Hup-2-3-4... Do we stop at Four?
A perspective on the wireless industry
Agenda

1. The technology today
2. The challenges
3. Some new Technology Directions
Smartphone: our most personal device

~106
Avg. number of daily app launches by US Android users

~64%
In Brazil used them to watch video in a web browser

~80%
Chinese users sleep with them at arm’s reach

~78%
On global basis use them to play games

~80B
DOWNLOADED APPS in 2013

Percentages of smartphone users / owners.
Sources: comScore custom research avg. over Q3’13, GroupM, Jul. ’13, Nielsen, Feb. ’13, Strategy Analytics, Q2 ’12
Mobile is redefining computing

PC Era
CPU-centric (Gigahertz race)

Mobile Era
User experience oriented (System level innovation)

Always on
Always connected
Always with you

~7 BILLION
Cumulative smartphone unit sales forecast between 2013–2017
Comprehensive platforms at the heart of mobile computing
Integration of multiple specialized cores on a single-die SoC

- **Qualcomm® Gobi™ Modem**
  - 3G/4G Baseband
  - LTE FDD/TDD
  - Multi-SIM
  - Broadcast/Multicast Carrier aggregation

- **Krait™ CPU**
  - Up to 2.5GHz/core

- **Qualcomm® Adreno™ GPU**
  - OpenGL ES 2.0/3.0
  - OpenCL
  - RenderScript

- **Bluetooth (BT)**
  - 4.1

- **USB**
  - 3.0, 5Gbps

- **Display Processing**
  - 4K (external), 1080p, Miracast, picture enhancement

- **Location**
  - GPS, GLONASS, Beidou Satellites

- **Image Signal Processing**
  - Camera
  - Dual ISP

- **Multimedia Processing**
  - Audio
  - Adv. Voice Clarity
  - Voice Activation
  - Gestures
  - Studio Access Security

- **Sensor processing**

- **Memory**
  - 2MB L2 Cache
  - LPDDR2/3

- **Hexagon™ DSP**
  - Ultra Low Pwr

- **Wi-Fi**
  - 802.11ac
Mobile devices getting more powerful
Faster processing, better graphics, longer battery life enabling breakthrough experiences

Qualcomm Technologies Flagship Processors Over Time

Qualcomm Technologies Flagship GPUs Over Time

Scorpion: First 1GHz processor in the market
Evolution of integrated sensors
Technologies enabling the “Digital 6th Sense”

Environment
- Temperature
- Ambient Light

Navigation
- Touch
- Proximity
- RF Enhancement

Context
- Microphone
- Gyroscope
- Accelerometer

Health and fitness
- Temperature
- Humidity
- Pressure

Sensor assisted location
Industry preparing for 1000x

**Richer content**
- more video

Bestseller example:
- **5.93 GB**
  - Movie (High Definition)
- **2.49 GB**
  - Movie (Standard Definition)
- **0.0014 GB**
  - Homepage
- **1.8 GB**
  - Game for Android
- **0.34 GB**
  - Soundtrack
- **0.00091 GB**
  - Book

**More devices**
- everything connected

- **~25 Billion**
  - Interconnected device forecast in 2020
- **~7 Billion**
  - Cumulative smartphone forecast between 2013-2017

*1000x would be e.g. reached if mobile data traffic doubled ten times, but Qualcomm does not make predictions when 1000x will happen. Qualcomm and its subsidiaries work on the solutions to enable 1000x*
Traffic growth outpacing operator revenue

Example of ARPU and traffic for a major Asian operator

Sources: GSMA Intelligence, Feb. '14
HEVC (H.265) Performance

- HEVC gains over H.264 are on average higher for higher resolutions and for low delay configuration.

<table>
<thead>
<tr>
<th>Content</th>
<th>HEVC vs. H.264 - Rate Savings for Equal PSNR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Random Access</td>
</tr>
<tr>
<td>4k x 2k @ 30 fps</td>
<td>-43%</td>
</tr>
<tr>
<td>1080p @ 24 fps</td>
<td>-44%</td>
</tr>
<tr>
<td>WVGA @ 30 &amp; 60 fps</td>
<td>-34%</td>
</tr>
<tr>
<td>WQVGA @ 30 &amp; 60 fps</td>
<td>-31%</td>
</tr>
<tr>
<td>720p @ 60 fps (Video Telephony)</td>
<td>-38%</td>
</tr>
<tr>
<td>Average</td>
<td>-38%</td>
</tr>
</tbody>
</table>

- Subjective gains (measured by MOS score) higher than objectives gains measured traditionally by PSNR, average reduction over 50% over H.264.
Rising to meet the 1000x mobile data challenge

Higher efficiency

Evolve 3G/4G/Wi-Fi
HetNets Interference Mgmt/SON
Intelligently Access 3G/4G/Wi-Fi

More spectrum
In low and higher bands

More small cells
Everywhere!

