Snapdragon 820 - LTE and Connectivity

March 31, 2016
Singapore
Why the modem matters

Top 10 consumer smartphone activities

- Phone calls
- SMS/text
- Browse Web
- Take/share photos
- Check weather
- Connect to Wi-Fi
- Check/write email
- Connect using 3G/4G
- Use location/GPS service
- View social media content

The modem enables the vast majority of apps and use cases

- AP benchmarking tools measure app performance essentially in \textit{airplane mode}
- Modem performance matters in the user experience -- it’s not just the network

Mobile experience cannot be boiled down to a single spec

CPU core analogy: V4 vs. V8 engine

LTE Cat 6

20 MHz | 20 MHz
How many lanes does your LTE have?

LTE Cat 4

20 MHz
How many cores does your CPU have?

V4

V8

SPEED LIMIT 65

SPEED LIMIT 35
What Web browsing benchmarks can’t show you

Web user experience enhanced by Uplink Data Compression

Source: QTI lab testing.
Qualcomm® Snapdragon™ 820 processor with X12 LTE

- Up to 600 Mbps  Cat 12 DL
- Up to 150 Mbps  Cat 13 UL
- Multi-Band Wi-Fi  2.4GHz, 5GHz, 60GHz
- LTE-U and LWA convergence with unlicensed
- Next-gen Calling enhanced mobility + quality

Industry’s 1st 14nm FinFet LTE SoC
Qualcomm® TruSignal™ Technology

Fewer dropped calls, more bars, longer battery life*

Call Reliability & Quality
• Up to 30% reduction in dropped calls*
• Improved voice quality

Faster Data
• Up to 49% improvement* in data speeds in real use scenarios
• Better signal quality* in the presence of signal impediments

Longer Battery Life
• Up to 20% longer* battery life
• Lower power consumption* for the same throughput

* Based on measurements on test versions of commercial smartphone devices in commercial networks, compared to a device configuration that does not have antenna tuning technology, and operating under the same signal conditions.

TruSignal is designed to optimize signal strength at all times no matter how the device is held.
Snapdragon 820 supports superior VoLTE experiences

- Enhanced call reliability
- Superior sound quality
- Higher network capacity

Ultra HD voice with next gen EVS codec

Smart Wi-Fi calling

- Wi-Fi signal quality
- Internet reachability
- End-to-end Wi-Fi throughput
Device-level convergence
On path to deeper hardware-level sharing of components

Power efficient hotspot

- Hotspot functionality with extended AP sleep
- Up to 45% lower power consumption*

LTE - Wi-Fi Antenna sharing

- Enabling attractive form factor with fewer antennas
- Intelligent switching between LTE/Wi-Fi:
  - LTE 4x4 MIMO, Wi-Fi 2x2 MU-MIMO and LTE-U
  - Superior performance

* Based on Qualcomm Technologies Inc. testing, as compared to the previous generation
Multi-band Wi-Fi improves capacity and user experience

11ac MU-MIMO for 2-3x performance

- Up to 3x user throughput & capacity in crowded places*
- Peak rates of 867 Mbps
- Optimized for platform power and performance

802.11ad for multi-gigabit connectivity

- Multi-gigabit islands in homes & businesses
- Up to 4.6 Gbps data rate in 60GHz (3rd Wi-Fi band)
- Low latency media experiences

* Compared to SU-MIMO
Strong MU-MIMO and 11ad ecosystem

MU-MIMO is becoming main-stream

11ad is gaining momentum

World's first devices announced at CES 2016
Snapdragon LTE Modem
A history of setting higher expectations for premium smartphone
Snapdragon Premium Tier Modem Superiority
Competitor A’s 2015 premium LTE modem vs. Snapdragon X10 LTE

Snapdragon Advantage

Throughput
• Up to 31% faster\(^1\)

Power
• Up to 35% lower\(^2\)

Quality
• 0% call drop vs 15%\(^3\)

Source: QTI lab testing. Based on previous generation products. \(^1\)Bi-directional LTE throughput. \(^2\)3G data power. \(^3\)CSFB call failures.
Snapdragon Premium Tier Modem Superiority

