LTE: Readiness for 5G & IoT

5th May 2016

Mombasawala Mohmedsaeed
General Manager (Applications)
Agenda

– 5G Update: 3GPP Perspective
  • Story continues…(we talked about this last year)

– LTE Release 13: Exciting enablers
  • LTE in unlicensed spectrum: Marriage or Friendship!
  • MTC (IoT): New kid on the block asking for preferences
  • MIMO OTA
Proposed 5G Use Cases
5G capability perspectives from the ITU-R IMT-2020 vision
5G Enabling Technologies

Evolution of existing technology + Revolution of new technology

New Technology (Revolution)

- Microwave and mmWave frequency bands (licensed and unlicensed)
- Wide bandwidth – up to 2 GHz or wider
- Massive MIMO - Number of BS antennas >> Number of UE's
- New waveforms and new radio access technology (RAT)
- In-band full duplex
- Software based network architecture: SDN and NFV

Evolution of existing technology (Sub-6 GHz)

- Evolution of current cellular technologies – LTE-A/LTE-A Pro
  - Example: license assisted access (LAA); enhancement to machine type communication (MTC) or NB-IoT
- New waveforms and new radio access technology (RAT)
- New frequency bands below 6 GHz
- Ultra-dense networks – small cells and WLAN access points
- Evolution of RAN architecture (Advanced C-RAN)

With tight interworking between exiting technologies and the new technologies
5G Update: 3GPP Perspective

3GPP Release 13 & 14

- Study on channel model for frequency spectrum above 6 GHz

- The study item aims to develop a channel model to enable feasibility study and developing framework of using high frequency spectrum ranging from 6 GHz to 100 GHz. In order to achieve this, the study item should fulfil the following objectives.

  • From RAN#69 (Sep 2015) to RAN#70 (Dec 2015), RAN identifies the status/expectation of existing information on high frequencies (e.g. spectrum allocation, scenarios of interest, measurements, etc.).

  • From Q1 2016, RAN1 develops a channel model(s) for frequencies up to 100 GHz taking into account the outcome of RAN-level discussion and discussion in the ‘5G’ requirement study item.

  • Consider the work done outside 3GPP as well as earlier 3GPP work, such as the 3GPP 3D-channel model, as a starting point for modelling of wireless channels of the high frequency spectrum for the identified scenarios.
Study on channel model for frequency spectrum above 6 GHz

- The main industry position is represented by R1-160704 which references a Globecom 2015 white paper proposing the continued use of stochastic modelling. It is supported by NTT DOCOMO, AT&T, CMCC, Ericsson, Huawei, HiSilicon, Intel, KT Corporation, Nokia, Qualcomm and Samsung.

- This enables continued use of existing stochastic modelling tools but will they work?

- The main alternative proposal is coming from Keysight (Anite) and that is to use a deterministic model augmented with local stochastic elements. Keysight papers are:

  - R1-160487 METIS Map-Based Model
  - R1-160823 5G Channel Model Requirements vs. Modelling Approaches
  - R1-160824 An Implementation Based on Map–Based Model
  - R1-160825 Map–based Hybrid Model Compared to geometric-based stochastic model
  - R1-160826 Rays and Graphs

- The conclusion was that the stochastic model will be the default and further study will be made on the deterministic approach.
An aspect worthy of early consideration is the testability of future mmWave RAT.

- **R4-160155** “On the testability of RF requirements for potential 5G devices” covers key issues including the likely absence of connectors at mmWave frequencies and the need to characterize active antenna arrays.

- There is much to learn from the previous OTA experiences with MIMO OTA and Active Antenna System that need to be used to ensure good choices in the future.
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# Evolution of Existing Technology: LTE in unlicensed spectrum

## LTE-Advanced/LTE-Advanced Pro

<table>
<thead>
<tr>
<th>LTE-U / LTE-LAA</th>
<th>• 5 GHz ISM Band</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data + Control</td>
<td>LTE-Unlicensed (LTE-U): based on 3GPP Rel 10-12 and LTE-U Forum spec</td>
</tr>
<tr>
<td>Licensed Anchor</td>
<td>LTE-License Assisted Access (LAA) part of 3GPP Rel-13</td>
</tr>
<tr>
<td>Data only</td>
<td></td>
</tr>
<tr>
<td>Unlicensed (5 GHz)</td>
<td></td>
</tr>
</tbody>
</table>

- Licensed spectrum remains top priority for operators
- LTE over unlicensed gives operators another option to offload traffic to unlicensed spectrum using LTE-U/LTE-LAA