More unplanned small cells
And inside-out deployment
Technologies for small cells everywhere
All venues; residential, enterprise, metro, indoor, outdoor and multiple deployment models

Highly compact, low-cost Small Cells
To enable densification & ease of deployment

Self-organizing networks (UltraSON)
To enable low cost hyper-dense deployments

Interference Management
So that capacity scales with small cells added

Backhaul Solutions
Fixed, wireless, relays
User provided

UltraSON is Qualcomm’s suite of Self Organizing features for small cells.
We need to make best use of all spectrum types for 1000x

**Licensed Spectrum**
Auctions of cleared spectrum for 3G/4G

**Shared Licensed Spectrum**
Complementary licensing for 3G/4G: Authorized/Licensed Shared Access (ASA/LSA)

**Unlicensed Spectrum**
Multiple technologies (Wi-Fi, LTE in unlicensed, BT & others)

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**Exclusive use**
Industry’s top priority, ensures quality of service (QoS), mobility and control

**Shared exclusive use**
ASA/LSA required when government spectrum cannot be cleared within a reasonable timeframe, or at all locations

**Shared use**
Unpredictable QoS, ideal for local area access, and opportunistic use for mobile broadband
Towards WRC-15

- WRC-15 – November 2015
- JTG 4-5-6-7
  - Goal is to complete the CPM-15 report by June 2014
  - Agenda item 1.1: considering additional spectrum in support of IMT and other mobile broadband services
  - Agenda item 1.2: usage of the 694-790 MHz band in Region 1 for IMT
- Bands in Discussion for Agenda Item 1.1
  - 470-806 MHz – currently broadcast (some has been assigned for mobile)
  - L-band 1300-1400/1427-1530 MHz – currently earth exploration satellite, aeronautical mobile telemetry (AMT), digital sound broadcasting, and fixed services
  - 2025-2110 MHz and 2200-2290 MHz – currently co-primary basis to space services
  - 2.7-2.9 GHz - currently used by aeronautical radio navigation, maritime navigation and radiodetermination services
  - 3.4-4.2 GHz – currently satellite C-band
  - 5 GHz RLAN bands - 5350-5460 MHz and 5460-5470 MHz – currently satellite, space and radio navigation
We need to make best use of all spectrum types for 1000x

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Near-Term Solutions to Wi-Fi Network Issues

Getting to Carrier Grade WiFi

• Some of the field-issues in current Wi-Fi networks currently could addressed in the WFA
  – Using selected features from existing IEEE addendums
    – 11ai (Faster connection and handoff signaling, reduction in probe storms)
    – 11k (Efficient measurement & management of radio resources)
    – 11v (Improved network management)
  – Agreeing on best practices and testing to prevent poorly behaving devices
    – More airtime for user traffic by reducing Probe request/response traffic
    – More consistent AP return codes and resulting STA behaviour to prevent “association storms”
    – Efficient use of airtime by managing low data rate users.
Extending LTE to Unlicensed Spectrums Helps Mobile Operators

- High penetration in smartphones
- Good opportunistic offload tool used by many wireless operators
- Evolving towards 802.11ax (HEW) for higher efficiency

LTE in Unlicensed (LTE-U)
- Optimized offload performance with tighter integration with LTE network
- Provides greater range and capacity compared to 802.11n/ac
- Builds on LTE scale and ecosystem which addresses entire system
- LTE carrier transmitted according to unlicensed spectrum regulations
LTE-U* Carrier Aggregation Modes

- **Anchor carrier is on licensed spectrum**
  - Acquisition, access, registration, paging and mobility performed on anchor
  - Control plane signaling, control channels (grants, acknowledgments) and QoS sensitive data sent on anchor

- **Secondary carrier uses unlicensed spectrum**
  - Opportunistic data offload.

