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Mobility in LTE

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Abstract – This study presents the mobility in the 4G (Fourth Generation Wireless Systems) technology, LTE (Long Term Evolution). The points that will be achieved are the types of mobility, intra and inter frequency handover, the events for the handover procedure, and what measurement gap is for.

I. INTRODUCTION

The Long Term Evolution (LTE) of UMTS (Universal Mobile Telecommunications System) is just one of the latest steps in an advancing series of mobile telecommunications systems [1]. The development of mobile communications has traditionally been viewed as a sequence of successive generations. The first generation (3G) of analogue mobile telephony was followed by the second, digital generation. Then, the third generation was envisaged to enable full multimedia data transmission as well as voice communications [2]. LTE has ambitious requirements for data rate, capacity, spectrum efficiency, and latency. In order to fulfill these requirements, LTE is based on new technical principles. LTE uses new multiple access schemes on the air interface: OFDMA (Orthogonal Frequency Division Multiple Access) in downlink and SC-FDMA (Single Carrier Frequency Division Multiple Access) in uplink. Furthermore, MIMO (Multiple Input Multiple Output) antenna schemes form an essential part of LTE. To simplify protocol architecture, LTE brings some major changes to the existing UMTS protocol concepts: impact on the overall network architecture including the core network. LTE includes an FDD (Frequency Division Duplex) mode of operation and a TDD (Time Division Duplex) mode of operation. [3]

<u>LTE characteristics:</u>

Spectrum efficiency:
- DL: 3-4 times HSDPA (High Speed Downlink Packet Access) for MIMO (2, 2)
- UL: 2-3 times E-DCH (Enhanced-Dedicated Channel) for MIMO (1, 2)

Frequency Spectrum:
- Scalable bandwidth: 1.4, 3, 5, 10, 15, 20 MHz

Peak data rate (scaling linearly with the spectrum allocation)
- DL: > 100Mb/s for 20 MHz spectrum allocation
- UL: > 50Mb/s for 20 MHz spectrum allocation

Capacity
- 200 users for 5MHz, 400 users in larger spectrum allocations (active state)

Latency
- C (control)-plane: < 100 ms to establish U-plane
- U (user)-plane: < 10 ms from UE (User Equipment) to server

Coverage
- Performance targets up to 5km, slight degradation up to 30km

Mobility
- LTE is optimized for low speeds 0-15 km/h
- Connection maintained for speeds up to 350 or 500km/h
- Handover between 3G & LTE

Real-time < 300 ms
Non-real-time < 500 ms

II. MOBILITY IN LTE

A. Types of mobility

Mobility procedures are essential to maintain connections when the users are moving. LTE defines UE-assisted network controlled hard handover procedures in ECM (Evolved Packet System Connection Management) connected mode. LTE supports two types of mobility procedures:

1. RAN (Radio Access Network) Mobility: as the UE moves from one eNB (E-UTRAN Node B) to another eNB within the same S-GW (Serving Gateway), radio mobility procedures are performed to transfer connections. RAN Mobility Hard Handover (HHO) procedures can occur with intra-eNB, intra- frequency and inter-frequency conditions.

2. CN (Core Network) Mobility: when the mobile moves between S-GWs, two options are possible. One option is an Intra-MME (Mobility Management Entity)/Inter-S-GW HHO without changing the anchor P-GW (Packet Data Node Gateway). The other option is an Inter-MME HHO where both the serving MME and S-GW change. The P-GW remains the same during the HHO for both options.

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B. Intra MME Handover

This procedure is used to handover a UE from a source eNodeB (S-eNB) to a target eNodeB (T-eNB) using the X2 interface when the Mobility Management Entity and Serving Gateway are unchanged. It is possible only if direct connectivity exists between the source and target eNodeB's with the X2 interface.

The X2 handover procedure is performed without Evolved Packet Core (EPC) involvement, i.e. preparation messages are directly exchanged between the S-eNB and T-eNB. The release of the resources at the source side during the handover completion phase is triggered by the T-eNB.

Measurement Reports: The UE transmits a Measurement Report in response to the Measurement Control sent by eNB.

Handover Decision: The source eNB decides to handover the UE to the target eNB based on the measurement report and the RRM (Radio Resource Management) entity.

Handover Request: Once the source eNB makes a handover decision, it transmits a Handover Request message to the target eNB.

Admission Control: This is performed at the target eNB to decide whether to accept or decline the handover. The decision to accept the handover is based on the resources available for the UE at the target eNB. If the admission control function permits the target eNB to accept the handover, then the target eNB configures the radio resources for the UE.

