Qualcomm’s 5G Vision
Mobile is the largest technology platform in history

- ~7.5 billion connections, almost as many as people on earth
- Evolving into Internet of Everything: cars, meters, sensors, health devices, etc.
- More prevalent than electricity or running water in some regions
- At the center of breakthrough experiences like 4K UHD video

1 ~7.5B connections (~3.7B subs) — GSMA Intelligence, May '15.
Mobile has made a leap every ~10 years

1G
Analog voice
AMPS, NMT, TACS

1980s

2G
Digital voice
D-AMPS, GSM, IS-95 (CDMA)

1990s

3G
Mobile broadband
WCDMA/HSPA+, CDMA2000/EV-DO

2000s

4G
Faster and better MBB
LTE, LTE Advanced

2010s
The evolution and impact of mobile networks

2002
Mobile surpassed fixed voice

Redefined telephony
by mobilizing communications

2010
Mobile surpassed fixed BB

Redefined computing
by mobilizing the Internet

Today
Redefining everything
by creating the connectivity fabric for everything and bringing new levels of on-device intelligence

Fixed connections per ITU, mobile per GSMA, MBB per GSMA, Jul. '14; Fixed connections: BB per WBIS, Oct. '14
Creating the connectivity fabric for everything
Rising up to meet significantly expanded connectivity needs

Requires a new connectivity paradigm

- Human communication: Scaling to connect virtually anything, anywhere
- Devices as end-points: New and intelligent ways to connect & interact
- Best effort data services: Also, new kinds of control & discovery services
- Disparate networks: Convergence of access, spectrum types, services
Requires new levels of on-device intelligence

Bringing cognitive technologies to life

Machine learning

Intuitive security

Computer vision

Intelligent connectivity

Always-on sensing

Immersive multimedia

For more information:
www.qualcomm.com/cognitive
5G to meet significantly expanding connectivity needs

Building on the transformation started in 4G LTE

Connecting
new industries and devices

Enabling
new services

Empowering
new user experiences

Scalable
To an extreme variation of requirements

Edgeless
For uniform experiences with new ways of connecting

Unified
Across all spectrum types/bands, services and deployments
Proposed 5G standardization for 2020 launch

4G evolution—LTE will evolve in parallel with 5G

First 5G launch¹

R16 5G work items

R17+ 5G evolution

R15 5G work items

Note: Estimated commercial dates.¹ Forward compatibility with R16 and beyond
In parallel: driving 4G and 5G to their fullest potential

Expanding and evolving LTE Advanced – setting the path to 5G

- Fully leverage 4G investments
- Improve cost and energy efficiency
- Enable a wide range of new services
- A unified, much more capable platform

LTE
- CoMP
- Flat architecture
- TDD/FDD

LTE Advanced
- Carrier aggregation
- Unlicensed spectrum
- Dual connectivity
- 256QAM

LTE Advanced Pro
- IoT
- Massive/3D MIMO
- V2X
- Enhanced CA
- Lower latency

Further backwards-compatible 4G enhancements

Timeline:
- 4G (2010)
- LTE Advanced (~2020)
- LTE Advanced Pro
Scalable across an extreme variation
Scalable across an extreme variation of requirements

- **Ultra-low energy**: 10+ years of battery life
- **Ultra-low complexity**: 10s of bits per second
- **Ultra-high density**: 1 million nodes per Km²
- **Extreme capacity**: 10 Tbps per Km²
- **Extreme data rates**: Multi-Gigabits per second
- **Deep coverage**: To reach challenging locations
- **Strong security**: e.g. Health / government / financial trusted
- **Ultra-high reliability**: <1 out of 100 million packets lost
- **Ultra-low latency**: As low as 1 millisecond
- **Extreme user mobility**: Or no mobility at all
- **Deep awareness**: Discovery and optimization

Based on target requirements for the envisioned 5G use cases.
Enhanced mobile broadband

Ushering in the next era of immersive experiences and hyper-connectivity

3D/UHD video telepresence

Tactile Internet

UHD video streaming

Demanding conditions, e.g. venues

Broadband ‘fiber’ to the home

Virtual reality

Extreme throughput
multi-gigabits per second

Ultra-low latency
down to 1ms e2e latency

Uniform experience
with much more capacity
Massive Internet of Things

Optimizing to connect anything, anywhere with efficient, low cost communications

Power efficient
Multi-year battery life

Low complexity
Low device and network cost

Long range
Deep coverage

Smart cities
Smart homes
Utility metering
Wearables / Fitness
Remote sensors / Actuators
Object tracking
Mission-critical control
Enabling new services with ultra-reliable, ultra-low latency communication links

- Autonomous vehicles
- Robotics
- Energy / Smart grid
- Industrial automation
- Aviation
- Medical

**High reliability**
Extremely low loss rate

**Ultra-low latency**
Down to 1ms e2e latency

**High availability**
Multiple links for failure tolerance and mobility
Natively incorporate advanced wireless technologies

