Evolution of LTE-Advanced

Milan Bavisi

17th September 2015
Agenda

- About Nokia
- LTE Advanced Evolution - Carrier Aggregation & Spectrum
- LTE Advanced Evolution – towards 5G
Two strong pillars for the future

Nokia Networks

• Serves more than 90 of the world’s 100 largest operators
• Leading company in mobile broadband
• An early leader in virtualization and cloud technologies

Nokia Technologies

• Hundreds of world class inventors
• Leading patent portfolio
• Established licensing business
• New business opportunities

Nokia Networks in the UK

• Supplier to all the UK MNOs

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3GPP Release Work Program
Smooth and backward compatible evolution

Release 13 Work Items
Enhance Multi Layer Network Performance

First release
With LTE-A functionalities


Rel. 8 Rel.9 Rel.10 Rel.11 Rel.12 Rel.13 Rel.14

LTE LTE-A

D2D and Dual Connect
LTE-Unlicensed / LAA
LTE - M
3D Beamforming
Carrier Aggregation
up to 100 MHz

2017 2018

LTE evolution to 5G
Converge Technologies

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Carrier Aggregation: We are still at the beginning of the long-term-evolution

More spectrum + carrier aggregation + new device capabilities

<table>
<thead>
<tr>
<th>Year</th>
<th>Unlicensed</th>
<th>TDD</th>
<th>Downlink</th>
<th>FDD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>5400</td>
<td>3500</td>
<td>1400</td>
<td>700</td>
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<td>2013</td>
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<td>2017</td>
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</tbody>
</table>

- **Unlicensed**: 5400 MHz
- **TDD**: 3500 MHz, 2600 MHz, 2300 MHz, 2100 MHz, 1800 MHz
- **Downlink**: 1400 MHz, 900 MHz, 800 MHz
- **FDD**: 700 MHz

- **2012**: 150 Mbps, 20 MHz 2x2 MIMO, Cat. 3, 4 devices
- **2013**: 150 Mbps, 10+10 MHz 2x2 MIMO, Cat. 6, 7 devices
- **2014**: 300 Mbps, 20+20 MHz 2x2 MIMO, Cat. 9, 10 devices
- **2015**: 450 Mbps, 3CA 2x2 MIMO, Cat. 11, 12 devices
- **2016**: 600 Mbps, 4CA or 4x4 MIMO, Cat. 15 device
- **2017**: 1 Gbps, 100 MHz, Cat. 15 device

Cat. 6, 7, 9, 10, 11, 12, 15 devices
32x Faster Through Evolution of Carrier Aggregation
From 20 MHz to 640 MHz aggregated spectrum to serve a user

<table>
<thead>
<tr>
<th></th>
<th>20 MHz</th>
<th>5 x 20 MHz</th>
<th>32 x 20 MHz</th>
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<tbody>
<tr>
<td>LTE</td>
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<td>3GPP Release 8-9</td>
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<tr>
<td>3GPP Release 10-12</td>
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<td>LTE-Advanced+</td>
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<tr>
<td>3GPP Release 13 -</td>
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Bandwidth/user: $x32$

<table>
<thead>
<tr>
<th></th>
<th>700</th>
<th>800</th>
<th>900</th>
<th>1400</th>
<th>1800</th>
<th>2100</th>
<th>2300</th>
<th>2600</th>
<th>3500</th>
<th>5400</th>
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Three-Band Aggregation 20+20+10 MHz in Live Nokia Network >370 Mbps

Peak throughput >370 Mbps

- Band 7 – 20 MHz
- Band 3 – 20 MHz
- Band 20 – 10 MHz

150-200 simultaneously connected live users
Devices Emerging in the next 6 months based on Qualcomm Chipset

- Xiaomi Mi Note
- Samsung Galaxy Note 4
- LG Flex 2

Samsung Galaxy Note 5
Samsung Galaxy S6
**LTE-Advanced Evolution: New Use Cases, new opportunities…...towards 5G?**

