RLCDL CFG  |mode  |LC ID |RB ID |Idx   |Type  |(ms)       |SN Length  |(ms)      |
   ------------------------------------------------------------------------------
   | RLCDL CFG|    AM|     1|     1|    33|   SRB|         35|         10|     0    |
   | RLCDL CFG|    AM|     2|     2|    34|   SRB|         35|         10|     0    |
   | RLCDL CFG|    AM|     3|     1|     1|   DRB|         80|         10|     60   |
```

Channel Mapping

EPS Bearer ID Mapping to RB ID and LC ID

- Evolved Packet Service (EPS) ID 1 is mapped to RB ID 1 (Config Idx 33) and LC ID 1.
- EPS ID 5 is mapped to RB ID 1 (Config Idx 1) and LC ID 3.

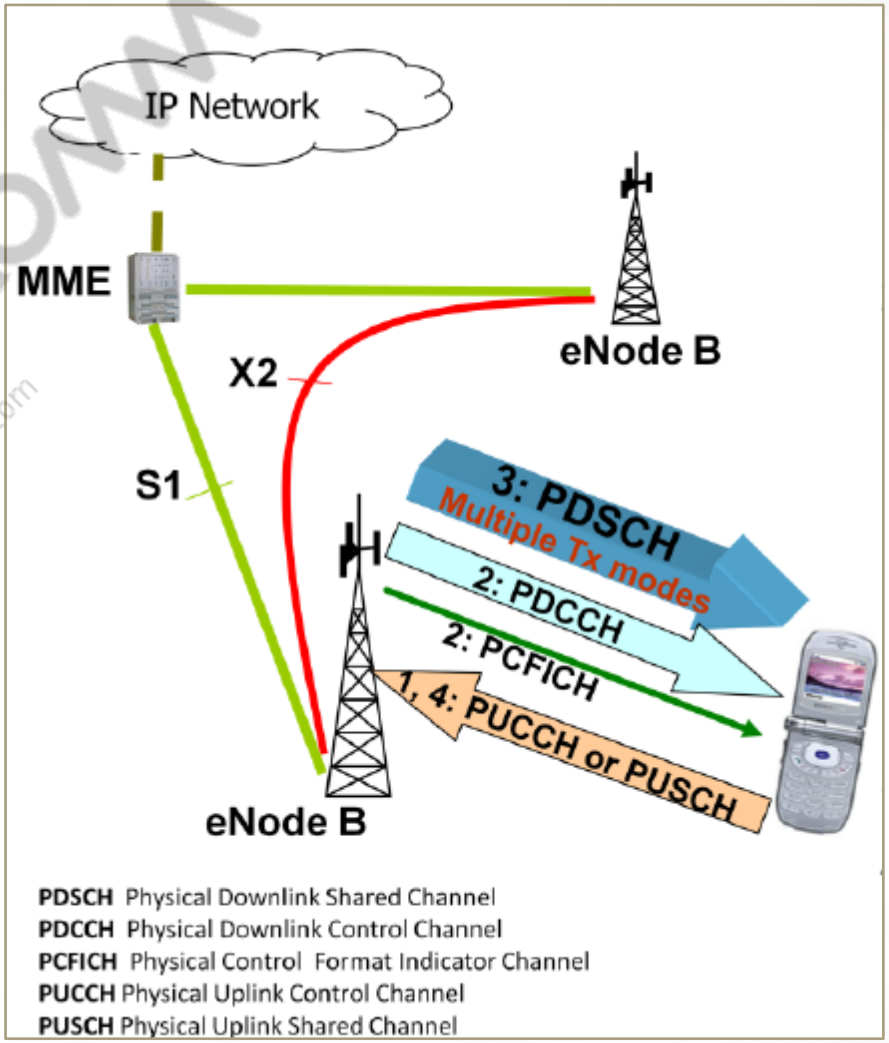
```
2011 Dec 9 10:22:42.233 [00] 0xB0A0 LTE PDCP DL Config
Version = 1
Number Subpackets = 1
Subpacket[0]
   Subpacket ID  = PDCP DL config (0xC0)
   Subpacket Version = 1
   Subpacket Size = 84 bytes
   Reason = Configuration
   Security Config:
      SRB Cipher Algo = None
      SRB Cipher Key Idx = 1
      SRB Integ Algo = Snow3G
      SRB Integ Key Idx = 0
      DRB Cipher Algo = None
      DRB Cipher Key Idx = 2
   Number released RB = 0
   Number added/modified RB = 2
   -------------------
   |RB Cfg Idx|Action|
   -------------------
   |         34|   Add|
   |          1|   Add|

   Number active RB = 3
   ---------------------------------------------------------------------------
   |           |  |       |    |    |     |SN     |       |RoHC|           |
   |           |RB|RB-Cfg |EPS |RB  |RB   |length |Status |Max |           |
   |           |ID|Idx    |ID  |mode|type |(bits) |report |CID |RoHC Mask  |
   ---------------------------------------------------------------------------
   |PDCPDL CFG| 1|      1|   5|  AM| DRB |     12|    YES|   0|0x00000000|
   |PDCPDL CFG| 1|     33|   1|  AM| SRB |      5|     NO|   0|0x00000000|
   |PDCPDL CFG| 2|     34|   2|  AM| SRB |      5|     NO|   0|0x00000000|
```

Data Transmission

DL Data Transmission Operation

1. UE reports Channel Quality Indicator (CQI), Precoding Matrix Index (PMI), and Rank Indicator (RI) in PUCCH (or PUSCH if there is UL traffic)
2. Scheduler at eNode B dynamically allocates DL resources to the UE
   - UE reads PCFICH every subframe and determines the number of OFDM symbols occupied by PDCCH
   - UE reads PDCCH to determine assigned DL resources (PRB and MCS) for a specific Tx mode
3. eNode B sends user data in PDSCH
4. UE attempts to decode the received packet and sends Ack/Nack using PUCCH (or PUSCH if there is UL traffic)



DL Data Transmission (Phy Layer)

- Log packet – 0xB126 LTE LL1 PDSCH Demapper Configuration
- Important parameters – Transmission Mode, Rank, Resource Block (RB) Allocation bitmap, Transport Block Size, and Modulation Coding Scheme (MCS) of the DL code word streams (CW0/CW1)

```
2011 Dec 9 10:23:16.733 [00] 0xB126 LTE LL1 PDSCH Demapper Configuration
Version                          = 1
Serving Cell ID                  = 1
Sub-frame Number                 = 4
System Frame Number              = 122
PDSCH RNTI1 ID                   = 65522
PDSCH RNTI Type                  = C-RNTI
Receiver Type Stream 0           = Maximum Likelihood (ML)
Receiver Type Stream 1           = Maximum Likelihood (ML)
SIC Enable                       = Disabled
SIC Ordering                     = Coe Word 0 followed by Code Word 1
Number of Tx Antennas (M)        = 2 antennas
Number of Rx Antennas (N)        = 2 antennas
Transmission Mode                = Closed-loop spatial multiplexing
Spatial Rank                     = rank 2
RB Allocation Slot 0             = 0x0003FFFFFFFFFFFF, 0x0000000000000000
RB Allocation Slot 1             = 0x0003FFFFFFFFFFFF, 0x0000000000000000
Rank 2 Single Codeword           = Disabled
Frequency Selective PMI          = Wideband
PMI Index                        = 1
Transport Block Size Stream 0    = 12960 bits
Modulation Stream 0              = 16QAM
Traffic to Pilot Ratio           = 1.000
Trnasport Block Size Stream 1    = 12960 bits
Modulation Stream 1              = 16QAM
Number of PDSCH TM Tasks         = 2
Source For TPR                   = Calculated
PB                               = PB = 1; RhoB/RhoA = 1
```

Resource block allocation bitmap (51-100 RBs)

Resource block allocation bitmap (0-50 RBs)

DL Data Transmission (Phy Layer) (cont.)

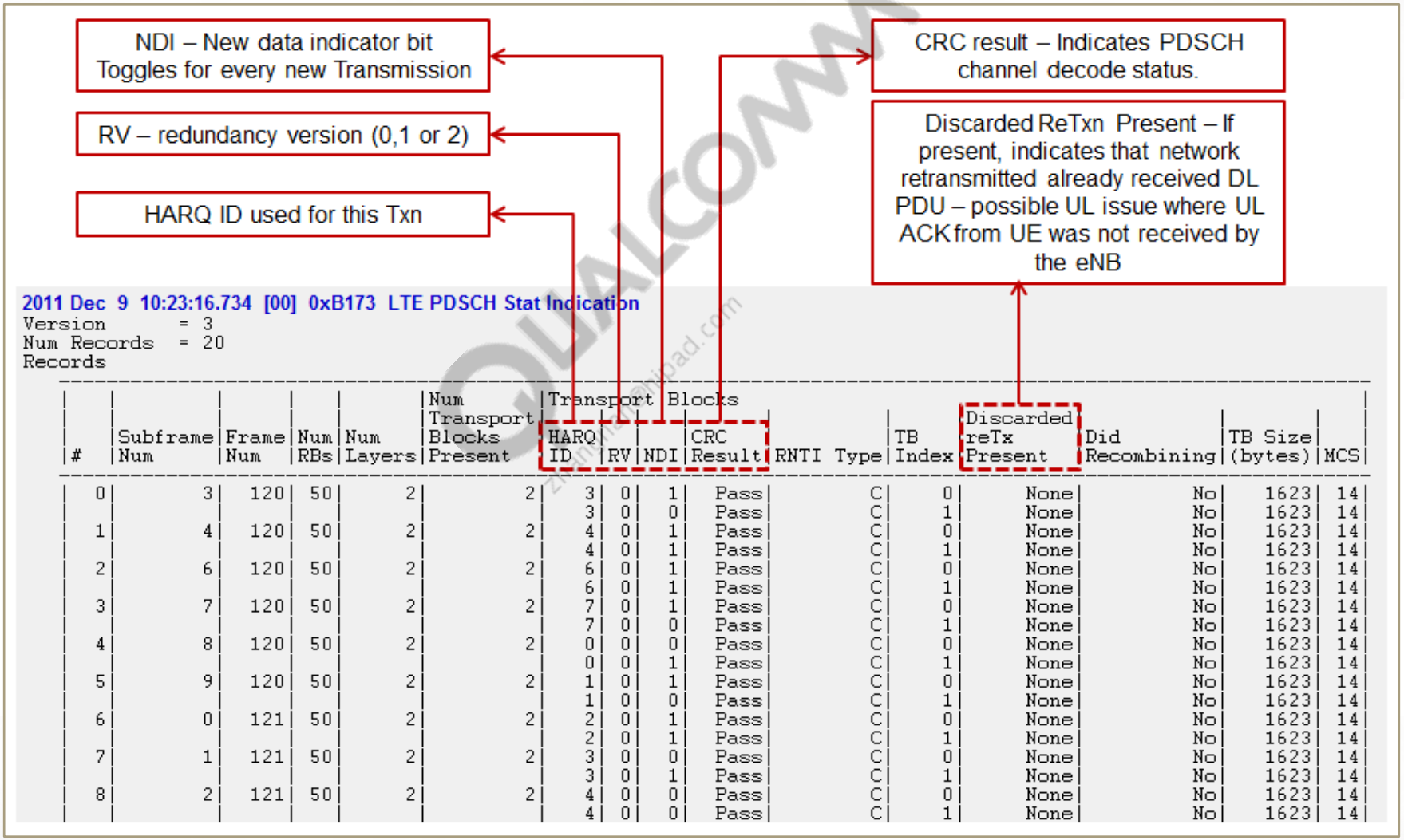
- Log packet – 0xB173 LTE PDSCH stat indication
- Important parameters – Number of RBs allocated, Number of Transport Blocks per TTI, redundancy version, new data indicator, CRC result, MCS, discarded retransmission flag
- Phy layer Throughput = (TB Size * 8 bits/byte * Num_Layers * 1000 ms/ sec) bits/sec

2011 Dec 9 10:23:16.734 [00] 0xB173 LTE PDSCH Stat Indication
Version = 3
Num Records = 20
Records

Phy layer Thput ~ 1623*8*2 = 25.96Mbps

#	Subframe Num	Frame Num	Num RBs	Num Layers	Num Transport Blocks Present	Transport Blocks HARQ ID	RV	NDI	CRC Result	RNTI Type	TB Index	Discarded reTx Present	Did Recombining	TB Size (bytes)	MCS
0	3	120	50	2	2	3	0	1	Pass	C	0	None	No	1623	14
						3	0	0	Pass	C	1	None	No	1623	14
1	4	120	50	2	2	4	0	1	Pass	C	0	None	No	1623	14
						4	0	1	Pass	C	1	None	No	1623	14
2	6	120	50	2	2	6	0	1	Pass	C	0	None	No	1623	14
						6	0	1	Pass	C	1	None	No	1623	14
3	7	120	50	2	2	7	0	1	Pass	C	0	None	No	1623	14
						7	0	0	Pass	C	1	None	No	1623	14
4	8	120	50	2	2	0	0	0	Pass	C	0	None	No	1623	14
						0	0	1	Pass	C	1	None	No	1623	14
5	9	120	50	2	2	1	0	1	Pass	C	0	None	No	1623	14
						1	0	0	Pass	C	1	None	No	1623	14
6	0	121	50	2	2	2	0	1	Pass	C	0	None	No	1623	14
						2	0	1	Pass	C	1	None	No	1623	14
7	1	121	50	2	2	3	0	0	Pass	C	0	None	No	1623	14
						3	0	1	Pass	C	1	None	No	1623	14
8	2	121	50	2	2	4	0	0	Pass	C	0	None	No	1623	14
						4	0	0	Pass	C	1	None	No	1623	14

DL Data Transmission (Phy Layer) (cont.)



