September, 2014

LTE TDD—the global solution for unpaired spectrum

QUALCOMM
LTE TDD: the global solution for unpaired spectrum

1. LTE is a common global standard for paired and unpaired spectrum

2. Common FDD/TDD technology ecosystem, common products

3. Inherent tight TDD/FDD interworking and seamless 3G interworking

4. Key to access higher spectrum bands on the path to 1000x
LTE is a common standard for paired and unpaired spectrum

The same 3GPP specifications for LTE FDD and LTE TDD
• Same features in same standards release

- Inherent FDD/TDD interworking
- Seamless 3G interworking
- Flexible spectrum support
- OFDMA based
- Low latency
- High data rates
- FDD and TDD support
Global LTE TDD spectrum opportunities

- **North America**
  - LTE TDD2600 (B41)

- **South America**
  - LTE TDD2600 (B38)

- **Europe**
  - LTE TDD2600 (B38)
  - LTE TDD2300 (B40)
  - LTE TDD3.5/3.6 (B42/43)

- **Russia**
  - LTE TDD2600 (B38)
  - LTE TDD3.5 (B42)

- **China**
  - LTE TDD1900 (B39)
  - LTE TDD2300 (B40)
  - LTE TDD2600 (B38/B41)

- **Japan**
  - LTE-TDD2600 (~B41)
  - "XGP"

- **MENA**
  - LTE TDD2600 (B38)
  - LTE TDD2300 (B40)
  - LTE TDD3.5 (B42)

- **India**
  - LTE TDD2300 (B40)

- **Australia**
  - LTE TDD2300 (B40)

---

**Global unpaired spectrum**
- 1.9 GHz (B39)
  - 1880 MHz to 1920 MHz
- 2.3 GHz (B40)
  - 2300 MHz to 2400 MHz
- 2.6 GHz (B38)
  - 2570 MHz to 2620 MHz
- 2.6 GHz (B41)
  - 2496 MHz to 2690 MHz
- ~3.6 GHz (B42/43)
  - 3.4 to 3.6 and 3.6 to 3.8

**Potential Spectrum**
- 40MHz
- 100 MHz
- 50 MHz
- 194 MHz
- 400 MHz

---

1IMT extension band provides 50 MHz TDD in addition to 70 MHz + 70 MHz FDD in most countries.

©2013-2014 Qualcomm Technologies, Inc. and/or its affiliated companies. All Rights Reserved.
LTE TDD is truly global—many combining FDD and TDD

Source: www.gsacom.com, Networks in deployment/planning as of April, 2014, Commercial launches as of Jul 2014
©2013-2014 Qualcomm Technologies, Inc. and/or its affiliated companies. All Rights Reserved.
There is a TDD/FDD tradeoff—eventually most will deploy both

TDD can assign more downlink capacity
Flexibility to assign more resources to meet asymmetric data usage

FDD can cover larger area
Only applicable to coverage driven deployments

1. Assuming same transmit power. The main reason for reduced coverage is that the uplink device power is used part of the time for TDD but continuously for FDD. As an example, an 1:1 UL/DL allocation means a duty cycle of ~50% in the uplink which contributes to a ~3dB reduced link budget; in capacity driven deployments, there is no coverage advantage.
Common LTE FDD and LTE TDD technology ecosystem, common products
LTE has a vibrant ecosystem with two flavors: FDD and TDD

Global LTE network launches
- 318 Launches
- 577 Operators investing in LTE

LTE TDD momentum
- 39 TDD Launches
- 26 Countries

Large and growing device ecosystem
- 1889 Devices
- 168 Vendors

Global LTE/3G multimode connections reached 200 Million in March 2014 - Informa
The vast majority of the standard is the same for FDD and TDD
Independent research analyzing ~83,000 3GPP contributions

The vast majority of contributions applies equally to both FDD and TDD modes

LTE Duplex Neutral 82.5%
35,447

LTE Duplex Specific 17.5%
7,550

LTE TDD Only 7.0%

LTE FDD & LTE TDD 6.8%

LTE FDD Only 3.7%

The global community contributed to the standard

Europe 30%
South Korea 15%
Japan 17%
US 19%
China 13%
Other 6%

LTE contributions per region

The vast majority of the contributions made to 3GPP for LTE are common to both modes

Source: Signals Research Group (SRG). report. SRG analyzed and classified nearly 83,000 3GPP contributions made during the LTE standardization process and identified ~43,000 that pertained to the LTE standard. 7% of these applies to the TDD mode only.
Common LTE standard enables common FDD/TDD products

Common Standard

Common LTE Core Network (EPC)

Combined LTE FDD/TDD

LTE FDD

LTE TDD

Common FDD/TDD radio network products

TDD shares most of FDD design and standard

Inherent seamless FDD/TDD interoperability

Even tighter FDD/TDD interworking planned\(^1\)

Common FDD/TDD devices

(with 2G/3G multimode and seamless 2G/3G interoperability)

\(^1\)Such as aggregation of FDD and TDD within the same node and different nodes (multiflow)
Qualcomm® Gobi™ LTE Modems: Four generations of FDD/TDD leadership

**First Generation**
- World's first integrated LTE/3G

**Second Generation**
- World's First Mobile Platform with integrated LTE/3G Multimode

**Third Generation**
- World's First LTE/3G multimode with Cat4 and Carrier Aggregation

**Fourth Generation**
- LTE/3G multimode with Cat6 with 3x Carr. Agg. and 60 MHz support

Common LTE FDD/TDD platform and FDD/TDD interworking
Enabling LTE TDD and FDD in all tiers

Scale across the tiers, scale across the globe!

