Bridging the gap between LTE and 1xEV-DO
LTE-to-HRPD handover –
A key element in LTE development

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Disclaimer
This technology presentation contains statements based on latest developments for LTE covered in 3GPP Release 8 and shows the current understanding of the technology. Even with careful analysis there is a certain risk that latest changes or improvements are not covered in this presentation. This should be considered while reading. Furthermore any roadmap or product information is subject to change.
General comments on LTE-to-1xEV-DO handoff
General and technology-related requirements

I General
  – Seamless service continuity between Evolved UMTS Terrestrial Radio Access Network (E-UTRAN; LTE) and High Rate Packet Data (HRPD; 1xEV-DO Rel. 0 and Rev. A),
  – Support of all frequency bands, dual, and single radio solutions (one TRX only!),
  – Principles of a network controlled radio access mobility should be used,
  – Transparent signaling to allow an independent protocol evolution for both access systems,
  – Impact to QoS, e.g. service interruption, should be minimized,

I …by 3GPP2
  – No impact on today’s available cdma2000, Rev. 0 or Rev. A access terminal,
  – Minimal impact to legacy, deployed cdma2000 radio access networks,
  – Influence on circuit switched core network should be minimized.

I …by 3GPP
  – Ability to tunnel signaling messages between E-UTRAN and 3GPP2 system
  – Support measurements of 3GPP2 channels from E-UTRAN,
  – Capability to trigger a handover to a 3GPP2 system,
General comments on LTE-to-1xEV-DO handoff

Work items for the standardization bodies

- Air interface specification for handoff between LTE → 1xEV-DO Rev. A finished and available (C.S0087-0 version 1.0, May 2009),
  - Non-optimized and optimized handoff from LTE to eHRPD,
  - Challenge: Preamble Initial Power for handover complete message,
  - Version 2.0 ready and under review process with handoff specification for 1xEV-DO Rev. A → LTE and LTE → 1xEV-DO Rev. B,
  - LTE → CDMA®2000 1xRTT handoff is not considered,
    - Circuit-Switched Fallback (CS fallback) currently specified in C.S0097-0 v0.4,
- Core network changes are covered in X.S0057-0 v2.0,
- System Information Block Type 8 (SIB Type 8),
- NAS message completed with an additional information element,
- Measurement command added,
Radio Resource Control states of a LTE terminal

**LTE_DETACHED**
- No IP address assigned,
- UE location unknown.

**LTE_ACTIVE (RRC_CONNECTED)**
- IP address assigned,
- Connected to known cell.
  - **OUT_OF_SYNCH**
    - DL reception possible,
    - No UL transmission.
  - **IN_SYNCH**
    - DL reception possible,
    - UL transmission possible.

**LTE_IDLE (RRC_IDLE)**
- IP address assigned,
- UE position partially known.

1. What about mobility, when UE is in IDLE state?
   - Release of C-RNTI, allocate DRX cycle for PCH

2. What about mobility, when UE is in CONNECTED state?
   - LTE random access procedure
     - Initial Access; allocate C-RNTI, TA-ID, IP address
     - Transition to LTE_ACTIVE state (IN_SYNCH)

**User Equipment (UE)**
LTE/eHRPD-capable terminal

Cell search and selection and system information acquisition

LTE random access procedure

1. What about mobility, when UE is in IDLE state?
2. What about mobility, when UE is in CONNECTED state?
UE mobility in LTE

- In **IDLE state** ⇒ Mobility control is UE controlled,
  - Mobility in *Idle Mode* (= cell reselection) is based on absolute priorities, where each frequency has its associated priority, which is assigned by the network,

- In **CONNECTED state** ⇒ Mobility control is E-UTRAN controlled,

General
- Mobility control depends in both cases on quality measurements of the received signal of the cell the UE camps on (serving cell) as well as for the target cell or Inter-RAT cell (i.e. CDMA2000 1xRTT or HRPD),
- Measurement configuration and reporting (How? What? When?) is network controlled and reconfigurable by RRC signaling,
- Initial configuration, key parameter, thresholds etc. for these measurements are provided within system information.
Organization of system information in LTE