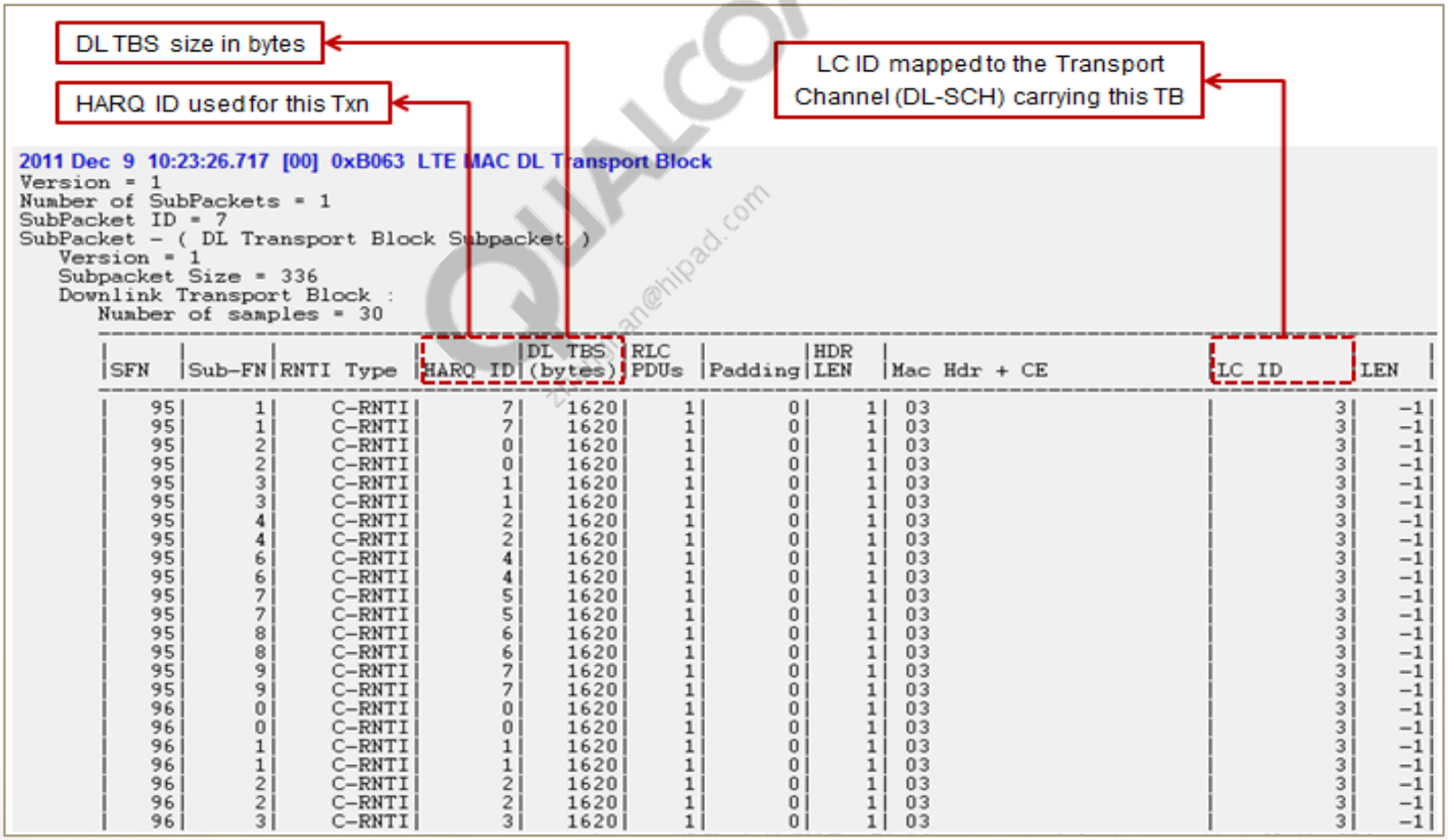
2011 Dec 9 10:23:16.734 [00] 0xB173 LTE PDSCH Stat Indication

Version = 3
Num Records = 20
Records

#	Subframe Num	Frame Num	Num RBs	Num Layers	Num Transport Blocks Present	Transport Blocks HARQ ID	RV	NDI	CRC Result	RNTI Type	TB Index	Discarded reTx Present	Did Recombining	TB Size (bytes)	MCS
0	3	120	50	2	2	3	0	1	Pass	C	0	None	No	1623	14
						3	0	0	Pass	C	1	None	No	1623	14
1	4	120	50	2	2	4	0	1	Pass	C	0	None	No	1623	14
						4	0	1	Pass	C	1	None	No	1623	14
2	6	120	50	2	2	6	0	1	Pass	C	0	None	No	1623	14
						6	0	1	Pass	C	1	None	No	1623	14
3	7	120	50	2	2	7	0	1	Pass	C	0	None	No	1623	14
						7	0	0	Pass	C	1	None	No	1623	14
4	8	120	50	2	2	0	0	0	Pass	C	0	None	No	1623	14
						0	0	1	Pass	C	1	None	No	1623	14
5	9	120	50	2	2	1	0	1	Pass	C	0	None	No	1623	14
						1	0	0	Pass	C	1	None	No	1623	14
6	0	121	50	2	2	2	0	1	Pass	C	0	None	No	1623	14
						2	0	1	Pass	C	1	None	No	1623	14
7	1	121	50	2	2	3	0	0	Pass	C	0	None	No	1623	14
						3	0	1	Pass	C	1	None	No	1623	14
8	2	121	50	2	2	4	0	0	Pass	C	0	None	No	1623	14
						4	0	0	Pass	C	1	None	No	1623	14

DL Data Transmission (MAC Layer)

- Log packet – 0xB063 LTE MAC DL Transport Block
- Important parameters – HARQ ID, DL Transport Block Size (TBS), LC ID

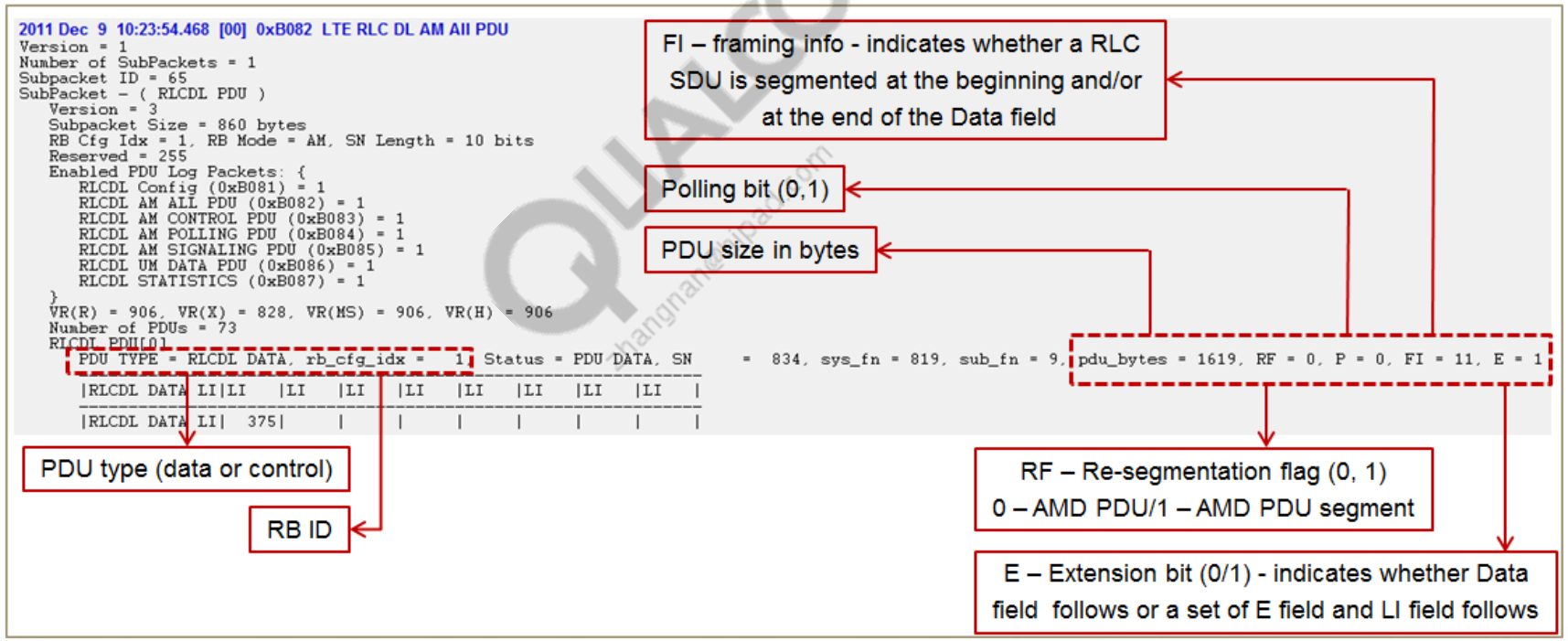


2011 Dec 9 10:23:26.717 [00] 0xB063 LTE MAC DL Transport Block
Version = 1
Number of SubPackets = 1
SubPacket ID = 7
SubPacket - (DL Transport Block Subpacket)
Version = 1
Subpacket Size = 336
Downlink Transport Block :
Number of samples = 30

SFN	Sub-FN	RNTI Type	HARQ ID	DL TBS (bytes)	RLC PDUs	Padding	HDR LEN	Mac Hdr + CE	LC ID	LEN
95	1	C-RNTI	7	1620	1	0	1	03	3	-1
95	1	C-RNTI	7	1620	1	0	1	03	3	-1
95	2	C-RNTI	0	1620	1	0	1	03	3	-1
95	2	C-RNTI	0	1620	1	0	1	03	3	-1
95	3	C-RNTI	1	1620	1	0	1	03	3	-1
95	3	C-RNTI	1	1620	1	0	1	03	3	-1
95	4	C-RNTI	2	1620	1	0	1	03	3	-1
95	4	C-RNTI	2	1620	1	0	1	03	3	-1
95	6	C-RNTI	4	1620	1	0	1	03	3	-1
95	6	C-RNTI	4	1620	1	0	1	03	3	-1
95	7	C-RNTI	5	1620	1	0	1	03	3	-1
95	7	C-RNTI	5	1620	1	0	1	03	3	-1
95	8	C-RNTI	6	1620	1	0	1	03	3	-1
95	8	C-RNTI	6	1620	1	0	1	03	3	-1
95	9	C-RNTI	7	1620	1	0	1	03	3	-1
95	9	C-RNTI	7	1620	1	0	1	03	3	-1
96	0	C-RNTI	0	1620	1	0	1	03	3	-1
96	0	C-RNTI	0	1620	1	0	1	03	3	-1
96	1	C-RNTI	1	1620	1	0	1	03	3	-1
96	1	C-RNTI	1	1620	1	0	1	03	3	-1
96	2	C-RNTI	2	1620	1	0	1	03	3	-1
96	2	C-RNTI	2	1620	1	0	1	03	3	-1
96	3	C-RNTI	3	1620	1	0	1	03	3	-1

DL Data Transmission (RLC Layer)

- Log packet – 0xB082 LTE RLC DL AM All PDU
- Important parameters – PDU Type, RB config index, polling bit, PDU size, E, RF, and LI bits

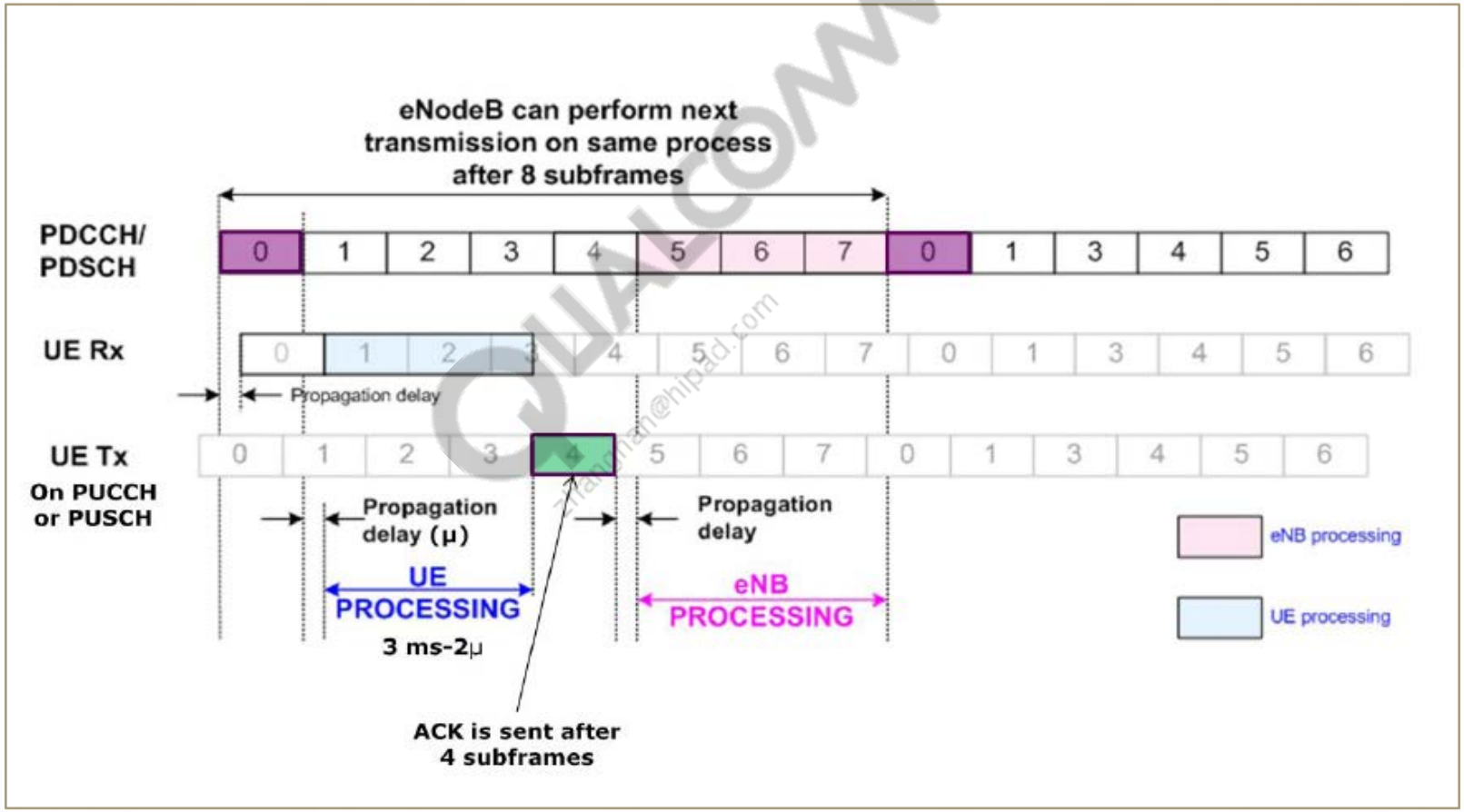


DL Data Transmission (RLC Layer) (cont.)