Snapdragon™
210

Snapdragon
410

Snapdragon
610/615

Snapdragon
808/810

The Snapdragon advantage

• A comprehensive 4G LTE solution across all tiers

• Qualcomm® RF360™ front end solution, CDMA support allow for truly global solution

Qualcomm Snapdragon, Qualcomm Gobi and Qualcomm RF360 are products of Qualcomm Technologies, Inc.

©2013-2014 Qualcomm Technologies, Inc. and/or its affiliated companies. All Rights Reserved.
Inherent tight TDD/FDD interworking and seamless 3G interworking
Seamless 3G interworking is the foundation to successful LTE

- Enables ubiquitous data coverage and user experience
- Enables ubiquitous voice services—even with VoLTE\(^1\)
- Enables global roaming in global FDD bands

**Common TDD/FDD platform**

**LTE** (FDD and/or TDD)

- **LTE/3G/2G Multimode**

**3G** (and 2G)

Enables ubiquitous data coverage, voice services, and global roaming

\(^1\)Fallback to 3G/2G (CSFB) since 2012; VoLTE with SRVCC ensures seamless voice; CSFB still needed for roaming

Qualcomm Gobi is a product of Qualcomm Technologies, Inc.
Multimode LTE devices enable global roaming
Inherent LTE FDD/TDD interworking and seamless voice

**Initial launches**

- **LTE data devices**
  - **LTE for data only**
    - LTE TDD/FDD with 2G/3G multimode launched globally
    - Inherent seamless TDD/FDD interworking for data

**Initial voice solution**

- **LTE data handsets**
  - **LTE for data**
    - 2G/3G for voice
  - Circuit switched fallback (CSFB) to 2G/3G voice launched globally (FDD and TDD)
  - Inherent seamless TDD/FDD interworking

**Long-term voice solution**

- **LTE VoIP handsets**
  - Simultaneous LTE VoIP and rich data services
  - VoLTE with single radio voice call continuity (SRVCC) + CSFB to 2G/3G voice for roaming
  - Inherent seamless TDD/FDD interworking for VoLTE

---

1. Including seamless data LTE and 3G interworking with mobility through redirection, and packet switched handover.
Qualcomm Technologies’ VoLTE technology leadership

Working closely with ecosystem for VoLTE deployments

Global VoLTE Solution

- World’s 1st commercial integrated VoLTE modem and IMS solution with SRVCC
- Chipsets enabled 1st major launches in Korea (Aug. 2012) and US (May 2014)
- Chipsets and IMS solution powered 1st nationwide launch in Japan (June 2014)

Long history of trials and deployments with major operators and infra vendors

Lab trials and inter-operability testing with infra vendors

Demos and field trials on live networks

Launch with service continuity to 2G/3G networks

Enhanced VoLTE based services (video calling, presence etc.)
Even tighter FDD and TDD interworking

Available: Seamless interworking\(^1\)

June 2013: FDD Carrier Aggregation
TDD Carrier Aggregation

Future: Aggregate FDD + TDD, even across nodes (multiflow)\(^2\)

---

1. Data seamless data interworking with mobility. First step in voice interworking is fallback to 2G/3G (CSFB) which is available, then single radio VoLTE with SRVCC for seamless fallback to 2G/3G. 3GPP R12 candidates

©2013-2014 Qualcomm Technologies, Inc. and/or its affiliated companies. All Rights Reserved.
LTE TDD key to access higher spectrum bands on the path to 1000x
Multiple enhancements required to reach 1000x

- Extend LTE to unlicensed spectrum
- Dynamic LTE Broadcast
- Enhanced receiver devices
- Carrier Aggregation (even across FDD/TDD)
- Authorized Shared Access (ASA)
- Hetnets with interference management (FeICIC/IC)
- Enabling hyper-dense networks for 1000x

More Small Cells is Key to 1000x
Many higher spectrum bands suited to LTE TDD and small cells

1. Some parts can be traditionally licensed, some parts need to be ASA licensed, such as ~3.5GHz in the US/EU. 3GPP has already defined 3G/4G bands 42/43 for 3.4 GHz to 3.8 GHz, 3.5GHz in the US defined as 3550–3650 MHz. In addition, Wi-Fi in unlicensed such as 2.4GHz, 5GHz (802.11 ac) and 60GHz (802.11 ad).