<table>
<thead>
<tr>
<th>Carrier Aggregation</th>
<th>• Up to 32 CCs including LAA operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• TDD-FDD joint operation</td>
</tr>
<tr>
<td>Dual Connectivity</td>
<td>• Simultaneous connection to macro &amp; small cell</td>
</tr>
<tr>
<td>Full-Dimension MIMO (FD-MIMO)</td>
<td>• Simultaneously supports elevation and azimuth Beamforming</td>
</tr>
<tr>
<td></td>
<td>• High order MIMO with up to 64 antenna ports at eNB</td>
</tr>
<tr>
<td>Narrow Band IoT (NB-IoT)</td>
<td>• New narrowband radio technology to address the requirements of the Internet of Things (IoT) (Rel. 13)</td>
</tr>
<tr>
<td>Vehicle to Vehicle (V2V) communication</td>
<td>• Support for V2V services based on LTE sidelink (Rel. 14)</td>
</tr>
</tbody>
</table>
LTE in unlicensed spectrum
It’s happening in multiple ways…

- 3GPP has focused in two areas to help Operators offload traffic in the unlicensed spectrum:
  - WLAN via LTE/WLAN Interworking (via offload or aggregation)
  - LTE over unlicensed spectrum

![Diagram showing offload and aggregation processes]
LTE in unlicensed spectrum
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  • WLAN via LTE/WLAN Interworking (via offload or aggregation)
  • LTE over unlicensed spectrum
# LTE in unlicensed spectrum: Summary

## Offload & Aggregation (LTE-WLAN and LTE only)

### Unified Network (LTE – WLAN)

<table>
<thead>
<tr>
<th>Complete name</th>
<th>RALWI</th>
<th>RCLWI</th>
<th>LWA</th>
<th>LWIP</th>
<th>LTE-U</th>
<th>LAA</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAN Assisted LTE-WLAN Interworking</td>
<td>RAN Controlled LTE-WLAN Interworking</td>
<td>LTE WLAN Aggregation</td>
<td>LTE WLAN Integration with IP Tunneling</td>
<td>LTE Unlicensed</td>
<td>License Assisted Access</td>
<td></td>
</tr>
<tr>
<td><strong>3GPP Release</strong></td>
<td>12</td>
<td>13</td>
<td>13</td>
<td>13</td>
<td>12*</td>
<td>13</td>
</tr>
<tr>
<td><strong>Infrastrcture</strong></td>
<td>EPC + legacy WLAN</td>
<td>EPC + legacy WLAN</td>
<td>EPC + WLAN</td>
<td>EPC + legacy WLAN</td>
<td>EPC</td>
<td>EPC</td>
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<td><strong>WLAN relation</strong></td>
<td>Offload</td>
<td>Offload</td>
<td>Aggregation</td>
<td>Aggregation</td>
<td>co-existence</td>
<td>co-existence</td>
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<tr>
<td><strong>Co-existence</strong></td>
<td>CSMA</td>
<td>CSMA</td>
<td>CSMA</td>
<td>CSMA</td>
<td>CSAT</td>
<td>LBT</td>
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<tr>
<td><strong>Aggregation layer</strong></td>
<td>IP</td>
<td>IP</td>
<td>PDCP</td>
<td>IP</td>
<td>MAC</td>
<td>MAC</td>
</tr>
<tr>
<td><strong>DL and/or UL</strong></td>
<td>DL and UL</td>
<td>DL and UL</td>
<td>DL only</td>
<td>DL (and UL)</td>
<td>DL only</td>
<td>DL only</td>
</tr>
</tbody>
</table>

### Single RAT (LTE)

<table>
<thead>
<tr>
<th>LTE-U</th>
<th>LAA</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTE Unlicensed</td>
<td>License Assisted Access</td>
</tr>
</tbody>
</table>

*Not a 3GPP feature

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**Keysight Restricted**

*LTE Summit 2016*
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**IoT Radio Technologies**

**Strong conformance regimes**

- NFC
- EMV

<10 cm

**Proximity**

WPAN

WHAN

WFAN

WLAN

WNAN

**Terms not precise**

**Cellular (licensed)**

- 3GPP LTE, LTE-MTC
- 3GPP GSM, WCDMA, EC-GPRS
- 3GPP2 Cdma2000
- WiMAX

<5 km

- 3GPP NB-IoT

<100 km

**LPWA (un-licensed)**

**Interop based conformance**

- Bluetooth
- ANT+
- MiWi
- ZigBee
- Z-Wave
- Thread (6LoWPAN)
- WirelessHART
- EnOcean
- Many others
- ISA 100.11a (6LoWPAN)
- Many others
- 802.11a/b/g/n/ac
- 802.11ah (1km)
- 802.11p (V2X)
- 802.11af (white space)
- Wi-SUN (6LoWPAN)
- ZigBee NAN (6LoWPAN)
- Wireless M-bus
- Many others
- SIGFOX
- LoRa
- Telensa
- OnRamp
- Positive Train Control
- Many others

