LTE in Public Safety/Utilities/Transportation

August, 2013
Benefits of LTE in Public Safety/Utilities/Transportation

HD Video
- Live Streaming
- Group Sharing
- Group Calling

Real-Time Situational

NG-911

Emergency Response

M2M and Telemetry

Fleet Management
LTE Main Features

- All IP
- High Speed Data in High Mobility Environments
- Optimized for Interactive IP applications
  - Always-on Connection
  - Fast Call Setup
  - Low Data Delay
- Enhancements for Public Safety/Utilities
  - Pre-emption, Prioritization, Network Control
- Commercial Economies of Scale
- Seamless Roaming onto Commercial Networks
- Self Optimizing Network (SON)
- Truly Open Standards

- Lowest Delays and Highest Data Rates
- Private Public Safety Network
- Full Interoperability
LTE - Solution Overview

- Distributed Control and User plane network elements (e.g. separate MME)
- Open interfaces developed within the 3GPP Standards body (www.3gpp.org)
LTE Network Architecture

Policy & Charging Rule Function
- Network control of Service Data Flow (SDF) detection, gating, QoS & flow based charging
- Dynamic policy decision on service data flow treatment in the PCEF (PGW)
- Authorizes QoS resources

Subscriber Profile Repository
- Subscription data for policy and charging

Home Subscriber Server
- UE Authentication
- User subscription data
- Location Tracking

Mobility Management Entity
- Authentication
- Tracking area list management
- Idle mode UE reach ability
- S-GW/PDN-GW selection
- Bearer management functions

Packet Gateway
- IP anchor point for bearers
- UE IP address allocation
- Per-user based packet filtering
- Connectivity to packet data network
- Policy Enforcement

Serving Gateway
- Local mobility anchor for inter-eNB handovers
- Idle mode DL packet buffering
- Packet routing and forwarding

eNodeB
- Radio admission control
- Scheduling of UL and DL data
- Scheduling and transmission of paging and system broadcast
- IP header compression
Typical LTE Call Setup – An Example

In a nutshell:
1. UE makes request to eNB using its global ID (IMSI)
2. eNB send requests to appropriate MME using its global ID
3. MME extracts user info from HSS
4. MME requests bearer setup to SGW
5. SGW forwards request to PGW (thru S8 if roaming)
6. PCRF determines QoS and Traffic policy
7. If successful MME accepts attachment of UE
8. Always-on IP setup uses P-GW as anchor
9. eNB sets up a radio bearer for UE
10. Communications starts

Up to 8 bearers per UE with distinct Quality of Service
LTE eNodeB

Sectorized Antenna

Sector

Radio Site (eNodeB)
LTE: Re-use Of 1

1G & 2G
(And Present-Day Land Mobile Radio)

≥3G (LTE)

|f_i| = 25 kHz, 200 kHz

Licensed Frequency Block

Skinny RF Channels

|F| = 5 MHz, 10 MHz ...

Licensed Frequency Block

Fat RF Channels

Sparse Re-Use

Re-Use of 1

Re-Use of 1 → Higher Data Rates, Higher Capacity
Interference Coordination

- A frequency reuse of 1, i.e. same carrier in every cell, calls for coordination at the border of cells for both uplink and downlink transmission
  - Distinction between cell edge and in-cell users facilitates the mechanism
  - Resource scheduling algorithm must ensure resources are used efficiently
- Coordination is established through signaling exchange between adjacent cells
  - On the uplink, indicators for RB interference measurements are used to schedule or adapt RB usage among users. Also power control is used
  - On the downlink, information on transmit power level per RB is exchanged with neighboring cells which then decide whether to schedule that particular RB and at what power level
  - Cells belonging to distinct providers will call for RF planning coordination with no future adaptability, i.e. static configuration with no need for eNB-to-eNB signaling
- Every vendor has its own resource scheduling mechanism for optimizing system capacity
  - Easiest method is not to use RBs used by neighboring cell
  - Basic method is to down-tilt antennas
LTE: Broadband Data

Peak User Data Rates (in 2x5 MHz)

Typical Per Sector Capacity (in 2x5 MHz)

* Layer 2 peak rates
Cell Edge

Target Edge Rate Has Large Impact On Network Cell Count (Costs)

Assuming 2x5 MHz 2x2 MIMO

Provides Highest Data Rates Possible Throughout the Coverage Area
LTE Provides End-To-End QoS