The networks help to judge the quality of the serving cell

<table>
<thead>
<tr>
<th>Master Information Block</th>
<th>SIB Type 1</th>
<th>SIB Type 2</th>
<th>SIB Type 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Layer Information</td>
<td>Access restrictions (PLMN identity), SIB scheduling information</td>
<td>Common and shared channel information</td>
<td>Cell re-selection information</td>
</tr>
<tr>
<td>SIB Type 4</td>
<td>Cell re-selection information, intra-frequency neighbor information</td>
<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>SIB Type 6</td>
<td>Cell re-selection information for UTRA</td>
<td></td>
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</tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>SIB Type 9</td>
<td>ETWS(^1) primary notification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home eNB identifier (HNBID)</td>
<td>ETWS(^1) secondary notification</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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1\(^{\text{ETWS = Earthquake and Tsunami Warning System}}\)
PBCH provides Master Information Block (MIB),

Primary and Secondary Synchronization Signal for cell search and initial acquisition (providing cell ID)

Cell–specific downlink reference signals

User Equipment
(UE; LTE-capable terminal)

UE estimates downlink channel quality based on cell-specific downlink reference signals (RS),

- RS are transmitted on well-defined RE,
- Received power level of RS is measured by the UE,
- Cell selection criteria is computed based on DLRS.
LTE-related Physical Layer Measurement

- **Reference Signal Received Power (RSRP),**
  - Reference signal received power (RSRP), is defined as the linear average over the power contributions (in [W]) of the resource elements that carry cell-specific reference signals within the considered measurement frequency bandwidth,
  - RSRP is applicable in RRC_IDLE and RRC_CONNECTED mode,

- **Reference Signal Received Quality (RSRQ),**
  - Reference Signal Received Quality (RSRQ) is defined as the ratio $N \times \frac{RSRP}{(E-UTRA\ carrier\ RSSI)}$, where $N$ is the number of RB’s of the E-UTRA carrier RSSI measurement bandwidth. The measurements in the numerator and denominator shall be made over the same set of resource blocks,
  - RSRQ is only applicable in RRC_CONNECTED mode.

\[
RSRQ = N \frac{RSRP}{RSSI} \quad [dB]
\]

N: Number of Resource Blocks
S is the criterion defined to decide if the cell is a suitable one; this criterion is fulfilled when the cell selection receive level is $S_{rxlev} > 0$.

- $Q_{rxlevmin}$ is the minimum required receive level in this cell, given in dBm. This value is signaled as $Q-RxLevMin$ as part of the SIB Type 1. $Q_{rxlevmin}$ is calculated based on the value provided within the information element (IE; -70 and -22) multiplied with factor 2 in dBm.

- $Q_{rxlevmeas}$ corresponds to the RSRP.

- $Q_{rxlevminoffset}$ this offset (1…8 multiplied with 2 in dB) is defined to avoid “ping-pong” between different PLMN (HPLMN and VPLMN), if it is not available with SIB Type 1, then $Q_{rxlevminoffset}$ is assumed to be 0 dB.

- $P_{Compensation}$ is a maximum function. $P_{E_{MAX}}$ is signaled within SIB Type 1 and $P_{U_{MAX}}$ is the maximum UE power.

\[
S_{rxlev} = Q_{rxlevmeas} - (Q_{rxlevmin} + Q_{rxlevminoffset}) - P_{Compensation} \quad [\text{dB}]
\]

where \( P_{Compensation} = \max(P_{E_{MAX}} - P_{U_{MAX}}, 0) \quad [\text{dB}] \)
Cell reselection in LTE
...not only in terms of CMDA2000/HRPD

I When the UE camps on a suitable LTE cell after successful execution of cell search and selection, it starts with the cell reselection process,

I Rules have been defined how often the UE is required to perform measurements in order to save battery power,

I First, the UE is required to perform intra-frequency measurements, when the quality of the serving cell ($S_{\text{rxlev}}$) is equal or below a certain, higher-layer defined threshold ($S_{\text{intraSearch}}$, see 3GPP TS 36.304),

I Second, the UE is required to perform measurements on E-UTRAN inter-frequency or inter-RAT cells when the quality of the serving cell ($S_{\text{rxlev}}$) is equal or below a certain, higher-layer defined threshold ($S_{\text{nonintraSearch}}$),

I And where does the UE knows these thresholds ($S_{\text{intraSearch}}$, $S_{\text{nonintraSearch}}$) from?
### Organization of system information in LTE

Important for LTE mobility in terms of cell re-selection LTE, C2K, HRPD

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<th>SIB Type 7</th>
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- **SIB Type 1**
  - Access restrictions (PLMN identity), SIB scheduling information

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  - Cell re-selection information for CDMA2000

- **SIB Type 9**
  - Home eNB identifier (HNBID)

