5G: New Adjacent and Vertical Markets

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Outline

• 5G Vision
• Spectrum
• Some emerging markets
A new kind of network to drive innovation and growth

- Significant connectivity upgrade
- Smartphone tech is extending into many industries
- Consumers want 5G smartphones
More autonomous manufacturing
Safer, more autonomous transportation
Reliable access to remote healthcare
Smarter agriculture

More efficient use of energy and utilities
Improved public safety and security
Sustainable cities and infrastructure
Digitized logistics and retail

5G will expand the mobile ecosystem to new industries

Powering the digital economy

*The 5G Economy, an independent study from IHS Markit, Penn Schoen Berland and Berkeley Research Group, commissioned by Qualcomm

>$12 Trillion
In goods and services by 2035*
5G is foundational to what’s next
And we’re the foundation of 5G

Enhanced mobile broadband
Mission-critical services
Massive Internet of Things
### Global snapshot of 5G spectrum

Around the world, these bands have been allocated or targeted.
Realizing the mmWave opportunity for mobile broadband

**Extreme bandwidth opportunity**
- Extreme bandwidths capable of Multi-Gbps data rates
- Flexible deployments (integrated access/backhaul)
- High capacity with dense spatial reuse

**Mobilizing mmWave challenge**
- Robustness due to high path loss and susceptibility to blockage
- Device cost/power and RF challenges at mmWave frequencies

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Smart beamforming and beam tracking
Increase coverage and minimize interference

Tight interworking with sub 6 GHz
Increase robustness, faster system acquisition

Optimized mmWave design for mobile
To meet cost, power and thermal constraints

Learn more at: [www.qualcomm.com/documents/promise-5g-mmwave-how-do-we-make-it-mobile](www.qualcomm.com/documents/promise-5g-mmwave-how-do-we-make-it-mobile)
Making 5G NR a commercial reality in 2019

18 Operators | 20 OEMs

Qualcomm Snapdragon is a product of Qualcomm Technologies, Inc. and/or its subsidiaries.
Using all available spectrum types and spectrum bands

**Licensed spectrum**
- Exclusive use
- Over 40 bands globally for LTE, remains the industry's top priority

**Shared spectrum**
- New shared spectrum paradigms
- Example: 2.3 GHz Europe / 3.5 GHz USA

**Unlicensed spectrum**
- Shared use
- Example: 2.4 GHz / 5-7 GHz / 57-71 GHz global
3GPP study on 5G NR operation in unlicensed spectrum

First time 3GPP studies cellular technology operating stand-alone in unlicensed spectrum.

NR-based LAA
NR in unlicensed aggregated with LTE (dual-connectivity) or NR (carrier-aggregation) in licensed spectrum

Stand-alone unlicensed
NR operating standalone in unlicensed spectrum. This will become the MulteFire™ evolution path to 5G

Across spectrum bands
Both below and above 6 GHz, e.g., 5GHz, 37GHz, 60GHz* (*assuming no change to waveform)

Fair co-existence in any unlicensed spectrum: NR/NR, NR/LTE, NR/Wi-Fi

1. Study item in Rel.15 (RP-170828), which could be followed by a work item that is completed in Rel. 16.
Expanding uses of 3GPP technology

Mission-critical services
- Drone
- Industrial automation

Digital TV broadcasting
- eMBMS
- enTV

Public safety
- D2D
- MCPTT

New spectrum types
- LSA
- LTE-U/LAA
- LWA
- CBRS
- MulteFire

Auto Services
- Telematics
- V2X
- Connected infotainment

M2M/IoT services
- MTC
- NB-IOT
- eMTC

Data services
- SMS
- MMS
- Email
- Web
- Multimedia
- Apps
- Immersive experiences

Voice services
- Analog
- VoIP
- Digital
- Telepresence
Transforming the in-car experience

Personalizing mobility
Enhanced range and reliability for direct communication without network assistance

**C-V2X**

Establishes the foundation for safety use cases and a continued 5G NR C-V2X evolution for future autonomous vehicles

- **V2V**
  - Vehicle-to-vehicle
  - e.g., collision avoidance safety systems

- **V2I**
  - Vehicle-to-infrastructure
  - e.g., traffic signal timing/priority

- **V2P**
  - Vehicle-to-pedestrian
  - e.g., safety alerts to pedestrians, bicyclists

- **V2N**
  - Vehicle-to-network
  - e.g., real-time traffic/routing, cloud services

- **Release 14 C-V2X** completed in 2017
- **5G** Broad industry support – 5GAA
- **Global trials started in 2017**
- **Our 1st announced C-V2X product in September, 2017**
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Technologies in IoT Stack

- **Applications**
  - Service Layer aka Service Platform Middleware Enablement Platform
  - Protocols
  - Access

- **Custom IoT Applications**
  - CoAP
  - RTPS
  - MQTT
  - HTTP
  - WebSocket
  - DTLS / UDP
  - TLS / TCP
  - IP
  - Protocol Industrial Non-IP: PROFIBUS, EtherCAT
  - Wired: IEEE 802.15.4, LoRa
  - Wireless: IEEE 802.11, Wi-Fi
  - IEEE 802.3

- **OSI equivalent**
  - Application
  - Presentation
  - Session
  - Transport
  - Network
  - Link
  - Physical
World’s first tri-mode Wi-Fi / Bluetooth 5 / 15.4 SoC for the IoT

To help address IoT fragmentation and software interoperability challenges

**Tri-mode with advanced smart co-existence**
2.4 GHz / 5 GHz Wi-Fi
802.15.4 ZigBee 3.0 and OpenThread Bluetooth 5

**Dual-core processing**
ARM® Cortex-M4 for apps
ARM Cortex-M0 for connectivity

**Advanced HW-based security features**
Secure boot
Trusted execution environment
Encrypted storage
Key provisioning

**Hostless Architecture**
- 300+ KB Internal RAM
- ARM Cortex-M4 up to 128 MHz

**Comprehensive set of peripherals**
- SPI, GPIOs, I2C, I2S, UART, PWM
- 8-channel ADC

**Multiple ecosystems with pre-integration support for cloud services**
- Homekit
- Open Connectivity Foundation
- AWS IoT SDK
- Microsoft Azure IoT SDK

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