Handover Response: After the successful Admission Control function, the target eNB sends a Handover Request acknowledge message to the source eNB notifying it with : message type, EPS bearer admitted list, EPS bearer not admitted list, target eNB to source eNB transparent container.

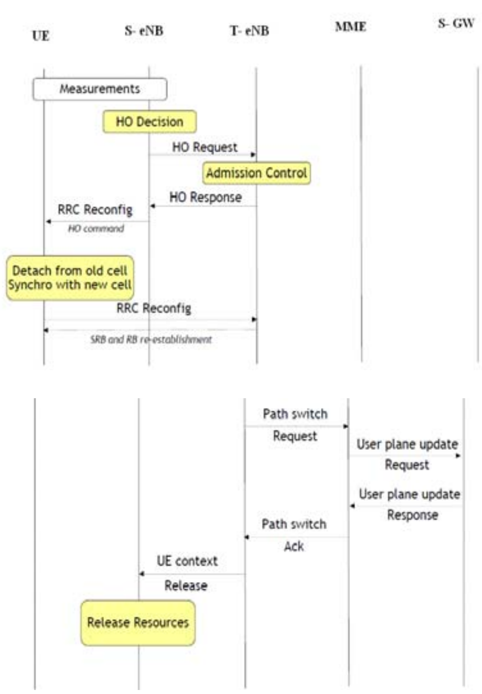


Fig.1. Handover procedure

Handover Command: On receiving the Handover Request Acknowledge message from the target eNB, the source eNB transmits a Handover Command message to the UE asking it to hook on to the target eNB. This RRC (Radio Resource Control) message contains the message type to identify this message and a Handover message. The handover order (command) and target eNB to source eNB transparent container information together form the Handover message.

On reception of the Handover Command, the UE performs a detach procedure with the source eNB and prepares to acquire the target eNB. At this time, the source eNB starts forwarding data from its buffer to the target eNB buffer.

Synchronization: When the UE receives the handover command message, it tries to sync with the target eNB.

RRC Reconfiguration: The UE is allocated with radio resources on the UL and the timing advance information to become synchronized with the target eNB. The UE sends the Handover Confirm message along with C-RNTI and an uplink Buffer Status Report to the target eNB. This indicate a successful handover procedure for the UE. The target eNB verifies the C-RNTI and starts sending data packets to the UE.

Path Switch Request: Receiving a successful Handover Confirm, the target eNB transmits the Path Switch Request message to set up a direct EPS tunnel with the S-GW.

User plane update request: S-GW switches the DL data path to the target eNB. (i.e., a new EPS S1 bearer is set up from the S-GW to the target eNB). Now, the S-GW starts forwarding DL data packets on this new bearer.

User plane update response: The target eNB should first deliver all the buffered source eNB forwarded packets to the UE before delivering the packets on the new DL path.

Path Switch Request Acknowledge: After setting up a new EPS data bearer (new DL path), the MME transmits the path switch request acknowledge message to the target eNB conveying the MME UE.

Release Resources: The target eNB transmits a Release Resource message to inform the source eNB about successful completion of the handover procedure and asks it to release the old resources. The source eNB, on completion of the data forwarding to target eNB, releases all the resources allocated to the UE and also UE, initiates the process of releasing the bearers. Now, the UE starts sending/receiving the data to/from the target eNB, [5].

C. Inter MME Handover

In an inter-MME handover, two MMEs are involved in the handover, the source MME (S-MME) and target MME (T-MME). The S-MME controls the S-eNB and the T-MME controls the T-eNB; both MMEs are connected to the same SGW. This handover is triggered when the UE moves from one MME area to another MME area.

As mentioned in the previous section (Intra-MME/ SGW handover), based on the MEASUREMENT REPORT (MR) from the UE, the S-eNB decides to handover the UE to another eNodeB (T-eNB). The handover procedure in this section is very similar to that in the previous section except for the involvement of two MMEs coordinating the handover signaling between the source and target eNodeBs.

Inter-frequency handover is different from intra frequency handover by the presence of Measurement Gap (MG) periods in eNB scheduling decisions on a per connection basis in order to allow the UE to perform radio measurement across collocated inter-frequency and inter-RAT layers. MG allows each single-receiver UE to make measurements on collocated RAT(s) or LTE carriers for a robust mobility solution across multi-RAT and multi-layer access networks.

III. EVENTS AND THRESHOLDS INVOLVED IN INTER - FREQUENCY HANDOVER

In cellular networks, when a mobile moves from cell to cell and performs cell selection/reselection and handover, it has to measure the signal strength/ quality of the neighbor cells. In LTE network, a UE measures two parameters on reference signal: RSRP (Reference Signal Received Power) and RSRQ (Reference Signal Received Quality).