Small Cell
TDD
e.g. 3.5GHz

Macro + Small Cell
FDD or TDD
e.g. 700MHz FDD, 2.3GHz TDD

Small cell densification starts in today’s bands

©2013-2014 Qualcomm Technologies, Inc. and/or its affiliated companies. All Rights Reserved.
ASA leverages underutilized spectrum for exclusive use

**Exclusive use**
- At given locations, times ensures predictability for long-term investments

**Both for macro and small cells**
- Small cells can be closer to incumbent than macros without interfering

---

**ASA required when spectrum cannot be cleared within reasonable timeframe, or at all locations**

**Protects incumbents**
- Binary use—either incumbent or rights holder
- Protection zones

---

1. No device impact due to ASA, just a regular 3G/4G device supporting global harmonized bands targeted for ASA. Carrier aggregation would be beneficial to aggregate new ASA spectrum with existing spectrum, but is not required.
ASA – Licensed Harmonized Spectrum
Leveraging global, available 4G technologies to ensure economies of scale

<table>
<thead>
<tr>
<th>ASA CANDIDATE EXAMPLES</th>
<th>2.3 GHz (100 MHz)</th>
<th>2.6 GHz (100+ MHz)</th>
<th>~3.5 GHz (100-200 MHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicable Regions</td>
<td>EUROPE (Traditionally licensed in e.g. India)</td>
<td>MENA (Traditionally licensed in e.g. Europe)</td>
<td>USA, EU, LATAM, SEAP</td>
</tr>
<tr>
<td>Incumbent Users</td>
<td>Telemetry, public safety, cameras</td>
<td>Various</td>
<td>Naval Radar (US) Satellite (EU, LATAM, SEAP)</td>
</tr>
<tr>
<td>Suitable Technology</td>
<td>LTE TDD</td>
<td>LTE FDD/TDD</td>
<td>LTE TDD</td>
</tr>
<tr>
<td>Possible Launch</td>
<td>~2015</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**3.4-3.8 GHz**
Key band for licensed small cells
Traditional licensed in most regions
ASA licensed in US

**2.3-2.4 GHz**
LSA (Licensed Shared Access)
Endorsed by EU 27 member states
Endorsed by CEPT
Standardized by ETSI

1 3GPP has already defined bands 42/43 for 3.4 GHz to 3.8 GHz, 3.5GHz in the US defined as 3550 – 3650 MHz, but up to 200MHz could be targeted for ASA in e.g. SEA/LATAM. Note that ASA targets IMT spectrum bands, but the concept can be applied generally to all spectrum bands and other technologies.
LTE TDD: the global solution for unpaired spectrum

1. LTE is a common global standard for paired and unpaired spectrum

2. Common FDD/TDD technology ecosystem, common products

3. Inherent tight TDD/FDD interworking and seamless 3G interworking

4. Key to access higher spectrum bands on the path to 1000x
Thank you

Follow us on:  

For more information, visit us at:  
www.qualcomm.com & www.qualcomm.com/blog

©2013-2014 Qualcomm Technologies, Inc. and/or its affiliated companies. All Rights Reserved.

Qualcomm, Snapdragon, and Gobi are trademarks of Qualcomm Incorporated, registered in the United States and other countries. All trademarks of Qualcomm Incorporated are used with permission. Other products and brand names may be trademarks or registered trademarks of their respective owners.

References in this presentation to “Qualcomm” may mean Qualcomm Incorporated, Qualcomm Technologies, Inc., and/or other subsidiaries or business units within the Qualcomm corporate structure, as applicable.

Qualcomm Incorporated includes Qualcomm’s licensing business, QTL, and the vast majority of its patent portfolio. Qualcomm Technologies, Inc., a wholly-owned subsidiary of Qualcomm Incorporated, operates, along with its subsidiaries, substantially all of Qualcomm’s engineering, research and development functions, and substantially all of its product and services businesses, including its semiconductor business.
A strong LTE evolution path

<table>
<thead>
<tr>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>2017+</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDD and TDD support</td>
<td>CSFB, VoLTE, LTE Broadcast</td>
<td>Carrier Aggregation, relays, HetNets (eICIC/IC), Adv MIMO</td>
<td>Realizes full benefits of HetNets (FeICIC/IC)</td>
</tr>
</tbody>
</table>

**LTE**
- DL: 73 – 150 Mbps (10 MHz – 20 MHz)
- UL: 50 Mbps (10 MHz)

**LTE Advanced**
- DL: 150 – 450 Mbps (20 – 60 MHz)
- UL: 50 Mbps (Up to 10 MHz)
- DL: 3 Gbps (Up to 100 MHz)
- UL: 1.5 Gbps (Up to 100 MHz)

---

1. Peak rates for 10 MHz or 20 MHz FDD using 2x2 MIMO, standard supports 4x4 MIMO enabling peak rates of 300 Mbps.
2. Peak data rates for 20 – 30 MHz (using CA) FDD and using 2x2 MIMO, standard supports much more higher (see note 3)
3. 3Gbps with 8x8 MIMO and 100MHz of spectrum. Similarly, the uplink can reach 1.5Gbps with 4x4 MIMO. These rates are defined in Rel. 10, not expected to be supported in the initial Rel 10 commercial launches, but later with Rel 11/12 or beyond launches Note: Estimated commercial dates.