### New Application Areas

<table>
<thead>
<tr>
<th>Application</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internet of things</td>
<td>LTE-M = Machine-to-Machine</td>
</tr>
<tr>
<td>Proximity services</td>
<td>LTE-D = Device-to-Device</td>
</tr>
<tr>
<td>Replace terrestrial TV</td>
<td>LTE-B = Broadcast = eMBMS</td>
</tr>
<tr>
<td>Run public safety on your LTE</td>
<td>LTE for Public Safety</td>
</tr>
<tr>
<td>Move voice to IP in LTE network</td>
<td>LTE for Voice (VoLTE)</td>
</tr>
<tr>
<td>Connectivity for car entertainment</td>
<td>LTE for Connected Cars</td>
</tr>
<tr>
<td>Wi-Fi backhaul for airplanes</td>
<td>LTE for Airplane Connections</td>
</tr>
</tbody>
</table>

### New Spectrum

<table>
<thead>
<tr>
<th>Spectrum Description</th>
<th>Details</th>
</tr>
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<tbody>
<tr>
<td>500 MHz more spectrum at 5 GHz</td>
<td>LTE-U = Unlicensed Band</td>
</tr>
<tr>
<td>Sharing with incumbent user</td>
<td>Authorized shared access</td>
</tr>
<tr>
<td>LTE on 470 – 700 MHz</td>
<td>LTE on UHF Bands</td>
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Driving the evolution of LTE-Advanced towards 5G
Opening up new business opportunities

Towards vehicular communications (V2X)
- Navigation
- Traffic control and safety
- Intelligent Transport Systems
- Vehicle to Vehicle Pedestrian Infrastructure Home

Towards the multi-cell broadcast
- All devices
- Low tower sites
- Single Frequency Network
- UHF (also sub-700MHz)

Towards public safety
- High power user equipment
- Proximity
- Group Communications

Towards the Internet of Things
- Low cost modems
- Long battery life
- Enhanced coverage
- Reliability – congestion control

LTE-A
Release 12…14

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More spectrum - LTE-U (LAA) for unlicensed bands
Unique combination of licensed + unlicensed bands

- Licensed band provides reliable connection and quality of service for mobility, signaling, voice and data
- Unlicensed band provides "Opportunistic use" to boost data rates especially in downlink (downlink: uplink asymmetry 10:1 in LTE networks)

<table>
<thead>
<tr>
<th>200 MHz</th>
<th>255 MHz</th>
<th>125 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>5150</td>
<td>5470</td>
<td>5725</td>
</tr>
<tr>
<td>5350</td>
<td>5470</td>
<td>5850</td>
</tr>
</tbody>
</table>

Indoor 30-200mW

U-NII Worldwide: Outdoor 1W

U-NII-Upper

*) U-NII: Unlicensed National Information Infrastructure

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Performance of LAA vs Wi-Fi – LAA for Public Areas and Outdoor

LAA provides double spectral efficiency vs Wi-Fi

Capacity with single technology

- Single Network
- Two Networks

Relative capacity

- LTE
- Wi-Fi

LAA provides double cell range vs Wi-Fi

Outdoor micro cell range

- Wi-Fi (5 GHz)
- LTE (5 GHz)

Meters

Min
Max

LTE (5 GHz)

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Myriad of new performance possibilities for people and things

- Augmented shopping
- Augmented dashboard
- 4k Video
- Augmented gaming
- Interconnected
- Real-time work in cloud
- Personal robot
- Real-time cloud access
- Mobile living
- Smart clothes
- 8k Video beamer
- Communication
- VR gaming
- Virtual 3D presence
- 3D printing
- Touch & steer
- Travel & commute
- Advanced monitoring
- HD Cams NW
- Human possibilities
- Time shift
- 4th industrial revolution
- Real mobility
- High performance infrastructure
- Virtual mobility
- People & Things
- Augmented dashboard
- Augmented gaming
- Augmented shopping
- Real-time remote control
- Reliability communications
- Reliable emergency communications
- Pollution control
- Traffic steering & management
- Transportation 
- Self driving
- Assisted driving
- Logistics
- Maintenance optimization
- Factory automation
- Real-time remote control
- Utility & Energy
- Traffic Mgmt.
- Industry 4.0
- Connected home
- Smart grids
- Waste mgmt.
- Tactile
- Real-time remote control
- HD Cams NW
- Work & game while traveling
- Real time
- Assisted driving
- Logistics
- Real-time remote control
- Reliable emergency communications
- Human possibilities
Thank you