The carrier RSSI (Receive Strength Signal Indicator) measures the average total received power observed only in OFDM symbols containing reference symbols in the measurement bandwidth over N resource blocks. The total received power of the carrier RSSI includes the power from co-channel serving & non-serving cells, adjacent channel interference, thermal noise, etc. Total measured over 12 subcarriers including RS (Reference Signals) from Serving Cell, traffic in the Serving Cell.

RSRP is the average power of Resource Elements (RE) that carry cell specific Reference Signals over the entire bandwidth, so RSRP is only measured in the symbols carrying RS. UE measures the power of multiple resource elements used to transfer the reference signal but then takes an average of them rather than summing them.

RSRQ means the quality considering RSSI and the number of used Resource Blocks (N) => RSRQ = (N * RSRP)/RSSI measured over the same bandwidth.

In the procedure of handover, the LTE specification provides the flexibility of using RSRP, RSRQ, or both.

RSRP does a better job of measuring signal power from a specific sector while potentially excluding noise and interference from other sectors. The reporting range of RSRP is defined from -140 dBm to - 44 dBm with 1 dB resolution [4].The mapping of measured quantity is defined in the table 1.

Table 1

Reported value	Measured quantity value	Unit
RSRP_00	RSRP < -140	dBm
RSRP_01	-140 ≤ RSRP < -139	dBm
RSRP_02	-139 ≤ RSRP < -138	dBm
…	…	…
RSRP_95	-46 ≤ RSRP < -45	dBm
RSRP_96	-45 ≤ RSRP < -44	dBm
RSRP_97	-44 ≤ RSRP	dBm

Information about various events is provided by eNB to UE in RRCConnectionReconfig message based on the RSRP or/and RSRQ measurements received from UE:

Event A1: serving cell becomes better than threshold

2x Event A2: serving cell becomes worse than threshold

-each event associated with its own separate threshold

-Higher threshold used for triggering measurement gaps – entering coverage alarm

-Lower threshold for connection release and blind redirection – below serving floor

Event A3: neighbor cell becomes offset better than the serving cell - associated with one offset

Event A5: serving becomes worse than threshold1 and target becomes better than threshold2

-associated with two thresholds.

The values of various thresholds involved in inter-frequency HO should respect following rules:

• A1 threshold is higher than A2 thresholds and A5 thresholds

• A2-higher-threshold is lower than A1 threshold and higher than A2-lower threshold.

• A5 threshold for serving cell is higher than A2-lower-threshold

• A5 threshold for target cell must be reached before serving cell reaches A2-lowerthreshold

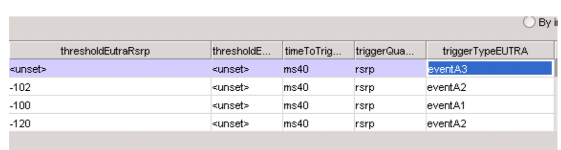
A1 > A2-higher > A5-serving <> A5-target > A2-lower

IV. PRACTICAL RESULTS

We will see the scenario for inter- frequency intra – eNB handover and which events will be involved.

The handover is done with DL traffic, in 5 MHz BW (Bandwidth), using a QUALCOMM UE band 2. The two frequencies between which the handover is made have the DL EARFCNs: 800 and 1100 (cell 16 and cell 13.).

The next step is to select the handover thresholds, where threshold = RSRP [dBm] - offset, offset= 3dB. The RSRP that I used can be seen in the figure 2:



thresholdEutraRsrp	thresholdE...	timeToTrig...	triggerQua...	triggerTypeEUTRA
<unset>	<unset>	ms40	rsrp	eventA3
-102	<unset>	ms40	rsrp	eventA2
-100	<unset>	ms40	rsrp	eventA1
-120	<unset>	ms40	rsrp	eventA2

Fig. 2. RSRP used for HO events

In this case the UE should send the the reported value by UE will be 35 dBm (-140 dBm + 105 dBm = -35 dBm). Measurement report when threshold = -105 (-102-3) based on Table1.