**Networks**

- WPAN: Wireless Personal Area Network
- WHAN: Wireless Home Area Network
- WFAN: Wireless Field (or Factory) Area Network
- WLAN: Wireless Local Area Network
- WNAN: Wireless Neighborhood Area Network
- WWAN: Wireless Wide Area Network
- LPWA: Low Power Wide Area

**Key Insight**

- Billion units/year now
- Emerging
3GPP Release 13 Cellular IoT timelines

**GERAN Objectives**
- 164dB link budget (GPRS +20dB)
- 40 devices per home (~50k/cell)
- >160bps at range limit
- 10 second latency
- 10 year life with 5Wh ~AA battery

**eMTC Cat M:**
- Machine Type Communication
- 1.4MHz Bandwidth LTE derivative
- Software update to LTE infrastructure
- 1Mbps, full mobility, 156dB link, 10 year batt

**NB-IoT:**
- Narrowband IoT
- 200 (180kHz) Clean sheet format
- Software update to LTE or GSM infrastructure
- <=250kbps, nomadic, 164dB, 10 year batt

**EC-GPRS**
- Extended coverage GPRS
- 200kHz GSM/EDGE
- Repetitions to get to 164dB link budget
- EC-PDTCH and EC-PACCH, ~52 min DRX
- Software update to GSM infrastructure

**GSMA Mobile IoT initiative backed by 21 MNOs:**
- AT&T, Bell Mobility, Bermuda Digital Comm, China Telecom, China Unicom, China Mobile, Deutsche Telekom, Etisalat, KDDI, KT, Mobistar, NTT DoCoMo, Orange, Singtel, Softbank, Taiwan Mobile, Telecom Italia, Telefonica, Telenor, Telstra, Verizon, Vodafone

**3GPP spec dev**
- 3GPP test case development
- Conformance testing
- Field trials
- Commercial service

*March-June 2016*
Cellular Internet of Things (CIoT)
Some new technologies and some enhancements over existing ones

<table>
<thead>
<tr>
<th>Technology</th>
<th>LTE-MTC</th>
<th>EC-GSM (EC-GPRS)</th>
<th>NB-IoT (Cat M2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cat 0</td>
<td>Cat M (M1)</td>
<td>Single tone mode</td>
</tr>
<tr>
<td>3GPP Rel 12</td>
<td>3GPP Rel 13</td>
<td>3GPP Rel 13</td>
<td>3GPP Rel 13</td>
</tr>
<tr>
<td>Technology</td>
<td>Based on LTE</td>
<td>Based on LTE</td>
<td>GSM extension</td>
</tr>
<tr>
<td>DL Bandwidth</td>
<td>20 MHz</td>
<td>1.4 MHz</td>
<td>200 kHz</td>
</tr>
<tr>
<td>UL Bandwidth</td>
<td>20 MHz</td>
<td>1.4 MHz</td>
<td>200 kHz</td>
</tr>
<tr>
<td>Multiple access DL</td>
<td>OFDMA</td>
<td>OFDMA</td>
<td>TDMA</td>
</tr>
<tr>
<td>Multiple access UL</td>
<td>SC-FDMA</td>
<td>SC-FDMA</td>
<td>TDMA</td>
</tr>
<tr>
<td>Modulation DL</td>
<td>QPSK, 16QAM, 64QAM</td>
<td>QPSK, 16QAM, 64QAM</td>
<td>GMSK</td>
</tr>
<tr>
<td>Modulation UL</td>
<td>QPSK, 16QAM</td>
<td>QPSK, 16QAM</td>
<td>GMSK</td>
</tr>
<tr>
<td>Peak data rate</td>
<td>1 Mbps</td>
<td>1 Mbps</td>
<td>10 kbps</td>
</tr>
<tr>
<td>Coverage</td>
<td>~141 dB link budget</td>
<td>~156 dB link budget</td>
<td>~164 dB link budget</td>
</tr>
<tr>
<td>Mobility</td>
<td>Full</td>
<td>Full</td>
<td>Full</td>
</tr>
</tbody>
</table>
NB-IoT

Modes of Operation

- NB-IoT is 200 kHz wide, self-contained carrier with three modes of operation:
  - stand-alone; guard band; and in-band
- **Downlink transmission:**
  - OFDMA with 180 kHz RF BW
  - 15 kHz subcarrier spacing
- **Uplink single tone transmission:**
  - FDMA with 180 kHz RF BW
  - 3.75 kHz and 15 kHz subcarrier spacing
- **Uplink multi-tone transmission:**
  - SC-FDMA with 180 kHz RF BW
  - 15 kHz subcarrier spacing

### Stand-alone operation
Utilizing dedicated spectrum. Example, re-farming GSM channels

### Guard band operation
Utilizing unused resource blocks within a LTE carrier’s guard-band

### In-band operation
Utilizing resource blocks within a normal LTE carrier
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MIMO OTA

Why the buzz?