Competitor B’s 2015 premium LTE modem vs. Snapdragon X10 LTE

Snapdragon Advantage

**Throughput**
- Up to 31% faster\(^1\)

**Power**
- Up to 24% lower\(^2\)

**Quality**
- 0% call drop vs 13%\(^3\)

Source: QTI lab testing. Based on previous generation products. \(^1\)Cat 6 throughput. \(^2\)3G voice call power. \(^3\)CSFB call failures.
Snapdragon leads LTE voice performance

Comparison with competitors

<table>
<thead>
<tr>
<th>Metric</th>
<th>Snapdragon</th>
<th>Competitors</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSFB (3G) call failures</td>
<td>0%</td>
<td>13 - 20% failures</td>
</tr>
<tr>
<td>Return to LTE after call</td>
<td>best</td>
<td>6 - 10 sec longer</td>
</tr>
<tr>
<td>Packet handover failure</td>
<td>0%</td>
<td>25 - 28% failures</td>
</tr>
<tr>
<td>VoIP over LTE (VoLTE)</td>
<td>best</td>
<td>up to 76% worse</td>
</tr>
<tr>
<td>CSFB (3G) voice power</td>
<td>best</td>
<td>9 - 122% worse</td>
</tr>
</tbody>
</table>

1 3G CSFB call failures per 3GPP standardized testing. 2 Retrun to LTE after completion of 2G/3G CSFB call. Source: Qualcomm Technologies, Inc. labs testing, 2015.
A 14nm FinFET discrete LTE Advanced Pro Modem

Up to 1 Gbps - Cat 16 DL
4x4 MIMO on 2xCA + 2x2 MIMO on 3rd carrier; up to 4x20 MHz CA supported with 2x2 MIMO

Up to 150 Mbps - Cat 13 UL
via 2x20MHz CA and 64-QAM

LTE-U and LAA - Convergence with unlicensed
Globalizing access to LTE in unlicensed spectrum

3.5 GHz band support - New 3GPP bands
Additional licensed LTE spectrum access

Sampling now
Commercial devices expected in 2H 2016
The Snapdragon X16 LTE modem represents several firsts*
Continuing the tradition of technology leadership by Qualcomm Technologies

1st announced Cat 16 Gigabit Class LTE modem
1st LTE Advanced Pro (3GPP Rel. 13) modem
1st LTE modem to support Licensed Assisted Access (LAA)
1st discrete LTE modem built on 14nm FinFET process

*Firsts with respect to public announcement of a commercial LTE modem chipset.
A significant milestone for the entire mobile industry
And the first real glimpse of our 5G future

Peak Download Speed Supported in Modem (Mbps)

<table>
<thead>
<tr>
<th>Year</th>
<th>Snapdragon X16 LTE Modem</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>1.8 Mbps</td>
</tr>
<tr>
<td>2006</td>
<td>7.2 Mbps</td>
</tr>
<tr>
<td>2007</td>
<td>7.2 Mbps</td>
</tr>
<tr>
<td>2008</td>
<td>10.2 Mbps</td>
</tr>
<tr>
<td>2009</td>
<td>21.1 Mbps</td>
</tr>
<tr>
<td>2010</td>
<td>100 Mbps</td>
</tr>
<tr>
<td>2011</td>
<td>100 Mbps</td>
</tr>
<tr>
<td>2012</td>
<td>150 Mbps</td>
</tr>
<tr>
<td>2013</td>
<td>300 Mbps</td>
</tr>
<tr>
<td>2014</td>
<td>450 Mbps</td>
</tr>
<tr>
<td>2015</td>
<td>600 Mbps</td>
</tr>
<tr>
<td>2016</td>
<td>1 Gbps</td>
</tr>
</tbody>
</table>

Subject to network availability.
Premium-tier features cascade quickly to mid and low tiers