The steps for HO procedure: Event A2 was triggered – serving became worse than threshold (-105):

```
message c1 : rrcConnectionReconfiguration :
    {
      rrc-TransactionIdentifier 0,
      criticalExtensions c1 : rrcConnectionReconfiguration-r8 :
        {
          measConfig
          {
            measObjectToRemoveList
            {
              1
            },
            reportConfigToRemoveList
            {
              3
            },
            reportConfigToAddModList
            {
              {
                reportConfigId 2,
                reportConfig reportConfigEUTRA :
                  {
                    triggerType event :
                      {
                        eventId eventA2 :
                          {
                            a2-Threshold threshold-RSRP : 38
                          },
                        hysteresis 6,
                        timeToTrigger ms40
                      },
                    triggerQuantity rsrp,
                    reportQuantity sameAsTriggerQuantity,
                    maxReportCells 1,
                    reportInterval ms1024,
                    reportAmount r1
                  }
              }
            },
            measIdToAddModList
            {
              {
                measId 2,
                measObjectId 2,
                reportConfigId 2
              }
            }
          }
        }
    }
```

MR corresponding to A2 :

• Measurement was performed on serving cell;

• Measurement gap was triggered by eNB through a Measurement Reconfiguration:

measGapConfig setup:

{ gapOffset gp0: 6 }

```
message c1 : measurementReport :
    {
      criticalExtensions c1 : measurementReport-r8 :
        {
          measResults
          {
            measId 2,
            measResultPCell
            {
              rsrpResult 35,
              rsrqResult 21
            }
          }
        }
    }
```

```
measGapConfig setup :
  {
    gapOffset gp0 : 34
  }
```

Measurement Gap was activated so the neighbor frequencies will be scanned. Then the UE will report to eNB the RSRP for the neighbor cell 13, which is 55. this mean that the RSRP measured for the neighbor cell is: -144 + 55 = -89, based on Table1.

So the RSRP for the cell 13 (-89) is better than RSRP for the serving cell 16 (-105). This is the moment when the HO decision is made.

```
message c1 : measurementReport :
    {
      criticalExtensions c1 : measurementReport-r8 :
        {
          measResults
          {
            measId 5,
            measResultPCell
            {
              rsrpResult 35,
              rsrqResult 21
            },
            measResultNeighCells measResultListEUTRA :
              {
                {
                  physCellId 13,
                  measResult
                  {
                    rsrpResult 55,
                    rsrqResult 26
                  }
                }
              }
          }
        }
    }
```

The UE will now synchronize with the new cell, cell 13, with EARFCN 1100. The UE uses a non-contention based random access procedure because it received preamble.

```
{
  message c1 : rrcConnectionReconfiguration :
      {
        rrc-TransactionIdentifier 2,
        criticalExtensions c1 : rrcConnectionReconfiguration-r8 :
          {
            mobilityControlInfo
            {
              targetPhysCellId 13,
              carrierFreq
              {
                dl-CarrierFreq 1100,
                ul-CarrierFreq 19100
              },
              carrierBandwidth
              {
                dl-Bandwidth n25,
                ul-Bandwidth n25
              },
              t304 ms2000,
              newUE-Identity '11101011 00000111'B,
              radioResourceConfigCommon
              {
                rach-ConfigCommon
                {
                  preambleInfo
                  {
                    numberOfRA-Preambles n56
                  },
                  powerRampingParameters
                  {
                    powerRampingStep dB6,
                    preambleInitialReceivedTargetPower dBm-104
                  },
                  ra-SupervisionInfo
                  {
                    preambleTransMax n3,
                    ra-ResponseWindowSize sf5,
                    mac-ContentionResolutionTimer sf64
                  },
```

Now the HO is complete and the UE starts receiving the data from the cell 13.

```
Radio Bearer ID = 1, Physical Cell ID = 13
Freq = 1100
SysFrameNum = N/A, SubFrameNum = 0
PDU Number = UL_DCCH Message,    Msg Length = 2
SIB Mask in SI =  0x00

Interpreted PDU:

value UL-DCCH-Message ::=
{
  message c1 : rrcConnectionReconfigurationComplete :
      {
        rrc-TransactionIdentifier 2,
        criticalExtensions rrcConnectionReconfigurationComplete-r8 :
          {
          }
      }
}
```

V. REMARKS

The eNodeB database can be modified and you have the possibility to change the RSRP and implicitly the HO events and so you can assure the mobility in the 4G network. Depending of the network demands and capabilities you can let an UE to a cell or you can move it to another cell as soon as the signal gets weaker.

REFERENCES

[1] S. Sesia, I. Toufik, M. Baker, “LTE – The UMTS Long Term Evolution: From Theory to Practice”, 2009 John Wiley & Sons Ltd, Publication
[2] T. Ali-Yahiya, Understanding LTE and its Performance, Springer Science+Business Media, LLC 2011
[3] C.Gessner, “UMTS Long Term Evolution (LTE) Technology Introduction”, 09.2008 ROHDE & SCHWARZ GmbH & Co
[4] http://www.3gpp.org TS 36.133 V8.9.0
[5] Alcatel- Lucent, Internal document.