- Log packet – 0xB087 LTE RLC DL statistics
- Important parameters – Num Data PDU, Num Retx PDU (number of retransmitted DL PDUs), Num Complete Nack (number of DL PDUs Nacked)

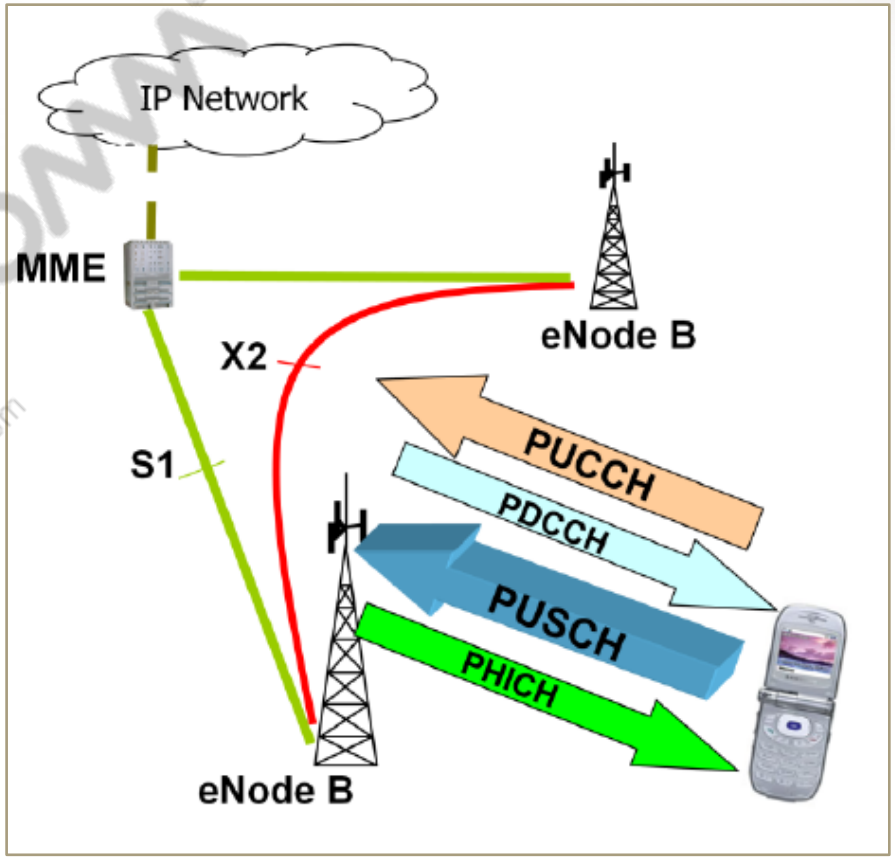
```
2011 Dec  9  10:23:54.429  [00]  0xB087  LTE RLC DL Statistics
Version = 1
Number of SubPackets = 1
Subpacket ID = 66
SubPacket - ( DL Statistics )
   Version = 2
   Subpacket Size = 560 bytes
   Num RBs = 3
   RLC PDCP Q Full Count = 0
   RLCDL Error Count = 0
..
   RBs[2]
      Rb Cfg Idx = 1  Mode = AM, Num RST = 0
                        Cumulative Total                          Total since last re-establishment
      RLC DL Stats[ 1]  Num Data PDU              = 46914, Num Data PDU Rst          = 46914
      RLC DL Stats[ 1]  Data PDU Bytes            = 74808022, Data PDU Bytes Rst       = 74808022
      RLC DL Stats[ 1]  Num Status Rxed           =   478, Num Status Rxed Rst       =   478
      RLC DL Stats[ 1]  Status Rxed Bytes         =   956, Status Rxed Bytes Rst     =   956
      RLC DL Stats[ 1]  Num Invalid PDU           =     0, Num Invalid PDU Rst       =     0
      RLC DL Stats[ 1]  Invalid PDU Bytes         =     0, Invalid PDU Bytes Rst     =     0
      RLC DL Stats[ 1]  Num Retx PDU              =     0, Num Retx PDU Rst          =     0
      RLC DL Stats[ 1]  Retx PDU Bytes            =     0, Retx PDU Bytes Rst        =     0
      RLC DL Stats[ 1]  Num Dup PDU               =     0, Num Dup PDU Rst           =     0
      RLC DL Stats[ 1]  Num Dup Bytes             =     0, Num Dup Bytes Rst         =     0
      RLC DL Stats[ 1]  Num Dropped PDU           =     0, Num Dropped PDU Rst       =     0
      RLC DL Stats[ 1]  Dropped PDU Bytes         =     0, Dropped PDU Bytes Rst     =     0
      RLC DL Stats[ 1]  Num Dropped PDU FC        =     0, Num Dropped PDU FC Rst    =     0
      RLC DL Stats[ 1]  Dropped PDU Bytes FC      =     0, Dropped PDU Bytes FC Rst  =     0
      RLC DL Stats[ 1]  Num SDU                   = 65186, Num SDU Rst             = 65186
      RLC DL Stats[ 1]  Num SDU Bytes             = 74595337, Num SDU Bytes Rst        = 74595337
      RLC DL Stats[ 1]  Num NonSeq SDU            =     0, Num NonSeq SDU Rst        =     0
      RLC DL Stats[ 1]  Num Ctrl PDU              =   442, Num Ctrl PDU Rst          =   442
      RLC DL Stats[ 1]  Num Complete NACK         =     0, Num Complete NACK Rst     =     0
      RLC DL Stats[ 1]  Num Segments NACK         =     0, Num Segment NACK Rst      =     0
      RLC DL Stats[ 1]  Num t_reorder Expired     =     0, Num t_reorder Exp Rst     =     0
      RLC DL Stats[ 1]  reserved                  =     0, reserved                  =     0
```

DL HARQ Operation



UL Data Transmission Operation

1. If UE does not have UL-SCH resources, UE sends Scheduling Request (SR) on PUCCH
2. Scheduler at eNode B allocates resources to UE in terms of uplink grant on PDCCH
   - Assigned resources – Physical Resource Blocks (PRB) and Modulation and Coding Scheme (MCS)
3. UE sends user data on PUSCH
4. If eNode B decodes the uplink data successfully, it sends Ack on PHICH



Note: In absence of PUCCH resources, the UE must complete a RACH procedure to request UL-SCH resources.