- **SIB Type 10**
  - ETWS primary notification

- **SIB Type 11**
  - ETWS secondary notification

**Acquired during cell search and initial acquisition,**
providing system bandwidth, system frame number (SFN),
# of transmit antennas (indirect), PHICH configuration,

**PLMN identity for cell selection,**
information on cell-specific parameters
to compute cell selection criteria

1) **ETWS** = Earthquake and Tsunami Warning System
Organization of system information in LTE

System Information Block Type 3 (SIB Type 3)

```
SystemInformationBlockType3 ::= SEQUENCE {
  cellReselectionInfoCommon  SEQUENCE {
    q-Hyst

    speedStateReselectionParams  SEQUENCE {
      mobilityStateParameters  SEQUENCE {
        q-HystSF
        sf-Medium
        sf-High
      }
    }

    cellReselectionServingFreqInfo  SEQUENCE {
      s-NonIntraSearch  ReselectionThreshold  OPTIONAL,  -- Need OP
      threshServingLow  ReselectionThreshold,  CellReselectionPriority
      cellReselectionPriority
    },

    intraFreqCellReselectionInfo  SEQUENCE {
      q-RxLevMin  Q-RxLevMin,
      P-Max      P-Max
      s-IntraSearch  ReselectionThreshold  OPTIONAL,  -- Need OP
      allowedMeasBandwidth  AllowedMeasBandwidth
      presenceAntennaPort1  PresenceAntennaPort1,
      neighCellConfig  NeighCellConfig,
      t-ReselectionEUTRA  T-Reselection,
      t-ReselectionEUTRA-ST  SpeedStateScaleFactors
    },
    ...
  }
}
```

Srxlev (= cell selection criteria)

see TS 36.331 V8.8.0 RRC protocol specification, December 2009
In **IDLE state** the UE performs measurements in further E-UTRA and HRPD bands, relevant parameters are provided by SIB Type 3 and 8,

- Cell reselection priority for HRPD and E-UTRA is important,
  - HRPD cell has lower priority than current E-UTRA frequency (= serving cell), quality measurements may be done when $S_{\text{ServingCell}} > S_{\text{nonintrasearch}}$, if either $S_{\text{ServingCell}} \leq S_{\text{nonintrasearch}}$
    - Measurement shall be done,
  - HRPD cell has higher priority measurements are performed at least every $N_f \times T_{\text{measureHRPD}}$ (see table), where $N_f$ is the number of entries in BandClassListCDMA2000,
    - Measurement result is $S_{\text{nonServingCell,HRPD}}$,

- Cell reselection (HRPD with higher priority),
  - HRPD is selected, if $S_{\text{nonServingCell,HRPD}} < \text{Thresh}_{x,\text{high}}$,

- Cell reselection (HRPD with lower priority),
  - HRPD is selected, if $S_{\text{ServingCell}} < \text{Thresh}_{x,\text{low}}$ and $S_{\text{nonServingCell,HRPD}} > \text{Thresh}_{x,\text{low}}$ 

<table>
<thead>
<tr>
<th>DRX cycle length [s]</th>
<th>$T_{\text{measureHRPD}}$ [s] (# of DRX cycles)</th>
<th>$T_{\text{evaluateHRPD}}$ [s] (# of DRX cycles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.32</td>
<td>5.12 (16)</td>
<td>15.36 (48)</td>
</tr>
<tr>
<td>0.64</td>
<td>5.12 (8)</td>
<td>15.36 (24)</td>
</tr>
<tr>
<td>1.28</td>
<td>6.4 (5)</td>
<td>19.2 (15)</td>
</tr>
<tr>
<td>2.56</td>
<td>7.68 (3)</td>
<td>23.04 (9)</td>
</tr>
</tbody>
</table>
UE mobility in LTE (RRC CONNECTED state)
Measurement configuration, related RRC messages & information elements

- **RRCConnectionReconfiguration**
  - ... MeasConfig ...
- **MeasConfig**
  - MeasObjectToAddModList
  - ReportConfigToAddMod
  - QuantityConfig
  - measGapConfig
- **MeasObjectToAddModList**
  - MeasObjectCDMA2000
- **ReportConfigToAddMod**
  - ReportConfigInterRAT
- **QuantityConfig**
  - QuantityConfigCDMA2000
- **measGapConfig**
  - gp0 (0…39), gp1 (0…79)

**How? What? When?**

- **SFN mod T = FLOOR(gapOffset/10)** with T = MGRP/10
- **Subframe = gapOffset mod 10**

Type of CDMA network (1xRTT, HRPD), CDMA2000 carrier configuration, search window size, cells to add/modify/remove from the neighboring list, cell index (up to 32 cells), PN offset...