<table>
<thead>
<tr>
<th>QCI</th>
<th>Priority</th>
<th>Service Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (GBR)</td>
<td>2</td>
<td>Conversational Voice</td>
</tr>
<tr>
<td>2 (GBR)</td>
<td>4</td>
<td>Conversational Video</td>
</tr>
<tr>
<td>3 (GBR)</td>
<td>3</td>
<td>Robotics</td>
</tr>
<tr>
<td>4 (GBR)</td>
<td>5</td>
<td>Streaming Video</td>
</tr>
<tr>
<td>5 (non-GBR)</td>
<td>1</td>
<td>IMS Signalling</td>
</tr>
<tr>
<td>6 (non-GBR)</td>
<td>6</td>
<td>www, e-mail, chat, ftp, p2p file sharing, etc.</td>
</tr>
<tr>
<td>7 (non-GBR)</td>
<td>7</td>
<td>Voice, Video (Live Streaming)</td>
</tr>
<tr>
<td>8 (non-GBR)</td>
<td>8</td>
<td>www, e-mail, chat, ftp, p2p file sharing, etc.</td>
</tr>
<tr>
<td>9 (non-GBR)</td>
<td>9</td>
<td>www, e-mail, chat, ftp, p2p file sharing, etc.</td>
</tr>
</tbody>
</table>

- PGW maps traffic onto EPC bearers (associated with QCIs) which are mapped onto DiffServ Classes (CS7, EF, ...); re-marks IP header to reflect priorities as close as possible
- During congestion, core and backhaul routers drop packets according to DSCP
LTE Provides Priority and Preemption Allocation Retention Priority (ARP)

- ARP is stored in the Subscriber profile (HSS) on a per APN basis (at least one APN must be defined per subscriber) and consists of:
  - Priority level: 1 – 15, with 1-8 intended for prioritized treatment within operator domain (per 3GPP 29.212, Section 5.3.45)
  - Pre-emption capability flag: can pre-empt other users
  - Pre-emption vulnerability flag: can be pre-empted by other users

- At every Radio Bearer (RB) setup request (including HO and RRC connection re-establishment), the eNodeB Radio Admission Control (RAC) entity checks the current eNodeB’s ability to accept the request, considering factors such as:
  - maximum number of UEs and RBs,
  - number of RBs on GBR
  - hard capacity limit
Network Sharing

**Site Sharing**
- Site
- Tower
- Antenna
- Shelter
- Transmission
- Power
- Site Support

**RAN Sharing**
- Multi-Operator
- Core Network

**Core Network Sharing**

**Network Roaming**

Sites | eNodeB | Core | Coverage

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LTE Network Sharing Multi-operator Core Network

- Shared Spectrum
- Service Level Agreements (Traffic Policing)
- Backhaul Traffic Separation
  - Separate IPSec Tunnels for Commercial Service Providers and Public Safety
- Prioritization, QoS

Shared Radio Access Network

Hardened Sites
State/Local Sites
**LTE: Public Safety Voice Evolution**

- **Mission Critical Voice**
  - Talkaround
  - Large Group Push-to-Talk
- **Small Group Push-to-Talk**
  - Broadcast/Multicast (eMBMS)
- **Unit-to-Unit Voice**
- **Interoperability with Legacy Land Mobile Radio**

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Factors Influencing Speed Of Public Safety LTE Network Evolution

- Funding
- RFPs
- Legacy Systems

Policy
Testing
Systems

Speed Of Public Safety LTE Rollout
Standards Development
Speed Of Commercial LTE Evolution
Mission Critical Voice Over LTE