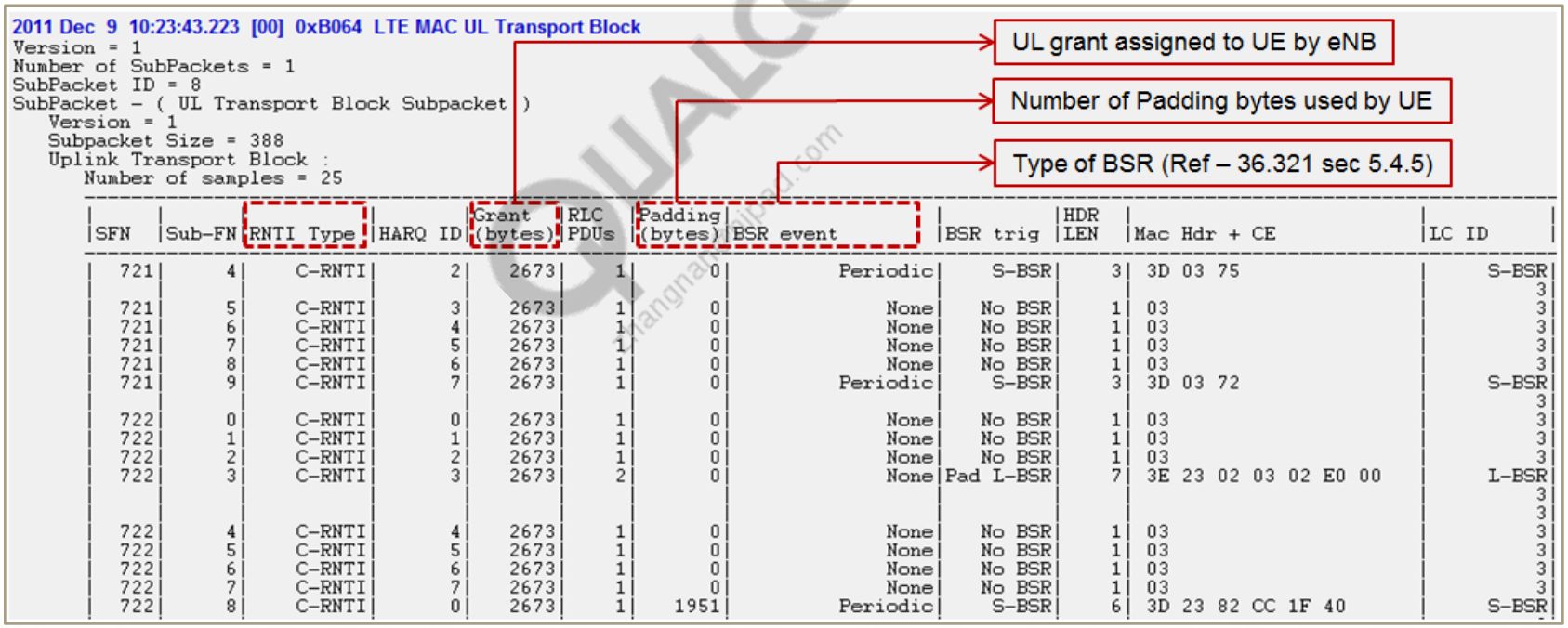
UL Data Transmission (RLC Layer)

- Log packet – 0xB092 – LTE RLC UL AM All PDU
- Important parameters – RLC SN, System frame number and subframe number for transmission, PDU bytes, and polling bit

```
2011 Dec 9 10:23:43.182 [00] 0xB092 LTE RLC UL AM All PDU
Version = 1
Number of SubPackets = 1
Subpacket ID = 70
SubPacket - ( RLCUL PDU )
   Version = 3
   Subpacket Size = 520 bytes
   RB Cfg Idx = 1, RB Mode = AM, SN Length = 10 bits
   Reserved = 136
   Enabled PDU Log Packets: {
      RLCUL Config (0xB091) = 1
      RLCUL AM ALL PDU (0xB092) = 1
      RLCUL AM CONTROL PDU (0xB093) = 1
      RLCUL AM POLLING PDU (0xB094) = 1
      RLCUL AM SIGNALING PDU (0xB095) = 1
      RLCUL UM DATA PDU (0xB096) = 1
      RLCUL STATISTICS (0xB097) = 1
   }
   VT(A) = 890, VT(S) = 909, PDU Without Poll = 3, Byte Without Poll = 8002, Poll SN = 905
   Number of PDUs = 40
   RLCUL PDU[0]
      PDU TYPE = RLCUL DATA, rb_cfg_idx =   1, SN     =  870, sys_fn = 715, sub_fn = 5, pdu_bytes = 88, RF = 0, P = 1, FI = 00, E = 1
      ------------------------------------------------------------
      |RLCUL DATA LI|LI   |LI   |LI   |LI   |LI   |LI   |LI   |
      ------------------------------------------------------------
      |RLCUL DATA LI|   42|     |     |     |     |     |     |
```

UL Data Transmission (MAC Layer)

- Log packet – 0xB064 – LTE MAC UL Transport Block
- Important parameters – Radio Network Temporary Identifier (RNTI) used, Grant, RLC PDUs, Type of Buffer Status Report (BSR), and Padding



2011 Dec 9 10:23:43.223 [00] 0xB064 LTE MAC UL Transport Block
Version = 1
Number of SubPackets = 1
SubPacket ID = 8
SubPacket – (UL Transport Block Subpacket)
Version = 1
Subpacket Size = 388
Uplink Transport Block :
Number of samples = 25

UL grant assigned to UE by eNB

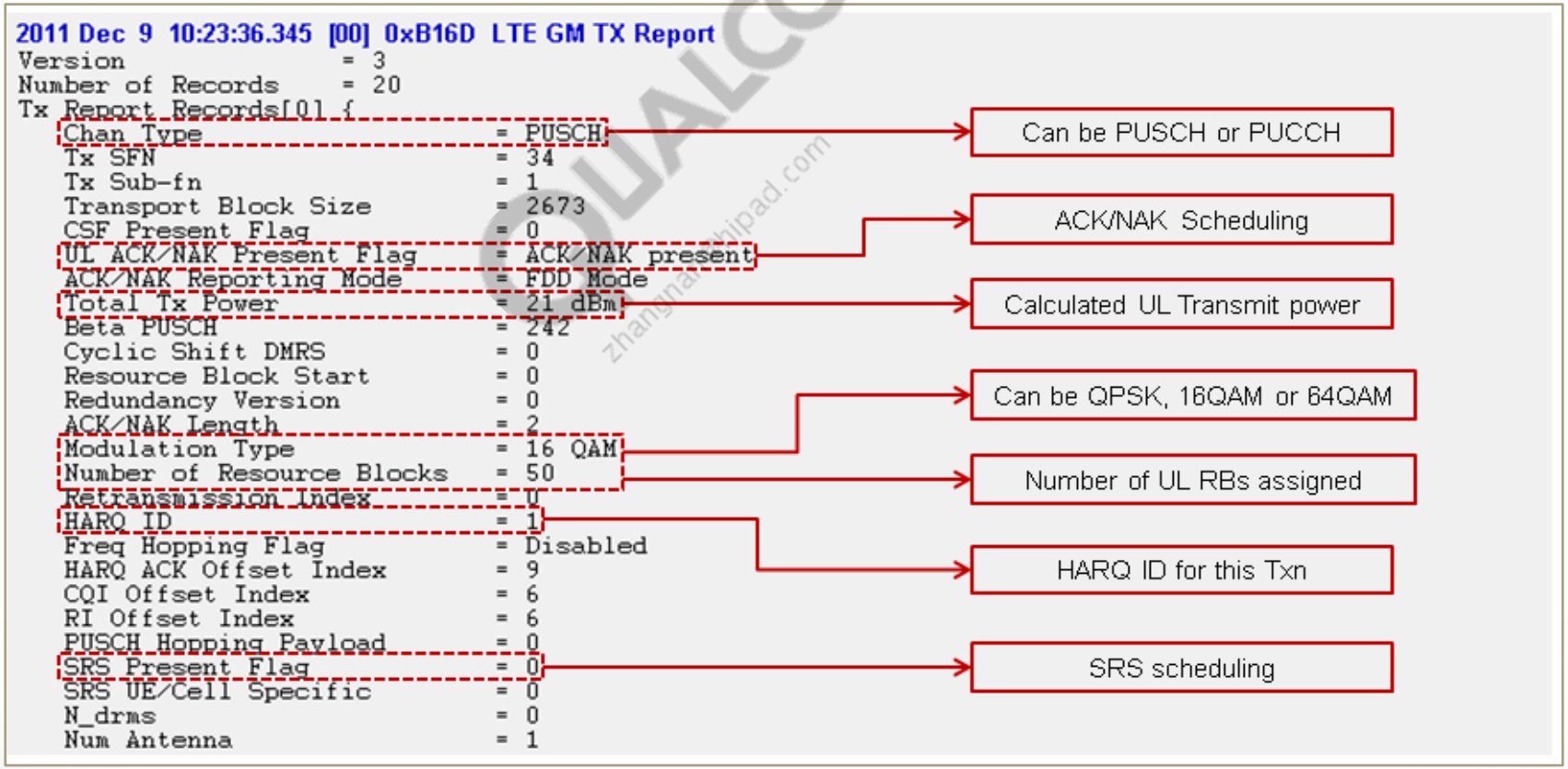
Number of Padding bytes used by UE

Type of BSR (Ref – 36.321 sec 5.4.5)

SFN	Sub-FN	RNTI Type	HARQ ID	Grant (bytes)	RLC PDUs	Padding (bytes)	BSR event	BSR trig	HDR LEN	Mac Hdr + CE	LC ID
721	4	C-RNTI	2	2673	1	0	Periodic	S-BSR	3	3D 03 75	S-BSR
721	5	C-RNTI	3	2673	1	0	None	No BSR	1	03	3
721	6	C-RNTI	4	2673	1	0	None	No BSR	1	03	3
721	7	C-RNTI	5	2673	1	0	None	No BSR	1	03	3
721	8	C-RNTI	6	2673	1	0	None	No BSR	1	03	3
721	9	C-RNTI	7	2673	1	0	Periodic	S-BSR	3	3D 03 72	S-BSR
722	0	C-RNTI	0	2673	1	0	None	No BSR	1	03	3
722	1	C-RNTI	1	2673	1	0	None	No BSR	1	03	3
722	2	C-RNTI	2	2673	1	0	None	No BSR	1	03	3
722	3	C-RNTI	3	2673	2	0	None	Pad L-BSR	7	3E 23 02 03 02 E0 00	L-BSR
722	4	C-RNTI	4	2673	1	0	None	No BSR	1	03	3
722	5	C-RNTI	5	2673	1	0	None	No BSR	1	03	3
722	6	C-RNTI	6	2673	1	0	None	No BSR	1	03	3
722	7	C-RNTI	7	2673	1	0	None	No BSR	1	03	3
722	8	C-RNTI	0	2673	1	1951	Periodic	S-BSR	6	3D 23 82 CC 1F 40	S-BSR

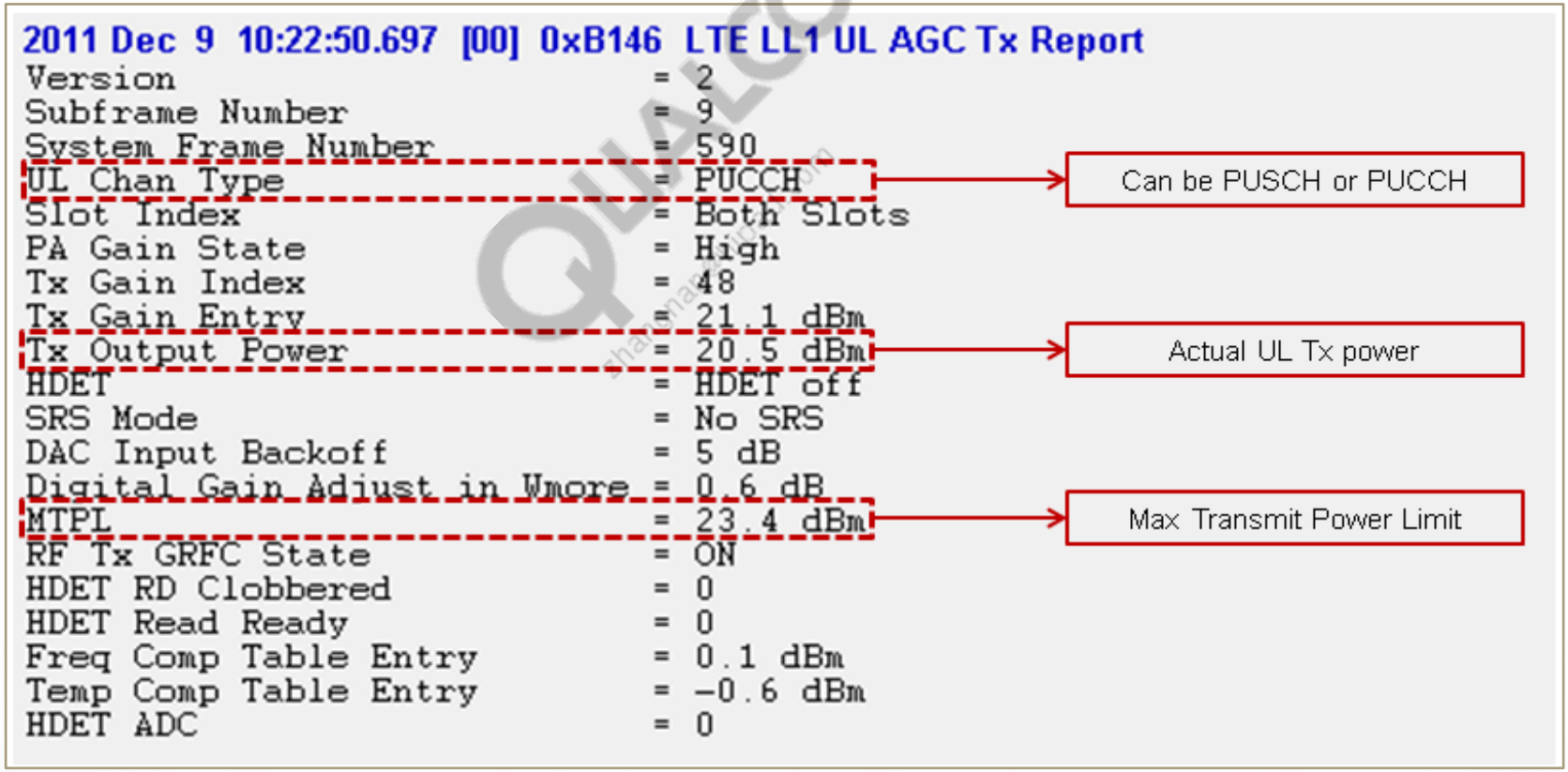
UL Data Transmission (Phy Layer)

- Log packet – 0xB16D – LTE GM Tx Report
- Important parameters – UL Channel Type (PUSCH/PUCCH), Ack/Nack Scheduling, Calculated Tx power, MCS, Hopping, CQI, SRS scheduling

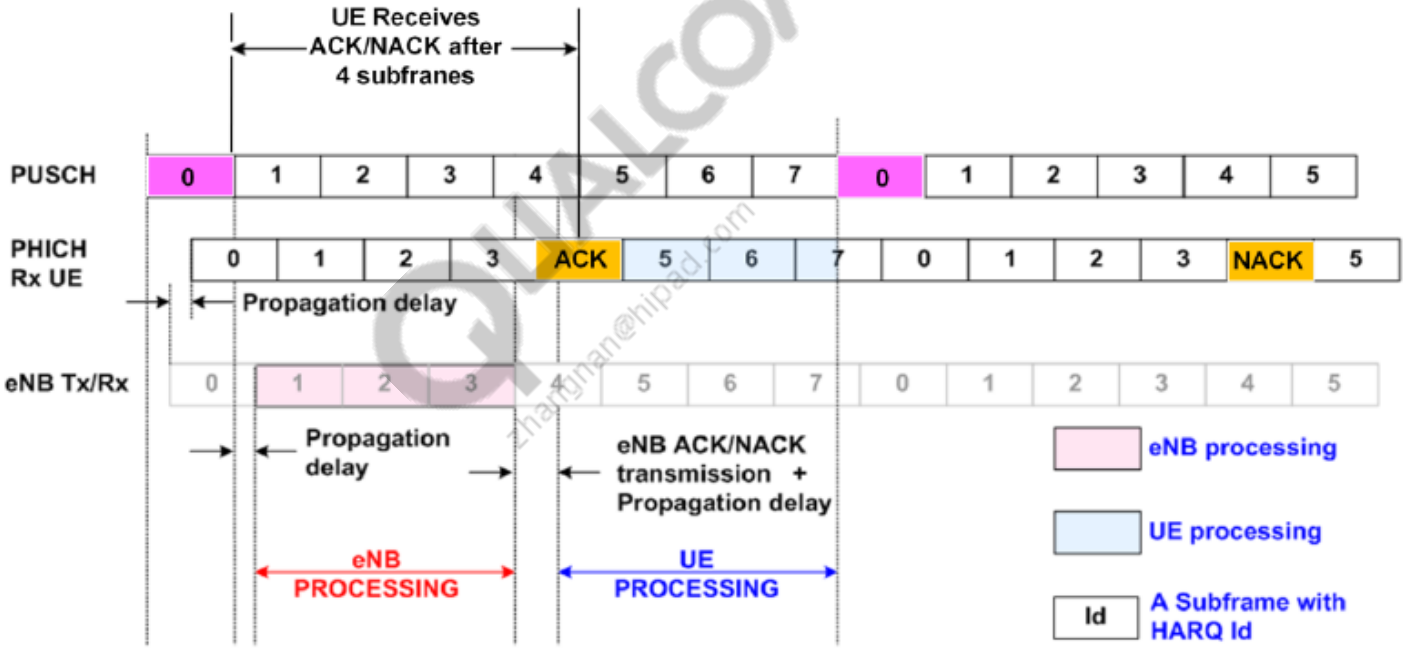


UL Data Transmission (Phy Layer) (cont.)