Periodic or event (InterRAT: B1, B2) triggered Reporting, hysteresis (0…15 dB), # of cells to report excluding serving cell, report interval (120, ..., 10240ms, ..., 60 min), time-to-trigger, CDMA2000 threshold (0…63)

Pilot PN phase (0…32767), indicates the arrival time of a CDMA2000 pilot, measured relative to the UE’s time reference in units of PN chips,

**Pilot Strength** (0…63) the ratio of pilot power to total power in the signal bandwidth of the Forward Channel

Two gap pattern 0 and 1, gap length is 6 ms, using two different Measurement Gap Repetition Rates (MPRG) of 40 or 80 ms

When to retune the receiver to measure e.g. CDMA2000 or HRPD...
Network Architecture (optimized handoff)
New network interfaces and elements for HRPD
Transformation to enhanced HRPD (eHRPD)

- **S101 interface,**
  - Pure signaling (tunneling) interface, which enables interaction between Evolved Packet Core (EPC) and HRPD,
  - Passes signaling messages without modification, provides S101 Session ID to distinguish between different UE’s,
  - Allows pre-registration, session maintenance, signaling for handover to the desired system in both directions,

- **S103 interface,**
  - Forward downlink data during mobility from E-UTRAN to HRPD,
  - Signaling procedures on the S101 are used to setup the required tunnel on the S103 interface,

- **HRPD High Speed Gateway (HSGW),**
  - S103 interfaces not directly with HRPD core network, due to additional interfaces and interconnection required for handoff between LTE/SAE and HRPD,
  - Packet routing and forwarding, DL packet buffering and flow mapping, UL and DL bearer binding, support of simple IPv4 and IPv6 addressing,
  - Provides IP address and Generic Routing Encapsulation (GRE) keys to be used by Serving-Gateway for forwarding user data packets.
Handoff from E-UTRAN to HRPD

UE mobility in LTE (RRC CONNECTED state)

- Ability of pre-registration is indicated on PBCH or via dedicated RRC signaling
- E-UTRAN needs to decide, that HO to HRPD is required
- UE attached to E-UTRAN
- Pre-registration
- HO preparation
- HO execution

Remember!
Single radio solution = just 1 transceiver

- Reduces time for cell re-selection or handover,
- Reduces risk of radio link failure,

Connection Request issued by UE to HRPD, HRPD prepares for the arrival of the UE

HO command is delivered to UE, re-tune radio to HRPD channel, acquire HRPD channel, session configuration
Pre-registration phase

LTE/SAE network

eNB

S1-MME

S1-U

eAN

HRPD Serving GateWay

S101

eAN/PCF

A10'

A11'

A12

3GPP AAA Server

3GPP2 AAA Server

eAN

Mobility Management Entity

STa

STa

3GPP2 AAA Server

AN-AAA

UE registered/attached to E-UTRAN,
UE has acquired a IPv4 address or IPv6 prefix via PMIPv6 registration process,
Data transmission is ongoing,
UE is now registered to HRPD network and has been authenticated by the AAA/HSS
… to authenticate UE for access in HRPD
… to establish a new session in the HRPD network
Optional: UE establishes An AN-PPP connection
Get QoS rules for all PDNs the UE has connection with
… to perform Device Authentication Over A12
Initiate resource reservation procedures to establish dedicated bearers
Establish PPP connection

UE is now registered to HRPD network and has been
Establish A10 connection, indicating that access over tunnel PMIP bindings need not to be triggered
… to authenticate UE for access in HRPD
… to establish a new session in the HRPD network
Optional: UE establishes An AN-PPP connection
Get QoS rules for all PDNs the UE has connection with
… to perform Device Authentication Over A12
Initiate resource reservation procedures to establish dedicated bearers
Establish PPP connection
LTE/HRPD Handover – Key Aspect of LTE Deployment

Preparation and execution

LTE/SAE network

- eNB
- X2
- S1-MME
- Serving-Gateway
- Packet-Gateway
- HRPD Serving Gateway
- S101 Session
- S103 Session
- S11 Session
- S1-MME
- X2
- PBU to establish PMIPv6 tunnel
- PBUAck, containing UE IPv4 Address or IPv6 prefix
- RRQ: Active Start Airlink Record Indicator that UE is on HRPD
- RRP including HSGW IP address, GRE keys for forwarding data traffic through S103 interface
- Allocates requested radio resources
- A12
- AN-AAA