– MIMO OTA performance testing is used to assess the end user’s experience accessing data services on a mobile device.

– All critical parts of the mobile device design – including the antennas, RF front end, baseband processing – are thoroughly and simultaneously tested in real-life conditions.

– Measurements:
  • Transmitter performance: Total Radiated Power (TRP)
  • Receiver performance: Total Isotropic Sensitivity (TIS)

– MIMO OTA antenna test function (ATF) for LTE defined two new UE measurements:
  • RSAP – Reference Signal Antenna Power
    - The incident downlink power seen by the UE on each antenna
  • RSARP – Reference Signal Antenna Relative Phase
    - The observed phase difference between the antennas

Keysight Restricted
LTE Summit 2016
05-05-2016
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MIMO OTA Test Methods

- Anechoic Chamber Methods
  - Multi-probe method
  - Two stage method

- Reverberation Chamber Method
  - Reverberation chamber with channel emulator

**MPAC**
(Multi-Probe Anechoic Chamber)
- Method approved by CTIA for lab use for TM2 & TM3
- Works with Anite PropSIM Channel Emulator

**RTS**
(Radiated Two-Stage)
- Leverages existing chambers
- UXM incorporates chamber channel inversion matrix

**RC / RC+CE**
(Reverb Chamber + Channel Emulation)
- Method approved by CTIA for lab use for TM2
- Uses metallic stirrers (Rayleigh fading) in reverb chamber

*Cost effective using UXM’s internal channel emulator*
Test setup examples
Multi-Probe Anechoic Chamber (MPAC) & RC + CE MIMO OTA system

Multi-probe MIMO OTA system

2x4 MIMO 1*CC using external RF Fading
Finally, Keysight Solution for Wireless Ecosystem
Thank you.
The constant growing demand for higher data rates in mobile devices is causing network Operators to think on innovative paths to help cope with the mobile capacity crunch and, the active use of unlicensed spectrum has become a key enabler.

With more than half of the wireless internet traffic, WLAN is undoubtedly the leading technology for delivering ubiquitous wireless connectivity. Historically WLAN and cellular have been viewed as competing technologies with separate standards bodies and solutions; however, thinking is being challenged with recognition that, with inter-working, the two technologies can be used to complement each other and improve the overall performance of the network.

On the other hand, WLAN is also one of multiple technologies that make use of the ISM band. The lack of any licensing requirement makes this part of the spectrum very attractive to Operators and therefore it’s been a major driver in the standardization bodies lately which are working towards ensuring LTE can be deployed in the unlicensed spectrum.

This is happening in multiple ways…

- LTE and WLAN inter-working defines a framework to enable a seamless and smart traffic offload between the two technologies. In the 3GPP Release 13, RAN-controlled LTE-WLAN Interworking (RCLWI) takes RAN assisted WLAN Offload (Release 12) to a new level by increasing the offload control by the 3GPP network.

- LTE-WLAN link aggregation (i.e. Release 13 LWA and LWIP) goes beyond the offload and allows the simultaneous combination of both technologies to opportunistically boost data rates.

- LTE in the unlicensed spectrum (i.e. LTE-U, LAA) takes advantage of the LTE-A feature, carrier aggregation, to enable the use of LTE in the underutilized 5GHz ISM band. To ensure co-existence with other technologies, new mechanisms like LBT (Listen-Before-Talk) or carrier sensing have been defined by the 3GPP.
WLAN Offload: Use Case

– Delivery of mobile cellular traffic over WLAN to reduce congestion of the cellular network by taking advantage of:
  
  • Most of mobile devices usually have a built-in WLAN function
  • Readily available WLAN networks

– LTE – WLAN Inter-working standardization is needed to improve QoE:

1. **WLAN Calling offload** *(3GPP Network access through WLAN)*
   - Receive and place calls, SMS through IMS in areas with poor cellular coverage

2. **Smart Offload** *(Network selection)*
   - Select LTE or WLAN based on environment, network conditions and per-service

3. **Seamless Offload** *(Session mobility)*
   - Higher quality transitions when entering/exiting LTE or WLAN coverage
LTE WLAN User Plane Aggregation: Use Case