- Log packet – 0xB146 – LTE LL1 UL AGC Tx Report
- Important parameters – UL Channel Type, Actual Transmission power, MTPL, HDET



UL HARQ Operation



DL Ack/Nack from eNB for UL Data from UE

- Log packet – 0xB16B- LTE PDCCH-PHICH Indication Report
- Important parameters – PHICH Value – Ack at 625/5 for UL Txn at 625/1

```
2011 Dec  9  10:22:40.822  [00]  0xB092  LTE RLC UL AM All PDU
Version = 1
Number of SubPackets = 1
Subpacket ID = 70
SubPacket - ( RLCUL PDU )
   Version = 3
   Subpacket Size = 44 bytes
   RB Cfg Idx = 33, RB Mode = AM, SN Length = 10 bits
   Reserved = 0
   Enabled PDU Log Packets: {
      RLCUL Config (0xB091) = 1
      RLCUL AM ALL PDU (0xB092) = 1
      RLCUL AM CONTROL PDU (0xB093) = 1
      RLCUL AM POLLING PDU (0xB094) = 1
      RLCUL AM SIGNALING PDU (0xB095) = 1
      RLCUL UM DATA PDU (0xB096) = 1
      RLCUL STATISTICS (0xB097) = 1
   }
   VT(A) = 4, VT(S) = 5, PDU Without Poll = 0, Byte Without Poll = 0, Poll SN = 4
   Number of PDUs = 2

   RLCUL PDU[1]
      PDU TYPE = RLCUL DATA, rb_cfg_idx =  33, SN     =     4, sys_fn = 625, sub_fn = 1, pdu_bytes = 33, RF = 0,
      Hex Dump =  A0 04

2011 Dec  9  10:22:40.828  [00]  0xB16B  LTE PDCCH-PHICH Indication Report
Version            = 1
Number of Records    = 50
Info Records
   -------------------------------------------------------------------------------------------------
   |   |       |      |      |        |PHICH                    |PDCCH Info                                   |
   |   |Num    |PDCCH |PDCCH |        |PHICH |PHICH |     |     |           |PDCCH |           |
   |   |PDCCH  |Timing|Timing|PHICH   |Timing|Timing|PHICH|CRC  |           |Payload|Aggregation|
   |#  |Results|SFN   |Sub-fn|Included|SFN   |Sub-fn|Value|Status|RNTI Type |Size  |Level      |
   -------------------------------------------------------------------------------------------------
   |  0|      0|   623|     0|      No|      |      |     |      |          |      |           |
   |  1|      0|   623|     1|      No|      |      |     |      |          |      |           |
..
   | 16|      0|   624|     6|      No|      |      |     |      |          |      |           |
   | 17|      1|   624|     7|      No|      |      |     |  Pass|    C_RNTI|    43|          2|
   | 18|      0|   624|     8|      No|      |      |     |      |          |      |           |
   | 19|      0|   624|     9|      No|      |      |     |      |          |      |           |
..
   | 23|      0|   625|     3|      No|      |      |     |      |          |      |           |
   | 24|      1|   625|     4|      No|      |      |     |  Pass|    C_RNTI|    43|          3|
   | 25|      0|   625|     5|     Yes|   625|     5|  ACK|      |          |      |           |
   | 26|      0|   625|     6|      No|      |      |     |      |          |      |           |
```

LTE Throughput Debugging

LTE Throughput Debugging

- Overview of throughput performance troubleshooting
- Troubleshooting in Phy Layer
- Troubleshooting in layer 2

LTE Throughput Debugging (cont.)

- What can affect data throughput
  - RF conditions of the link established during the call (low SNR, fading, etc.)
  - Physical Layer BLER
  - Serving cell load limiting scheduling grants in time and frequency
  - Load in neighbor cells – Can cause interference
  - Frequent, unnecessary, serving cell changes
  - Backhaul limitation (network issue)

LTE Throughput Debugging (Phy Layer)

- Possible causes of low throughput from Phy layer perspective
  - Low Reference Signal Received Power (RSRP), Reference Signal Received Quality (RSRQ), or SNR – Points to coverage or intercell interference issues
  - Scheduling in time domain
    - Verify if DL grants occur in contiguous SFs
    - If there are gaps in scheduling and geometry is good, this points to:
      - Intracell load
      - Not enough data in eNB (backhaul limitation or traffic pattern)
      - Network/TE settings
  - Scheduling in frequency domain
    - RB allocation fluctuations could point to load, upper layer issue, or backhaul limitation
  - Neighboring cells with comparable RSRP as serving cell
  - MCS is lower than expected based on CQI
    - Points to eNB scheduling issue
  - 'Discarded Retransmissions' are frequently observed in PDSCH log packet
    - This points to a UL Ack issue or link imbalance or high eNB RSSI (Received Signal Strength Indicator)
  - Check if UE RSSI is reasonable and not close to sensitivity (RSSI < -90, RSRP < -105 dBm)

LTE Throughput Debugging (Phy Layer) (cont.)

Two layers defined in the DL even though there is no spatial multiplexing. Transmit Diversity is being used, denoting weak DL RF coverage

Lower MCS denotes weak coverage

1980 Jan 6 00:00:27.119 [10] 0xB173 LTE PDSCH Stat Indication

Version = 3
Num Records = 25
Records

#	Subframe Num	Frame Num	Num RBs	Num Layers	Num Transport Blocks Present	Transport Blocks HARQ ID	RV	NDI	CRC Result	RNTI Type	TB Index	Discarded reTx Present	Did Recombining	TB Size (bytes)	MCS
0	6	234	2	2	1	1	0	1	Pass	C	0	None	No	21	5
1	7	234	2	2	1	2	0	1	Pass	C	0	None	No	21	5
2	8	234	2	2	1	3	0	0	Fail	C	0	None	No	21	5
3	9	234	2	2	1	4	0	0	Fail	C	0	None	No	21	5
4	0	235	2	2	1	5	0	0	Fail	C	0	None	No	21	5
5	1	235	2	2	1	6	0	1	Fail	C	0	None	No	21	5
6	2	235	2	2	1	7	0	1	Fail	C	0	None	No	21	5
7	3	235	2	2	1	0	0	1	Pass	C	0	None	No	21	5
8	4	235	2	2	1	1	0	0	Fail	C	0	None	No	21	5
9	6	235	2	2	1	2	0	0	Pass	C	0	None	No	21	5
10	7	235	2	2	1	3	2	0	Pass	C	0	None	Yes	21	5
11	8	235	2	2	1	4	2	0	Pass	C	0	None	Yes	21	5
12	9	235	2	2	1	5	2	0	Pass	C	0	None	Yes	21	5
13	0	236	2	2	1	6	2	1	Pass	C	0	None	Yes	21	5
14	1	236	2	2	1	7	2	1	Pass	C	0	None	Yes	21	5
15	2	236	2	2	1	0	0	0	Pass	C	0	None	No	21	5
16	3	236	2	2	1	1	2	0	Pass	C	0	None	Yes	21	5
17	4	236	2	2	1	2	0	1	Pass	C	0	None	No	21	5
18	6	236	2	2	1	3	0	1	Pass	C	0	None	No	21	5
19	7	236	2	2	1	4	0	1	Pass	C	0	None	No	21	5
20	8	236	2	2	1	5	0	1	Pass	C	0	None	No	21	5
21	9	236	2	2	1	6	0	0	Pass	C	0	None	No	21	5
22	0	237	2	2	1	7	0	0	Pass	C	0	None	No	21	5
23	1	237	2	2	1	0	0	1	Pass	C	0	None	No	21	5
24	2	237	2	2	1	1	0	1	Pass	C	0	None	No	21	5

LTE Throughput Debugging (Phy Layer) (cont.)

UE is not being scheduled in consecutive sub frames – additional reason for throughput degradation

1st DL transmission successful, nevertheless eNB retransmits the same PDU indicating that the eNB did not receive UL ACK from UE

2010 Sep 5 15:12:48.202 [00] 0xB173 LTE PDSCH Stat Indication

Version = 3
Num Records = 16
Records

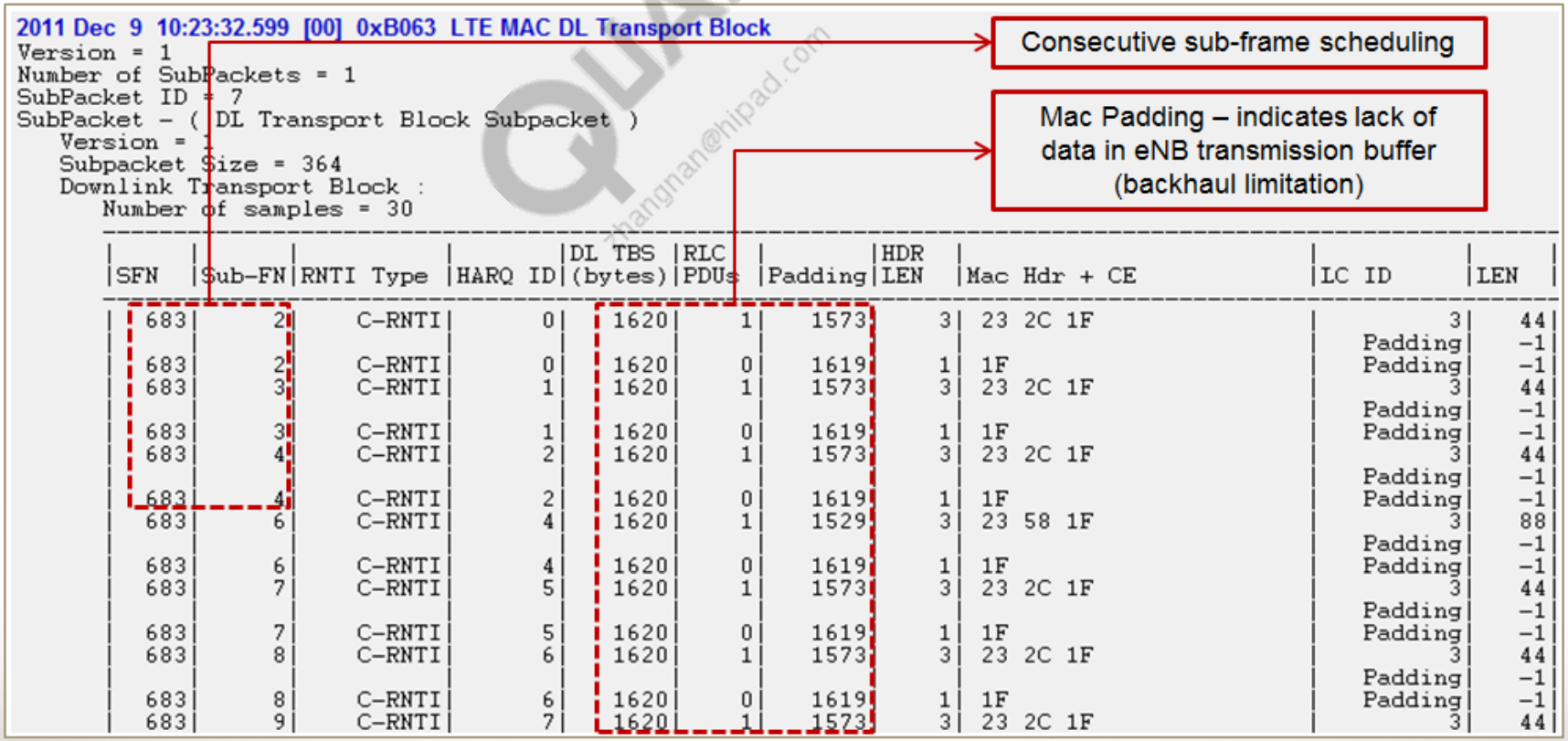
#	Subframe Num	Frame Num	Num RBs	Num Layers	Num Transport Blocks Present	Transport Blocks HARQ ID	RV	NDI	CRC Result	RNTI Type	TB Index	Discarded reTx Present	Did Recombining	TB Size (bytes)	MCS
0	8	351	50	2	2	6	1	0	Fail	C	0	None	Yes	4590	28
						6	1	1	Fail	C	1	None	Yes	4590	28
1	2	358	50	2	2	6	2	1	Fail	C	0	None	No	4590	28
						6	2	0	Fail	C	1	None	No	4590	28
2	0	359	50	2	2	6	3	1	Fail	C	0	None	Yes	4590	28
						6	3	0	Fail	C	1	None	Yes	4590	28
3	8	359	50	2	2	6	1	1	Fail	C	0	None	Yes	4590	28
						6	1	0	Fail	C	1	None	Yes	4590	28
4	0	360	44	2	2	0	0	1	Pass	C	0	None	No	4110	28
						0	0	0	Pass	C	1	None	No	4110	28
5	8	360	44	2	2	0	2	1	Fail	C	0	Present	No	4110	28
						0	2	0	Fail	C	1	Present	No	4110	28
6	6	361	44	2	2	0	3	1	Fail	C	0	Present	No	4110	28
						0	3	0	Fail	C	1	Present	No	4110	28
7	4	362	44	2	2	0	1	1	Fail	C	0	Present	No	4110	28
						0	1	0	Fail	C	1	Present	No	4110	28
8	2	366	50	2	2	6	2	0	Fail	C	0	None	No	4590	28
						6	2	1	Fail	C	1	None	No	4590	28
9	0	367	50	2	2	6	3	0	Fail	C	0	None	Yes	4590	28
						6	3	1	Fail	C	1	None	Yes	4590	28
10	8	367	50	2	2	6	1	0	Fail	C	0	None	Yes	4590	28
						6	1	1	Fail	C	1	None	Yes	4590	28
11	5	371	50	2	2	3	0	1	Pass	C	0	None	No	4590	28
						3	0	1	Pass	C	1	None	No	4590	28
12	2	374	50	2	1	6	2	1	Fail	C	0	None	No	4590	28
13	0	375	50	2	1	6	3	1	Fail	C	0	None	Yes	4590	28
14	8	375	50	2	1	6	1	1	Fail	C	0	None	Yes	4590	28
15	5	380	44	2	2	5	0	0	Pass	C	0	None	No	4110	28
						5	0	0	Pass	C	1	None	No	4110	28

LTE Throughput Debugging (MAC Layer)

- Possible causes of low throughput from MAC layer perspective
  - Scheduling duty cycle – How frequently a user is scheduled in MAC
  - Differences between scheduled and actual throughput
    - MAC PDUs – Provide the scheduled Transport Block Size (TBS) and the effective number of information bytes delivered to physical layer
    - It also provides additional information about zero padding not available in other layers

LTE Throughput Debugging (MAC Layer) (cont.)