Handover Decision is signaled to the UE by the eNB

Connection Req. eNB adds Sector ID, starting HO access

Handover complete message

Forward TCA message To UE

TCA, including HSGW IP address, GRE keys for data forwarding

Create Forwarding Tunnel (HSGW address, GRE keys)

Modifies IP-CAN Session

Forwarding downlink

RRP

RRP: Active Start Airlink Record Indicator that UE is on HRPD

HRPD Traffic Channel Complete (TCC) message

HRPD Network (1xEV-DO)

eNB

UE provides every xx ms a measurement report including PN offset, pilot signal strength measurements for C2K, HRPD

But: What is the Initial power?

Connection Req. eNB adds Sector ID, starting HO access

Handover complete message

Modifies IP-CAN Session

Forwarding downlink

RRP

RRP: Active Start Airlink Record Indicator that UE is on HRPD

HRPD Traffic Channel Complete (TCC) message

HRPD Network (1xEV-DO)
Testing LTE/eHRPD mobility in accordance with standardization

- TS 36.521 Part 3 – Radio Resource Management (RRM) conformance testing,
  - **Section 4** deals with “E-UTRAN RRC_IDLE State Mobility”, where section 4.5 and 4.6 includes test cases for E-UTRAN to HRPD cell reselection respectively E-UTRAN to CDMA2000 1xRTT cell reselection,

- TS 36.523 Part 1 – Protocol conformance specification,
  - **Section 6** focuses on “Idle Mode operations”, which includes test cases for HRPD,
  - **Section 8.3** deals with “Measurement configuration control and reporting“, which includes test cases for measurements on HRPD cells for event B2 and periodic reporting as well as for 1xRTT cells,

Testing LTE/eHRPD mobility
R&S®CMW500 – the first step

Motorola LTE UE prototype

Laptop with 1xEV-DO Rev. A data card

R&S®FSQ Signal Analyzer
Multi-standard platform for signal and spectrum analysis

R&S®CMW500
Multi-standard platform for protocol and RF/RRM testing
Testing LTE/eHRPD mobility

- **Single Box Solution**
  - Turnkey solution for InterRAT testing
  - Support for LTE↔LTE, LTE↔eHRPD, 1xRTT, WCDMA, GSM
  - Built in Data Application Support

- **Flexible Test Case Development Environment**
  - Cell Selection / Reselection,
  - Active Data Handovers with data continuity,

- **Support of multiple IP connections**
  - IPv4, IPv6

- **Prepared for Multiple PDN Connectivity**

- **Measurement Support During Protocol Tests**
  - Tx/Rx RF Measurements
  - Data Throughput Measurements

R&S®CMW500 Wideband Radio Communication Tester
Testing LTE/eHRPD mobility
InterRAT Active Data Handover Test

- Step #1
  - LTE attach / default bearer setup
  - Allocate IP address
  - Start data transfer

- Step #2
  - Start RF measurements

PC (DAU)
- Video stream

PC (UE)
- Video stream

R&S®CMW500
RF Measurements
Ethernet Switch
Test Scenario
Data App Unit
LTE
-50 dBm
IP data flow
LTE/eHRPD
RF
Ethernet

LTE/HRPD Handover – Key Aspect of LTE Deployment
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Testing LTE/eHRPD mobility
InterRAT Active Data Handover Test

- Step#3
  - Increase eHRPD, lower LTE signal

- Step #4
  - UE is redirected to eHRPD
  - UE opens eHRPD session
  - EAP-AKA authentication
  - Data transfer continues

PC (UE)
- Video stream
Testing LTE/eHRPD mobility

Inter-RAT Active Data Handover Test – log files, cont’d.

Session negotiation complete
Thank you for your attention

Question & answers

### 2010 North American R&S® LTE Forum

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<th>What?</th>
<th>Free 2-day industry forum with presentations from industry experts on LTE / LTE-Advanced</th>
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<tr>
<td>When?</td>
<td>May 4-5, 2010</td>
</tr>
<tr>
<td>Where?</td>
<td>Hilton DFW Lakes Executive Conference Center  1800 Highway 26 East, Grapevine, Texas 76051</td>
</tr>
<tr>
<td>Interested?</td>
<td>Check <a href="http://www.rohde-schwarz.com">http://www.rohde-schwarz.com</a> to register and for further details.</td>
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