- Enable link aggregation of LTE and WLAN to increase throughput
  - Reliable LTE used as control and mobility anchor to secure QoE
  - WLAN (using unlicensed spectrum) is opportunistically used to increase data rates

- Operators can use deployed WLAN network as standalone for legacy devices but also to increase data rates in new devices

- The benefits can be realized in:
  - **Co-located** (e.g. a small-cell that integrates both LTE and WLAN)
  - **Non-co-located** (e.g. agreement to use a partner’s WLAN network)
LTE over Unlicensed: Licensed Assisted Access

– Opportunistic use of LTE in the Unlicensed Spectrum represents an important complement to meet traffic demand and help boost data rates

– 3GPP has analyzed different modes of Operations depending on scenarios:

<table>
<thead>
<tr>
<th>Deployment model</th>
<th>Mode of operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cells w/ ideal backhaul (co-located or not)</td>
<td>Licensed-Assisted</td>
</tr>
<tr>
<td>Cells w/out ideal backhaul (non-colocated)</td>
<td>Dual Connectivity (Rel.14 eLAA)</td>
</tr>
<tr>
<td>Standalone cells</td>
<td>Standalone non-3GPP i.e. MulteFire</td>
</tr>
</tbody>
</table>

– Enhanced LAA (eLAA) has been proposed as a new Release 14 work item and will specify LAA support for Uplink and Dual Connectivity in the LAA SCell

– Standalone operation within unlicensed spectrum is not planned yet by 3GPP
LAA Overview and Design Targets

- Based on Carrier Aggregation with the Primary Cell being deployed in any Licensed Band to ensure highest reliability and a set of SCells in unlicensed spectrum to boost data rates.

- Design targets:
  - Single global solution compliant with any regional regulatory requirement
  - Effective and fair co-existence with WLAN
  - Effective and fair co-existence with others Operators’ LAA deployments

`LTE licensed (anchor)`

`LTE unlicensed (5GHz)`

`Carrier Aggregation`
Evolution of Existing Technology: Sub-6 GHz
LTE-U / LTE-LAA: How does it work?

1) Be a good neighbor!

- No Change to 3GPP Standard
- Adaptive duty cycle based on channel utilization
- Can be deployed now:
  - US, Korea, China, India

2) If no free carriers exist: fair sharing

- LTE-U
  - 20 ms – 100s ms
  - LTE ON
  - LTE Off

- LTE-LAA (3GPP Rel-13)
  - 1 – 10 ms LTE bursts…
  - Based on 3GPP R13 (completion ~H1 2016)
  - Listen before talk (LBT) - Sense channel every 20 us (clear channel assessment)
  - Dynamic frequency selection (DFS) for radar avoidance
  - Minor changes to physical layer
    - 1 ms – 10 ms transmissions
    - Add discovery signals / beacon signals
    - HARQ modified for asynchronous operation
  - Required for deployment in:
    - Europe, Japan

Source: Qualcomm
Release 13
Spectrum – new FDD bands

– As many as six new band may get added in Rel-13.
– So far three have been specified – band numbering has restarted at 65

<table>
<thead>
<tr>
<th>Band</th>
<th>Uplink MHz</th>
<th>Downlink MHz</th>
<th>Width</th>
<th>Duplex</th>
<th>Gap</th>
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</thead>
<tbody>
<tr>
<td>65</td>
<td>1920</td>
<td>2010</td>
<td>2110</td>
<td>2200</td>
<td>90</td>
</tr>
<tr>
<td>66</td>
<td>1710</td>
<td>1780</td>
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<tr>
<td>67</td>
<td>DNA</td>
<td>738</td>
<td>758</td>
<td>20</td>
<td>-</td>
</tr>
</tbody>
</table>

– Band 67 is the third supplemental downlink (SDL) band to be added
– SDL is used for downlink-only carrier aggregation to improve data rates
Release 13
Spectrum – new TDD bands

– Two new TDD bands have been defined.

<table>
<thead>
<tr>
<th>Band</th>
<th>Uplink MHz</th>
<th>Downlink MHz</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>1447</td>
<td>1447</td>
<td>20</td>
</tr>
<tr>
<td>46</td>
<td>5150</td>
<td>5150</td>
<td>775</td>
</tr>
</tbody>
</table>

– Band 45 is for TD-LTE in China

– Band 46 was introduced as part of the LAA work and is the 5 GHz ISM band.
Relevant Links


– [http://www.3gpp.org/release-13](http://www.3gpp.org/release-13)


– [http://www.3gpp.org/release-14](http://www.3gpp.org/release-14)