- Scheduling frequency can be determined analyzing System Frame Number (SFN) and Sub-FN UE assignments.
- DL TBS is the scheduled transport block size and effective number of transmitted bytes is given by LEN field (not counting the MAC header).
- MAC padding issue shown below is a cause for low throughput.



2011 Dec 9 10:23:32.599 [00] 0xB063 LTE MAC DL Transport Block
Version = 1
Number of SubPackets = 1
SubPacket ID = 7
SubPacket – (DL Transport Block Subpacket)
Version = 1
Subpacket Size = 364
Downlink Transport Block :
Number of samples = 30

Consecutive sub-frame scheduling

Mac Padding – indicates lack of data in eNB transmission buffer (backhaul limitation)

SFN	Sub-FN	RNTI Type	HARQ ID	DL TBS (bytes)	RLC PDUs	Padding	HDR LEN	Mac Hdr + CE	LC ID	LEN
683	2	C-RNTI	0	1620	1	1573	3	23 2C 1F	3	44
									Padding	-1
683	2	C-RNTI	0	1620	0	1619	1	1F	Padding	-1
683	3	C-RNTI	1	1620	1	1573	3	23 2C 1F	3	44
									Padding	-1
683	3	C-RNTI	1	1620	0	1619	1	1F	Padding	-1
683	4	C-RNTI	2	1620	1	1573	3	23 2C 1F	3	44
									Padding	-1
683	4	C-RNTI	2	1620	0	1619	1	1F	Padding	-1
683	6	C-RNTI	4	1620	1	1529	3	23 58 1F	3	88
									Padding	-1
683	6	C-RNTI	4	1620	0	1619	1	1F	Padding	-1
683	7	C-RNTI	5	1620	1	1573	3	23 2C 1F	3	44
									Padding	-1
683	7	C-RNTI	5	1620	0	1619	1	1F	Padding	-1
683	8	C-RNTI	6	1620	1	1573	3	23 2C 1F	3	44
									Padding	-1
683	8	C-RNTI	6	1620	0	1619	1	1F	Padding	-1
683	9	C-RNTI	7	1620	1	1573	3	23 2C 1F	3	44

LTE Throughput Debugging (RLC Layer)

- RLC retransmissions will lower throughput
  - In a critical situation, RLC window would not advance if a gap was created due to a missing RLC PDU.
  - It takes on average about 50 ms to recover from such a situation.
- Reasons behind RLC retransmissions
  - Bad DL channel conditions – If HARQ cannot recover errors, RLC retransmission may be necessary
  - Link imbalance – UE sends RLC-Acks, but these are not received by eNB (bad UL RF channel)

LTE Throughput Debugging (RLC Layer) (cont.)

- Large number of Nack'ed PDUs in both RLC DL/UL statistics packets causing retransmissions and thus lowering throughput

```
2010 Sep  5  15:13:03.906  [00]  0xB087  LTE RLC DL Statistics
Version = 1
Number of SubPackets = 1
Subpacket ID = 66
SubPacket - ( DL Statistics )
   Version = 2
   Subpacket Size = 560 bytes
   Num RBs = 3
   RLC PDCP Q Full Count = 0
   RLCDL Error Count = 0

   RBs[2]
      Rb Cfg Idx = 3  Mode = AM, Num RST = 0
                            Cumulative Total                Total since last re-establishment
      RLC DL Stats[ 3]      Num Data PDU            =  3137, Num Data PDU Rst            =  3137
      RLC DL Stats[ 3]      Data PDU Bytes          = 13317281, Data PDU Bytes Rst       = 13317281
      RLC DL Stats[ 3]      Num Status Rxed         =   327, Num Status Rxed Rst         =   327
      RLC DL Stats[ 3]      Status Rxed Bytes       =  1465, Status Rxed Bytes Rst       =  1465
      RLC DL Stats[ 3]      Num Invalid PDU         =     0, Num Invalid PDU Rst         =     0
      RLC DL Stats[ 3]      Invalid PDU Bytes       =     0, Invalid PDU Bytes Rst       =     0
      RLC DL Stats[ 3]      Num Retx PDU            =    85, Num Retx PDU Rst            =    85
      RLC DL Stats[ 3]      Retx PDU Bytes          = 194720, Retx PDU Bytes Rst         = 194720
      RLC DL Stats[ 3]      Num Dup PDU             =     1, Num Dup PDU Rst             =     1
      RLC DL Stats[ 3]      Num Dup Bytes           =  4586, Num Dup Bytes Rst           =  4586
      RLC DL Stats[ 3]      Num Dropped PDU         =     1, Num Dropped PDU Rst         =     1
      RLC DL Stats[ 3]      Dropped PDU Bytes       =  2523, Dropped PDU Bytes Rst       =  2523
      RLC DL Stats[ 3]      Num Dropped PDU FC      =     0, Num Dropped PDU FC Rst      =     0
      RLC DL Stats[ 3]      Dropped PDU Bytes FC    =     0, Dropped PDU Bytes FC Rst    =     0
      RLC DL Stats[ 3]      Num SDU                 =  7729, Num SDU Rst                 =  7729
      RLC DL Stats[ 3]      Num SDU Bytes           = 11263332, Num SDU Bytes Rst        = 11263332