<table>
<thead>
<tr>
<th>Tier</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premium/800</td>
<td>Cat 4 LTE</td>
<td>10+10 CA</td>
<td>20+20 CA</td>
<td>20+20+20 CA</td>
</tr>
<tr>
<td></td>
<td>VoLTE</td>
<td>7-Mode</td>
<td>Wi-Fi Calling</td>
<td>Uplink CA</td>
</tr>
<tr>
<td></td>
<td>802.11ac*</td>
<td>LTE-B</td>
<td>11ac MU-MIMO</td>
<td>FDD/TDD CA</td>
</tr>
<tr>
<td>600</td>
<td>Cat 4 LTE</td>
<td>10+10 CA</td>
<td>20+20 CA</td>
<td>Uplink CA</td>
</tr>
<tr>
<td></td>
<td>VoLTE</td>
<td>7-Mode</td>
<td>Wi-Fi Calling</td>
<td>FDD/TDD CA</td>
</tr>
<tr>
<td></td>
<td>802.11ac</td>
<td>LTE-B</td>
<td>11ac MU-MIMO</td>
<td>BT 4.2</td>
</tr>
<tr>
<td>400</td>
<td>Cat 4 LTE</td>
<td>10+10 CA</td>
<td>Wi-Fi Calling</td>
<td>20+20 CA</td>
</tr>
<tr>
<td></td>
<td>VoLTE</td>
<td>7-Mode</td>
<td>802.11ac</td>
<td>FDD/TDD CA</td>
</tr>
<tr>
<td></td>
<td>LTE-B</td>
<td>11ac MU-MIMO</td>
<td>BT 4.2</td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>Cat 4 LTE</td>
<td>10+10 CA</td>
<td>Wi-Fi Calling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>VoLTE</td>
<td>7-Mode</td>
<td>LTE-B</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*802.11ac was supported since 2012
Superior modem features in mid- and low-tier

Snapdragon advantage vs. competitor C

<table>
<thead>
<tr>
<th>Features</th>
<th>Snapdragon</th>
<th>Competitor C</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTE Cat 6/7 &amp; above</td>
<td>✓</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>Interference cancellation</td>
<td>✓</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>TD-SCDMA</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>TD-SCDMA RxD</td>
<td>✓</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>HS Cell FACH</td>
<td>✓</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>LTE to 2G/3G/4G IRAT</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>VAMOS</td>
<td>✓</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>CnE (LTE, Wi-Fi smart selection)</td>
<td>✓</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>NSRM (Gating signaling traffic)</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fast return to LTE</td>
<td>✓</td>
<td></td>
<td>Only in TDD</td>
</tr>
</tbody>
</table>

Advanced Features

<table>
<thead>
<tr>
<th>Features</th>
<th>Snapdragon</th>
<th>Competitor C</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>eMBMS (LTE Broadcast)</td>
<td>✓</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>eMBMS+G DSDS</td>
<td>✓</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>Mature, global VoLTE</td>
<td>✓</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>Smart Wi-Fi calling</td>
<td>✓</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>VoLTE+ G DSDS</td>
<td>✓</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>Global SKU</td>
<td>✓</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>hVoLTE/1xSRLTE</td>
<td>✓</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>Data Retry</td>
<td>✓</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>MASC/Smart pipe</td>
<td>✓</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>DAC/UDC (UL compression)</td>
<td>✓</td>
<td>×</td>
<td></td>
</tr>
</tbody>
</table>

Carrier/OEM Features
Superior throughput in mid- and low-tier

Snapdragon advantage vs. competitor C

<table>
<thead>
<tr>
<th>Use case</th>
<th>Peak traffic (high interference)</th>
<th>Off-peak traffic (low interference)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian</td>
<td>+ 40%</td>
<td>+ 10%</td>
</tr>
<tr>
<td>Vehicular</td>
<td>+ 18%</td>
<td>+ 19%</td>
</tr>
</tbody>
</table>

- Good coverage
  - Pedestrian: + 40%
  - Vehicular: + 18%

Cell edge
- Snapdragon 210/425/430; LTE FDD; Competitor C - Commercial low-tier smartphone
Superior LTE multi-mode experiences in mid- and low-tier
Snapdragon advantage vs. competitor C