*3GPP is currently using LAA (License Assisted Access)*

3GPP has a workshop in June, expect Study Items and then Work Items for Release 13
### 802.11ah Value Proposition – 3rd Band Wi-Fi

**Internet of Things & Extended Range Applications**

<table>
<thead>
<tr>
<th>802.11g</th>
<th>802.11n</th>
<th>802.11ac</th>
<th>802.11ah</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4 GHz</td>
<td>2.4 &amp; 5 GHz</td>
<td>5 GHz</td>
<td>(sub 1 GHz)</td>
</tr>
</tbody>
</table>

#### Rich Data Rates
- 150Kbit/s ~ 78 Mbits/s per spatial stream (sensor, audio, security camera, internet)
- 1,2,4,8,16 MHz bandwidths

#### Improved Range
- 10 dB link budget advantage over 2.4 GHz technologies, 1 MHz & 2 MHz mandatory modes

#### Low Power
- Whole home sensor coverage without power amplifier

#### Scalable
- Support thousands of nodes

#### IP connectivity
- Same as Wi-Fi

#### Outdoor Coverage
- Support for larger delay and doppler spreads, support for relays

#### Wi-Fi ecosystem
- WFA certified interoperability and Wi-Fi user experience
## Tentative Spectrum Availability in Key Geographies

<table>
<thead>
<tr>
<th>Region</th>
<th>Tx power regulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>US</td>
<td>Max e.r.p. ≤ 1 W</td>
</tr>
<tr>
<td>EU</td>
<td>max e.r.p. ≤ 14 dBm</td>
</tr>
<tr>
<td></td>
<td>PSD ≤ -4.5 dBm/100KHz (863–868.6MHz)</td>
</tr>
<tr>
<td></td>
<td>PSD ≤ 6.2 dBm/100KHz (865–868MHz)</td>
</tr>
<tr>
<td>Korea</td>
<td>3 mW or 10 mW (920.6–923.5MHz and six 200 KHz channels below 920.6 MHz)</td>
</tr>
<tr>
<td>China</td>
<td>Max e.r.p. ≤ 5 mW (755 – 779 MHz)</td>
</tr>
<tr>
<td></td>
<td>Max e.r.p. ≤ 10 mW (779 – 787 MHz)</td>
</tr>
<tr>
<td>Japan</td>
<td>1 mW, 20 mW or 250 mW (915.9–929.7MHz)</td>
</tr>
<tr>
<td></td>
<td>Max BW = 1 MHz</td>
</tr>
</tbody>
</table>
802.11ax High Efficiency WLAN (HEW)

- Next major IEEE 802.11 standard with a goal of improving Wi-Fi network throughputs in 2.4/5 GHz bands (.11 -> .11b -> .11a/g -> .11n -> .11ac -> .11ax)
  - Study group completed work in March
  - 802.11ax task group expected to begin in May

- Targets and scope
  - PAR: Four times improvement in the average throughput per station in a dense deployment scenario
    - Throughput is measured at the MAC data service access point
    - “Expected to provide improvements of 5 – 10x”
  - Maintaining or improving the power efficiency per station
  - Enabling backward compatibility and coexistence with legacy IEEE 802.11 devices operating in the same band
5G is about enabling **new services and devices**, connecting **new industries**, and empowering **new user experiences**

Qualcomm aims to be a leading force in bringing 5G to life
Broader dimensions of improvements will drive new 5G services

- **Capacity**
  - Fiber-like user experiences
  - Support large number and wide range of connected devices/things/wearables
  - Scale up to high performance or down to low complexity
  - Lower power and longer battery life
  - Improve cost efficiency through network architecture evolution

- **Data rate**
  - Low latency for real-time cloud services and control
  - Improved data and device security
  - Proximal and contextual awareness across network
  - Reliability for mission critical applications, deep coverage
  - And more…

- **Scalability**
  - Proximal and contextual awareness across network
  - Reliability for mission critical applications, deep coverage
  - And more…

- **Power**
  - Proximal and contextual awareness across network
  - Reliability for mission critical applications, deep coverage
  - And more…

- **Cost**
  - Proximal and contextual awareness across network
  - Reliability for mission critical applications, deep coverage
  - And more…

A unified 5G design that is scalable and adaptable across extreme variation of use cases
Hup-2-3-4... Do we stop at Four?

NO!
Thank you

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