      RLC DL Stats[ 3]      Num NonSeq SDU          =     0, Num NonSeq SDU Rst          =     0
      RLC DL Stats[ 3]      Num Ctrl PDU            =   237, Num Ctrl PDU Rst            =   237
      RLC DL Stats[ 3]      Num Complete NACK       =   604, Num Complete NACK Rst       =   604
      RLC DL Stats[ 3]      Num Segments NACK       =    12, Num Segment NACK Rst        =    12
      RLC DL Stats[ 3]      Num t_reorder Expired   =     9, Num t_reorder Exp Rst       =     9
      RLC DL Stats[ 3]      reserved                =     0, reserved                    =     0


2010 Sep  5  15:13:04.384  [00]  0xB097  LTE RLC UL Statistics
Version = 1
Number of SubPackets = 1
Subpacket ID = 71
SubPacket - ( UL Statistics   )
   Version = 1
   Subpacket Size = 388
   Num RBs = 3
   RLCUL Error Count = 0

   RBs[2]
      Rb Cfg Idx = 3, Mode = AM, Num RST = 0
                            Cumulative Total                Total since last re-establishment
      RLC UL Stats[ 3]      Num New Data PDU        = 13486, Num New Data PDU Rst        = 13486
      RLC UL Stats[ 3]      Num New Data PDU Bytes  = 35830085, Num New Data PDU Bytes Rst = 35830085
      RLC UL Stats[ 3]      Num SDU                 = 24578, Num SDU Rst                 = 24578
      RLC UL Stats[ 3]      Num SDU Bytes           = 35765382, Num SDU Bytes Rst        = 35765382
      RLC UL Stats[ 3]      Num Ctrl PDU Tx         =   237, Num Ctrl PDU Tx Rst         =   237
      RLC UL Stats[ 3]      Num Ctrl PDU Bytes Tx   =  1447, Num Ctrl PDU Bytes Tx Rst   =  1447
      RLC UL Stats[ 3]      Num Retx PDU            =   637, Num Retx PDU Rst            =   637
      RLC UL Stats[ 3]      Num Retx PDU Bytes      = 914659, Num Retx PDU Bytes Rst     = 914659
      RLC UL Stats[ 3]      Num Ctrl PDU Rx         =   334, Num Ctrl PDU Rx Rst         =   334
      RLC UL Stats[ 3]      Num Complete NACK       =   500, Num Complete NACK Rst       =   500
      RLC UL Stats[ 3]      Num Segm NACK           =    10, Num Segm NACK Rst           =    10
      RLC UL Stats[ 3]      Num Invalid Ctrl PDU Rx =     0, Num Invalid Ctrl PDU Rx Rst =     0
      RLC UL Stats[ 3]      Num Poll                =   388, Num Poll Rst                =   388
      RLC UL Stats[ 3]      Num T Poll Retx Expiry  =    19, Num T Poll Retx Expiry Rst  =    19
      RLC UL Stats[ 3]      reserved                =     0, reserved                    =     0
```

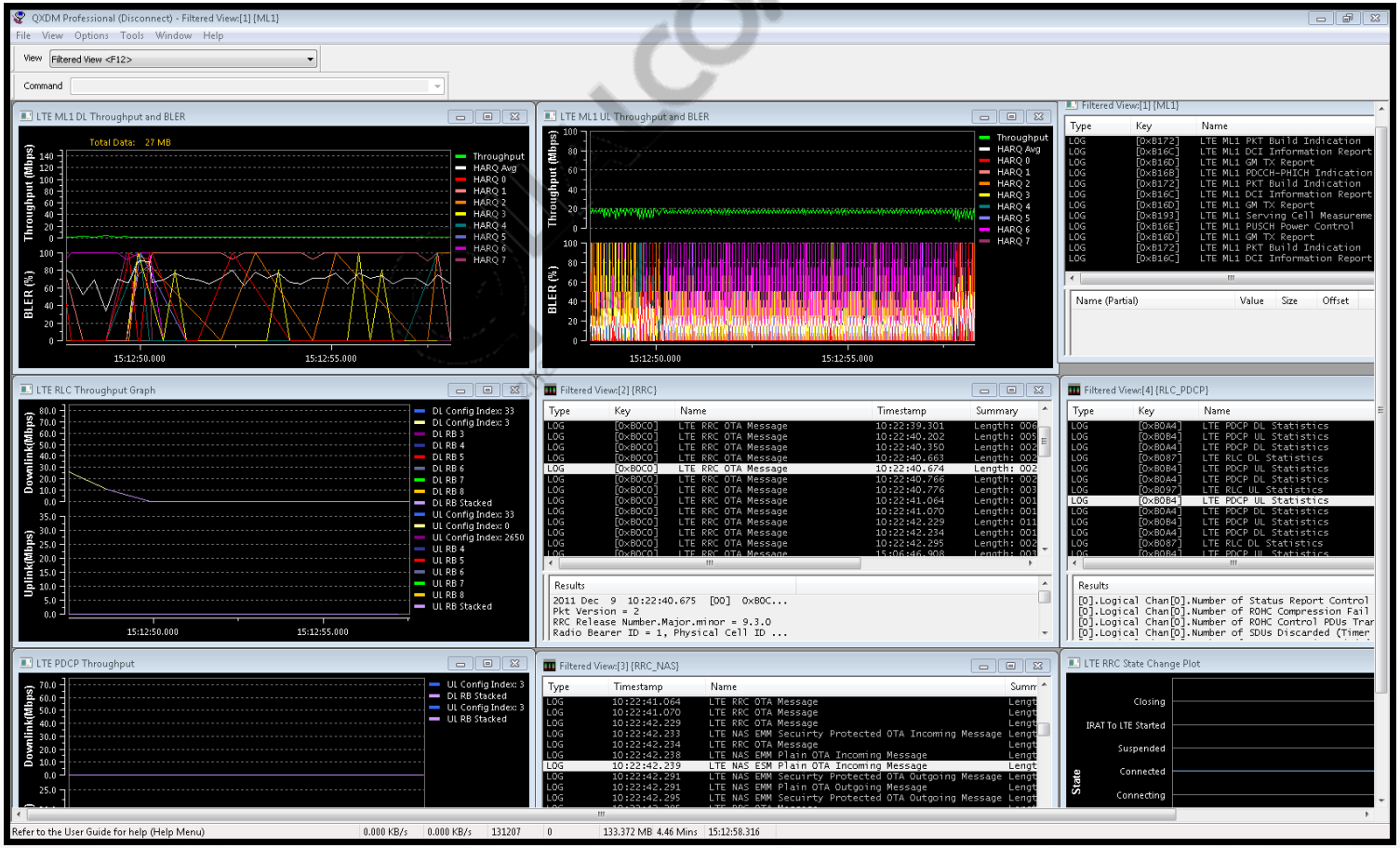
Summary

Summary

- Check if SNR from 0xB129 is low
  - High SNR is > 18 dB; medium SNR is > 10 dB; low SNR is < 3 dB
- Check if DL grants occur in contiguous SFs or if there are gaps in scheduling
  - If SNR is good, this points to upper layer issue or a network/TE setting issue
- Check if MCS is lower than expected based on CQI
  - Points to network scheduling issue
- Check if RB allocations are fluctuating
  - Points to network load or upper layer issue
- Check if 'Discarded Re-Tx' contains 'Present' often in 0xB173 log packet
  - Points to a UL Ack issue
- Check if there are neighboring cells with comparable RSRP as serving cell
- Check if RSSI is reasonable and not close to sensitivity (RSSI < -90 dBm, or RSRP < -105 dBm)
- Check if RSSI/RSRP across Rx antennas are similar

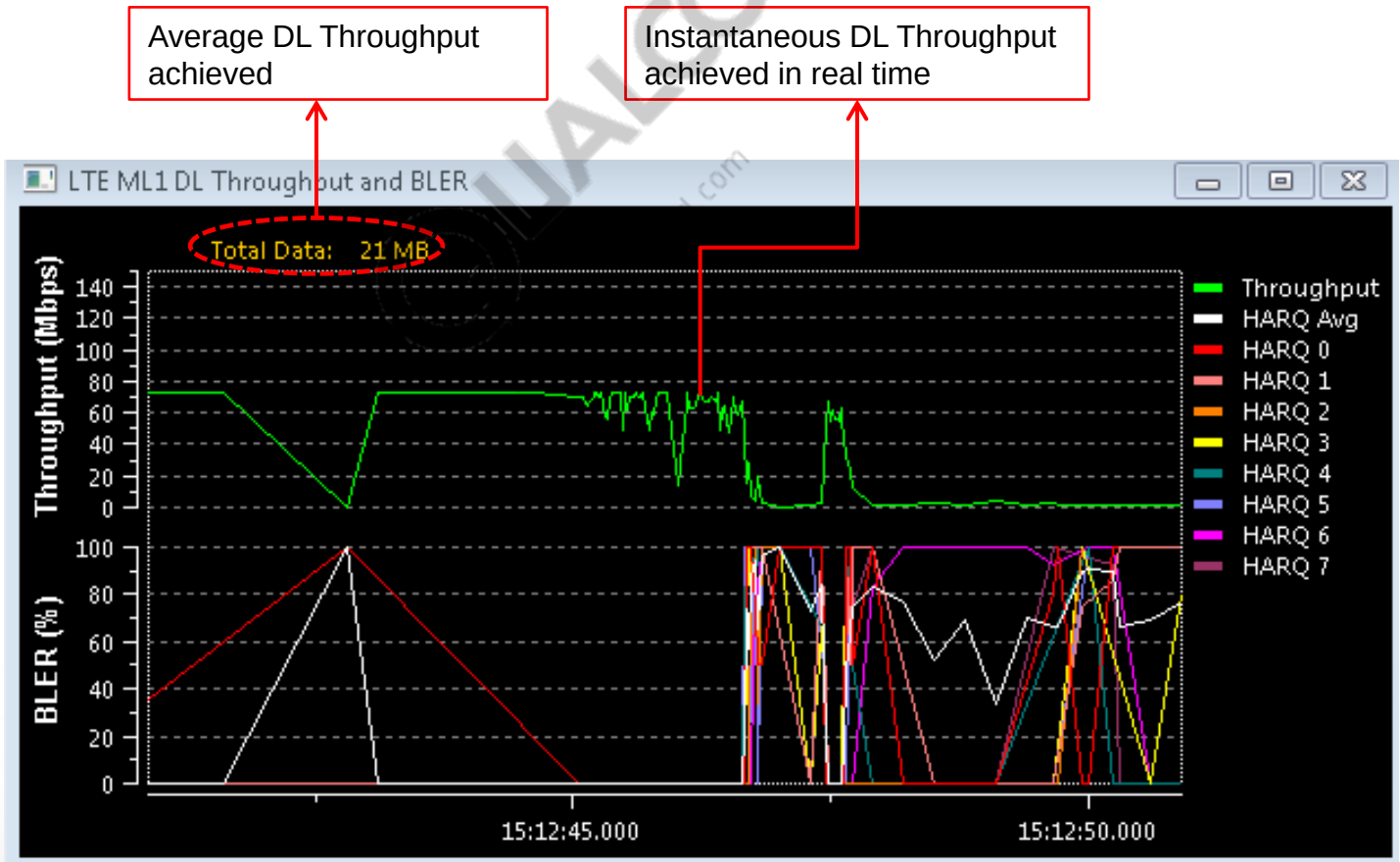
LTE Data Throughput: QXDM Pro Dashboard

- QXDM Pro Dashboard configured with LTE Layer1/RLC/PDCP throughput windows, filtered view for RRC/NAS signaling messages and RRC state change plot



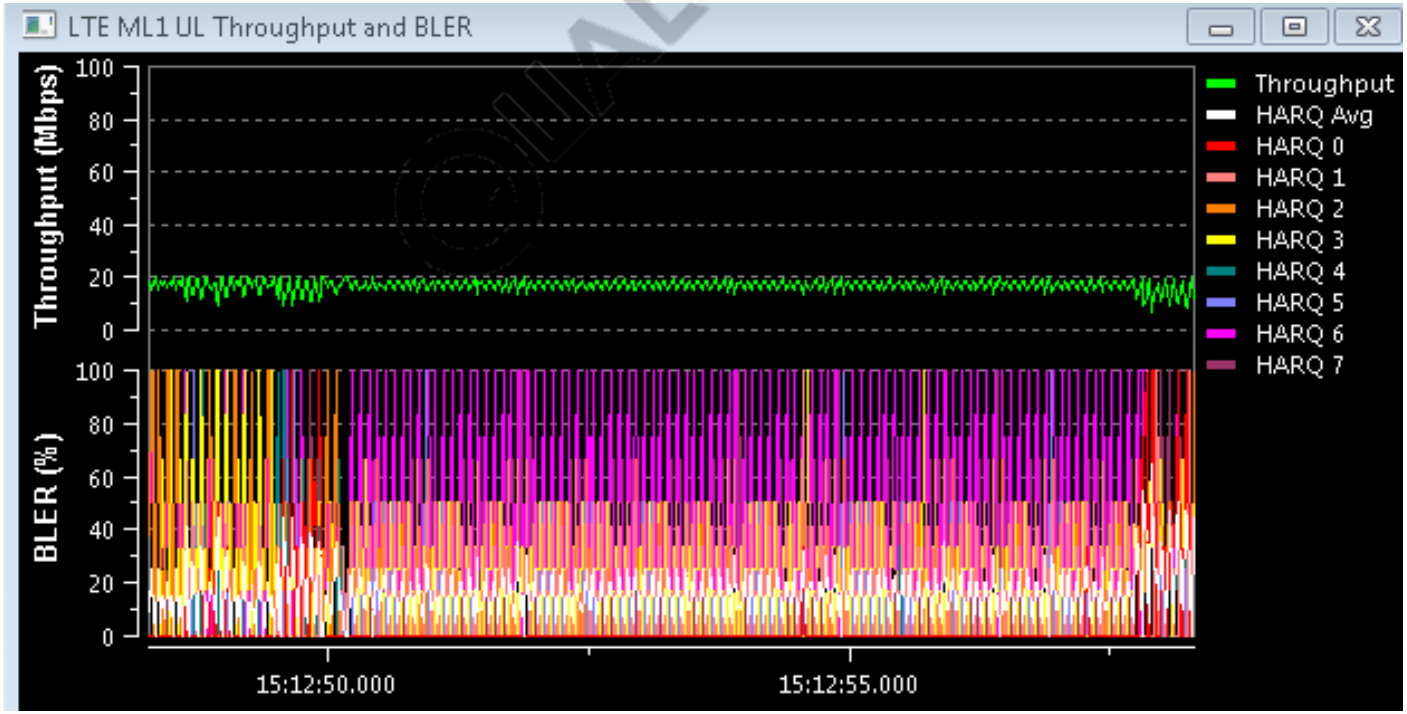
LTE Data Throughput: LTE→ML1 DL throughput and BLER

- LTE ML1 DL throughput and BLER (Block Error Rate) window – This window displays the real time DL throughput as seen by the UE. This window also plots the DL BLER of each HARQ process.



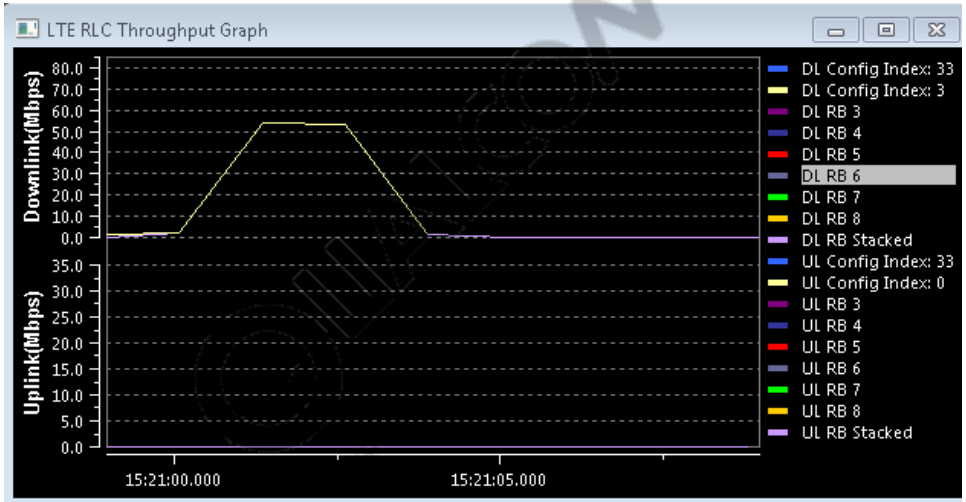
LTE Data Throughput: LTE→ML1 UL Throughput and BLER

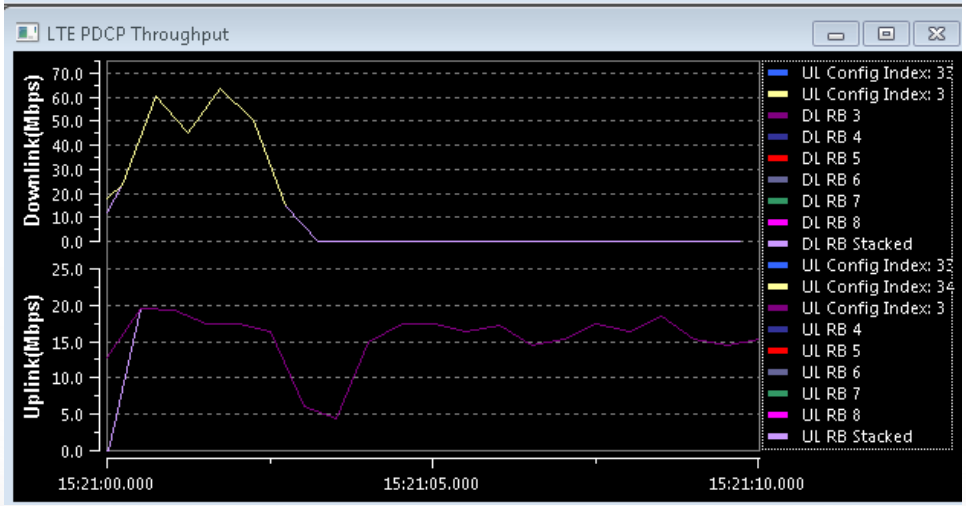
- LTE ML1 UL throughput and BLER window – This window displays the real time UL throughput as seen by the UE. This window also plots the DL BLER of each HARQ process.