<table>
<thead>
<tr>
<th></th>
<th>LTE ↔ GSM</th>
<th>LTE ↔ 3G (UMTS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paging Failure Rate (CSFB)</td>
<td>0% vs. 12%</td>
<td></td>
</tr>
<tr>
<td>LTE → GSM/3G Reselection Failure Rate</td>
<td>0% vs. 10%</td>
<td>0% vs. 4%</td>
</tr>
<tr>
<td>GSM/3G → LTE Reselection Failure Rate</td>
<td>0% vs. 10%</td>
<td>0% vs. 16%</td>
</tr>
<tr>
<td>LTE → GSM/3G Reselection Delay</td>
<td>49%</td>
<td>38%</td>
</tr>
<tr>
<td>GSM/3G → LTE Reselection Delay</td>
<td>50%</td>
<td>36%</td>
</tr>
<tr>
<td>LTE → GSM/3G CSFB delay</td>
<td>19%</td>
<td>0%</td>
</tr>
<tr>
<td>GSM → LTE Return time</td>
<td>173%</td>
<td></td>
</tr>
<tr>
<td>LTE → 3G CSFB Page Failure Rate</td>
<td></td>
<td>0% vs. 22%</td>
</tr>
<tr>
<td>LTE → 3G CSFB PS Handover Failure Rate</td>
<td></td>
<td>0% vs. 5.5%</td>
</tr>
<tr>
<td>LTE → 3G CSFB PS Handover Delay time</td>
<td></td>
<td>13.4%</td>
</tr>
</tbody>
</table>

Higher reliability and more seamless experience
Fewer missed and dropped calls and data interruptions
Camping on the optimal technology/network
Superior power efficiency in mid- and low-tier Snapdragon advantage vs. competitor C

Note: QTI: 8916; Competition - Commercial low-tier smartphone
Snapdragon All Modem and LTE carrier aggregation (4G+)

Supports all major connectivity features deployed worldwide\(^1\)

- **All Mode**
  - Carrier channel
  - Open channel

120+ Designs launched and in pipeline\(^2\)

- All 14 cellular and Wi-Fi modes
- All 50+ mobile radio bands\(^1\)
- All 98 4G+ networks\(^3\)
- All 20 voice modes
- All 16 Dual SIM modes

---

\(^1\)Includes 3GPP and Wi-Fi and other connectivity bands. Source: 3GPP, Qualcomm Technologies, Inc.

\(^2\)China OEM designs; source: Qualcomm Technologies, Inc.

\(^3\)GSA, January 2016 and Qualcomm Technologies Inc.
RF complexity driving platform integration

Band proliferation increasing front-end BOM

*High-end smartphone example. Source: Linley Group, June 2015. Other data: Qualcomm Technologies, Inc.

- More LTE bands
- Carrier Aggregation
- Global smartphones
- MIMO

Typical high-end smartphone

2015
- ~50 filters
- 15 bands
- 73% Modules (% of total)

2020
- ~100 filters
- 30-40 bands
- 80%

Early 4G multimode
Global All Mode
Global 4G+

~200 CA combinations

16 bands
49 bands
~200 CA combinations
TDK’s/QCT’s technologies will provide comprehensive solution

Extending the Qualcomm® RF360™ front end solution

"From digital to the antenna"

Connectivity technology leadership now requires end-to-end system design
OEM profitability with single SKU

Supported by Snapdragon All Mode and Qualcomm® RF360™ solution

Top Line
- Expand addressable customer base
- Faster time to global launch

Total Cost
- Efficiencies through SKU consolidation

SKU
- A unique design variant that can be tracked in inventory

SKU Consolidation
- Reducing the number of variants needed for world bands/modes

Single-SKU
- One consolidated SKU to support global and regional bands/modes
Single-SKU OEM Economics

Improved OEM profitability from Snapdragon All Mode and RF360 solution

- Fewer SKUs
- Lower total costs
  - R&D and Engineering
  - Mfg Overhead
  - Inventory Management
- Time to global launch
- De-risk EOL inventory
- Higher return on R&D
Defining next-gen connectivity experiences

Ubiquitous and seamless
Connectivity everywhere, roaming across networks with full service continuity

Contextual connectivity
Dynamically selects best link based on application, spectrum, and context

Immersive user experiences
Connectivity that delivers stunning and unfettered video, multimedia, and gaming experiences