1st Demonstration Of Technical Feasibility

Introduction of Higher Power Class LTE Mobile

2014/2015

RURAL ROLLOUTS

FIELD TESTING

URBAN/SUBURBAN ROLLOUTS
AT THE SPEED OF IDEAS
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>AMBR</td>
<td>Aggregate Maximum Bit Rate</td>
</tr>
<tr>
<td>ANR</td>
<td>Automatic Neighbor Relationship</td>
</tr>
<tr>
<td>AR</td>
<td>Access Router</td>
</tr>
<tr>
<td>ASN.1</td>
<td>Abstract Syntax Notation 1</td>
</tr>
<tr>
<td>AS</td>
<td>Application Server</td>
</tr>
<tr>
<td>BCCH</td>
<td>Broadcast Control Channel</td>
</tr>
<tr>
<td>BCH</td>
<td>Broadcast Channel</td>
</tr>
<tr>
<td>CAN</td>
<td>Connectivity Access Network</td>
</tr>
<tr>
<td>CCA</td>
<td>Credit Control Answer</td>
</tr>
<tr>
<td>CCCH</td>
<td>Common Control CHannel</td>
</tr>
<tr>
<td>CCR</td>
<td>Credit Control Request</td>
</tr>
<tr>
<td>CTCH</td>
<td>Common Traffic Channel</td>
</tr>
<tr>
<td>DCH</td>
<td>Dedicated Control Channel</td>
</tr>
<tr>
<td>DL-SCH</td>
<td>Downlink Shared Channel</td>
</tr>
<tr>
<td>DL TFT</td>
<td>Downlink Traffic Flow Template</td>
</tr>
<tr>
<td>DPI</td>
<td>Deep Packet Inspection</td>
</tr>
<tr>
<td>DTCH</td>
<td>Dedicated Traffic Channel</td>
</tr>
<tr>
<td>EIR</td>
<td>Equipment Identity Register</td>
</tr>
<tr>
<td>EMM</td>
<td>EPS Mobility Management (part of NAS)</td>
</tr>
<tr>
<td>ESM</td>
<td>EPS Session Management (part of NAS)</td>
</tr>
<tr>
<td>eNodeB</td>
<td>Evolved Node B</td>
</tr>
<tr>
<td>EPC</td>
<td>Evolved Packet Core</td>
</tr>
<tr>
<td>EPS</td>
<td>Evolved Packet System or Service</td>
</tr>
<tr>
<td>e-UTRAN</td>
<td>Evolved UMTS Terrestrial RAN</td>
</tr>
<tr>
<td>GTP</td>
<td>GPRS Tunneling Protocol</td>
</tr>
<tr>
<td>GW</td>
<td>Gateway</td>
</tr>
<tr>
<td>IMEI</td>
<td>International Mobile Equipment Identity</td>
</tr>
<tr>
<td>IMSI</td>
<td>International Mobile Station Identifier</td>
</tr>
<tr>
<td>MIMO</td>
<td>Multiple Input Multiple Output</td>
</tr>
<tr>
<td>MME</td>
<td>Mobility Management Entity</td>
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<tr>
<td>NACC</td>
<td>Network Assisted Cell Change</td>
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<td>NAS</td>
<td>Network Access Server &amp; Non-Access Stratum</td>
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<tr>
<td>PCRF</td>
<td>Policy Charging Rule Function</td>
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<tr>
<td>PDCP</td>
<td>Packet Data Convergence Protocol</td>
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<td>PDN</td>
<td>Packet Data Network</td>
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<tr>
<td>P-GW</td>
<td>PDN Gateway</td>
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<tr>
<td>PLMN</td>
<td>Public Land Mobile Network</td>
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<tr>
<td>PM</td>
<td>Policy Manager</td>
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<tr>
<td>RAT</td>
<td>Radio Access Technology</td>
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<tr>
<td>RB</td>
<td>Radio Bearer/Resource Block</td>
</tr>
<tr>
<td>RLC</td>
<td>Radio Link Control</td>
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<tr>
<td>RRC</td>
<td>Radio Resource Control</td>
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<tr>
<td>SAE</td>
<td>System Architecture Evolution</td>
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<tr>
<td>SDF</td>
<td>Service Data Flow</td>
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<tr>
<td>S-GW</td>
<td>Serving Gateway</td>
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<tr>
<td>SIB</td>
<td>Signalling Information Block</td>
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<tr>
<td>SON</td>
<td>Self Organizing Network</td>
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<tr>
<td>S-TMSI</td>
<td>Serving Temporary Mobile Subscriber Identifier</td>
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<tr>
<td>SRVCC</td>
<td>Single Radio Voice Call Continuity</td>
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<tr>
<td>TAC</td>
<td>Tracking Area Code</td>
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<tr>
<td>TAI</td>
<td>Tracking Area Identity</td>
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<tr>
<td>TAU</td>
<td>Tracking Area Update</td>
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<tr>
<td>TMSI</td>
<td>Temporary Mobile Station Identifier</td>
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<tr>
<td>UE</td>
<td>User Equipment</td>
</tr>
<tr>
<td>UL TFT</td>
<td>Uplink Traffic Flow Template</td>
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