LTE Data Throughput: LTE→RLC/PDCP Throughput Graph

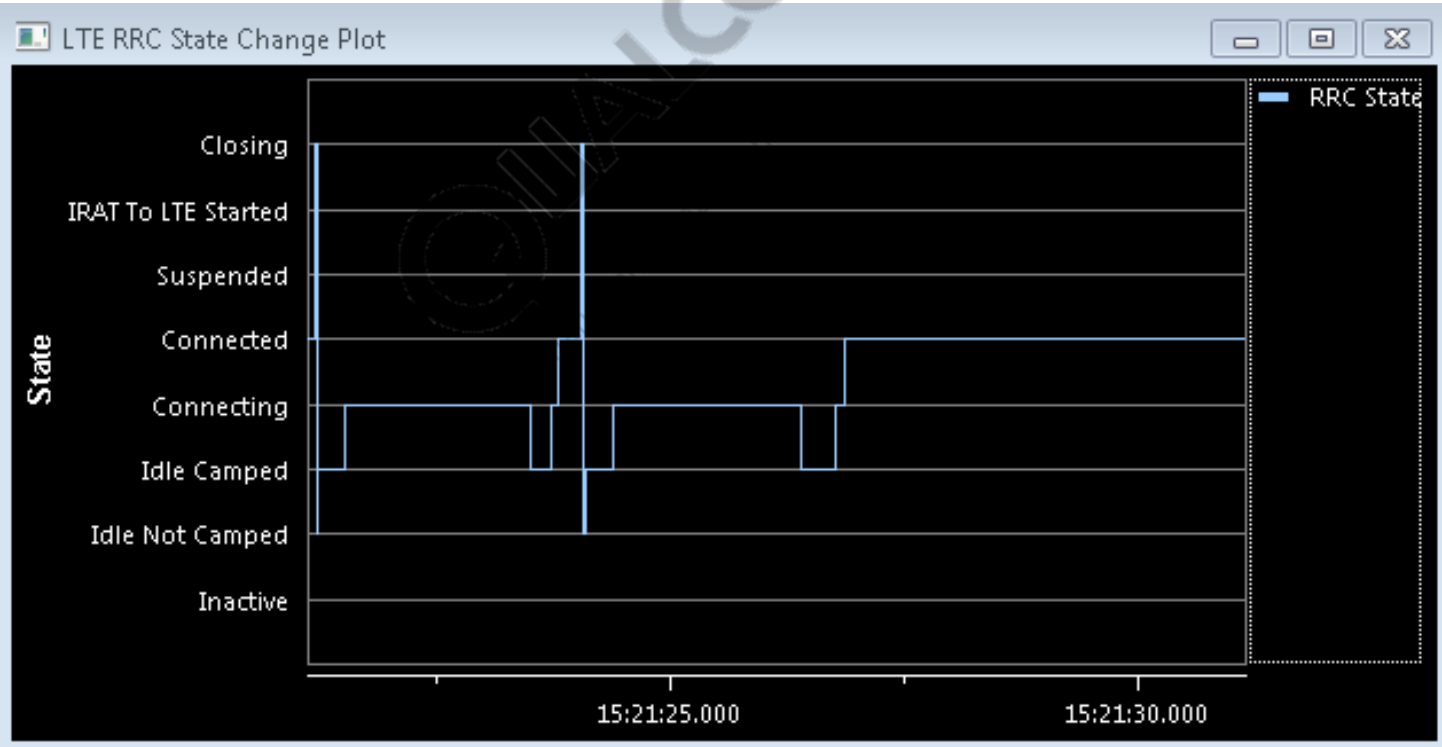
- LTE RLC/PDCP Throughput Graph – These windows show the instantaneous RLC/PDCP layer throughput in both directions (UL/DL).





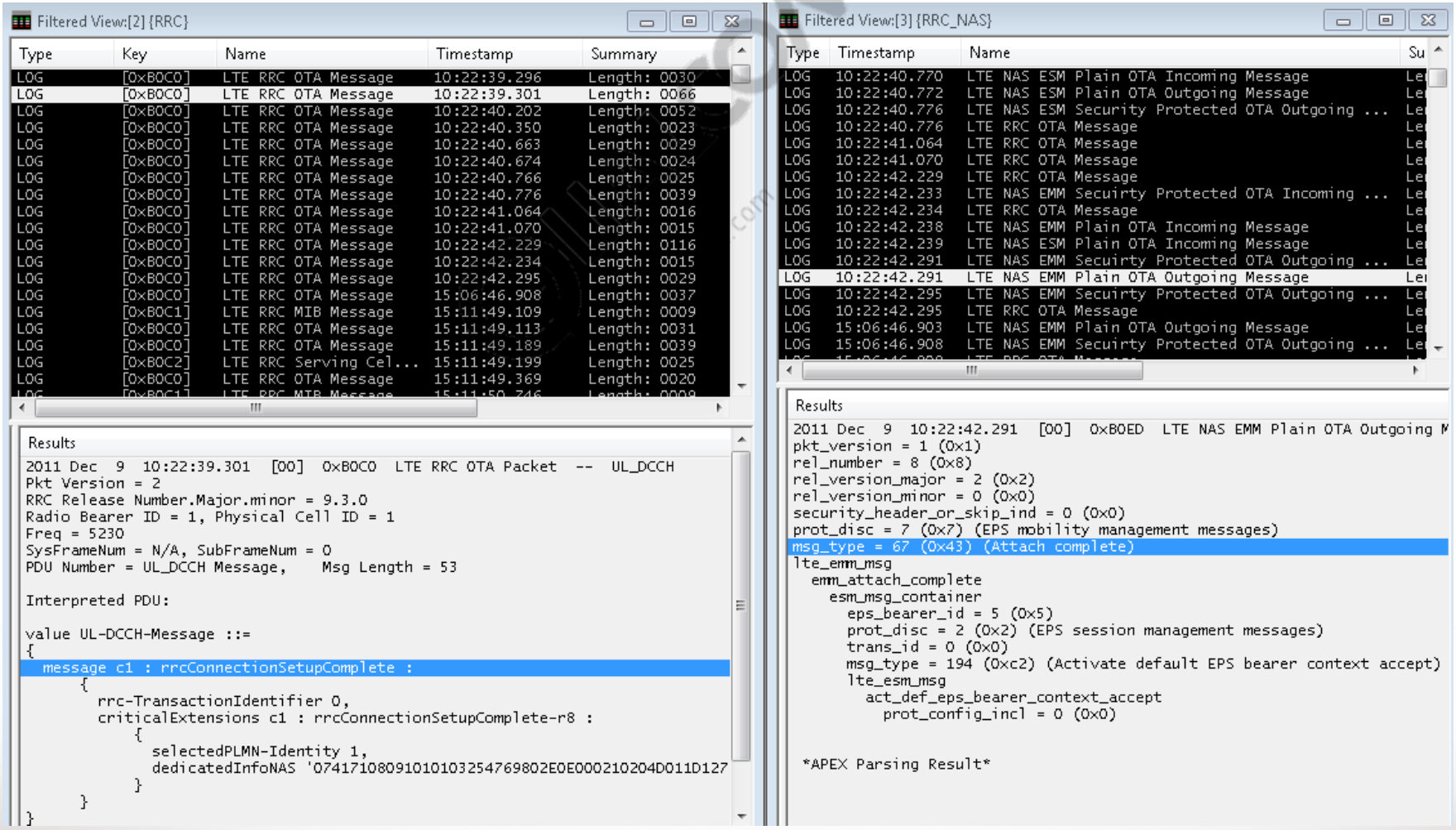
LTE Data Throughput: LTE→RRC State Change Plot

- LTE RRC State Change Plot – This window shows the current LTE RRC state of the UE during the call. This is useful during camping/registration process to quickly check UE's current RRC state.



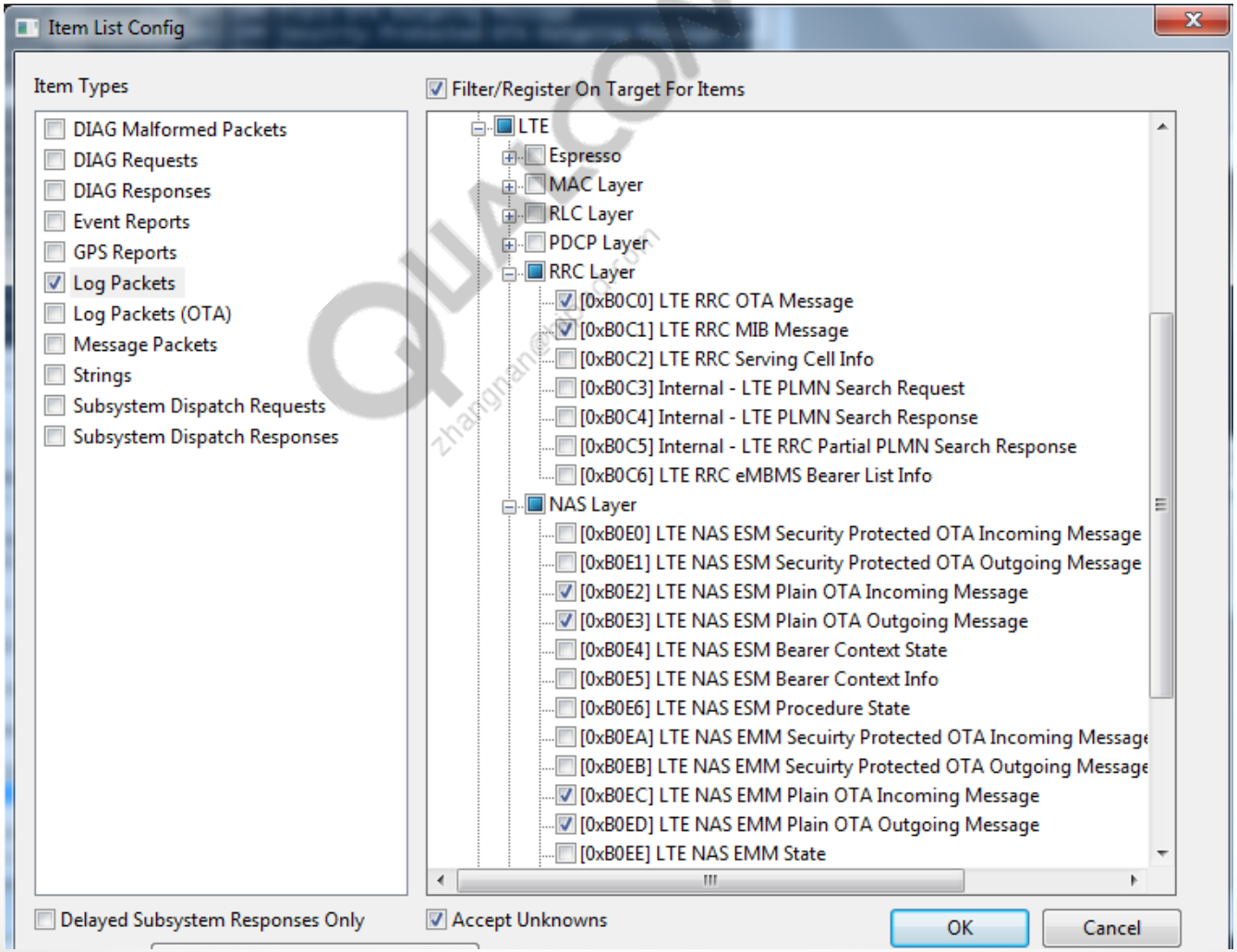
LTE Data Throughput: Filtered View – RRC/NAS Messages

- RRC/NAS messages filtered view – User can select the required filtered RRC messages of interest to be displayed in this window.



LTE Data Throughput: Filtered View – RRC/NAS Messages Configuration

- RRC/NAS filtered view configuration window – The required filtered RRC/NAS messages of interest to be displayed can be configured as:



References

Ref.	Document	
Qualcomm		
Q1	*Application Note: Software Glossary for Customers*	CL93-V3077-1
Q2	*LTE Air Interface (Book 1)*	80-W1953-1

Questions?

https://support.cdmatech.com