Many technology enablers to meet 5G requirements and services

- Full Self-Configuration
- Hyper dense deployments
- Integrated access and backhaul
- mmWave
- Coordinated Spatial Techniques
- Best use of all spectrum types
- Advanced Receivers
- Massive MIMO
- Beam forming
- Low latency & ultra-reliable communication
- Multicast
- Energy efficient, low cost IoT communications
- V2X
- Multi-hop & D2D communications
- Best use of all spectrum types
Edgeless connectivity
Bringing new ways to connect and interact

Devices much more than end-points—integral parts of network

- Multi-hop to extend coverage
- Vehicle-to-vehicle/infrastructure communications
- Integrated access and backhaul, relays
- Device-to-device discovery and communications

Utilizing and expanding upon today’s technologies, e.g. LTE Direct, LTE Relays
And multiple enablers for uniform user experiences and more capacity

Context and service awareness | Full Self-Configuration | Truly unplanned deployments | Hyper dense deployments

Coordinated Spatial Techniques | Backhaul | Advanced Receivers | Beam forming

Massive Spatial Processing
Leverage computing, content all the way to the device

Edge computing
- Dynamic user and control planes
- Agile edge security

Edge content
- Caching content at edge node
- Caching content on device

Edgeless Connectivity
- Device no longer just an end-point
A **unified** platform
Unified 5G design across diverse requirements
Building on the OFDM foundation adapted to new extremes

Diverse spectrum
- Licensed, shared licensed, and unlicensed spectrum
- Spectrum bands below 1 GHz, 1 GHz to 6 GHz, & above 6 GHz (incl. mmWave)
- FDD, TDD, half duplex

Diverse services and devices
- From wideband multi-Gbps to narrowband 10s of bits per second
- Efficient multiplexing of mission-critical and nominal traffic
- From high user mobility to no mobility at all
- From wide area macro to indoor / outdoor hotspots

Diverse deployments
- Device-to-device, mesh, relay network topologies
Designing the 5G Unified Air Interface
A new PHY & MAC design that is scalable to an extreme variation of requirements

- Optimized OFDM-based waveforms
  With scalable numerology and TTI, plus optimized multiple access for different use cases

- A common, flexible framework
  To efficiently multiplex services and features—designed for forward compatibility

- Advanced wireless technologies
  Such as massive MIMO, robust mmWave and a flexible self-contained TDD design
Simplifying 5G deployments with multi-connectivity

A phased 5G introduction that fully leverages 4G LTE and Wi-Fi investments

Today: 4G LTE below 6 GHz with Dual Connectivity and LTE-Wi-Fi Link Aggregation

Phase 1 (R15): New 5G radio access below 6 GHz using LTE anchor for mobility management

Phase 2 (R16+): New multi-access 5G core network, new 5G radio access above 6 GHz
Also requires a flexible end-to-end network architecture

- Multi-access core network
  - Continue to evolve 4G LTE and Wi-Fi access

- Flexible subscription models
  - Such as one subscription for multiple devices

- Dynamic creation of services
  - Such as dynamic MVNO or tailored verticals

- Dynamic control and user planes
  - Such as mobility on demand and functions at edge

- Modular, specialized functions
  - Not to burden other network services

- Configurable end-to-end connectivity
  - With network and service slicing\(^1\)

\(^1\) Leveraging Network Function Virtualization (NFV) and Software Defined Networking (SDN)
5G networks will be scalable to diverse deployments

From wide area to indoor / outdoor hotspots

Wide area network
Enterprise / Venue
Hotspot / Residential

Support different spectrum types individually or aggregate:
Licensed spectrum | Shared spectrum | Unlicensed spectrum
5G networks will be deployed by a variety of entities
With assets like physical location, fixed broadband and customer relationships

Mobile Operator 5G networks provide ubiquitous coverage—the backbone of 5G
A unified platform for expanded connectivity needs

Unified air interface
Optimized OFDM-based waveforms under a flexible framework that can scale to support an extreme variation of requirements

Multi-connectivity Framework
Simultaneous connectivity and aggregation across access technologies & nodes to deliver enhanced, uniform experiences

Flexible Network Architecture
Configurable end-to-end connectivity with distributed, specialized network functionality to dynamically create tailored services

For more detailed information on the unified 5G platform: www.qualcomm.com/invention/technologies/5g/platform
Leading the path to 5G
Qualcomm Research’s technical leadership role in 5G

Already working on 5G technologies for many years; focus area of research for future

Designing 5G system to meet new requirements
Driving standardization of 5G in 3GPP
Participating in impactful 5G demos, trials, …
Qualcomm LTE Advanced / LTE Advanced Pro leadership

Setting the path to 5G

Standards Leadership
- Main contributor to key LTE Advanced and LTE Advanced Pro features
- Pioneering work on LTE Direct, LTE Broadcast and LTE in unlicensed spectrum
- Harmonizing the industry on a narrowband IoT (NB-IoT) specification

Industry-first Demos
- MWC 2014: Enhanced HetNets with data-channel interference cancellation
- MWC 2015: First LAA demo, LTE Direct ecosystem demos

Industry-first Chipsets from QTI
- 1st LTE Advanced solution (Jun ‘13)
- 1st with LTE Broadcast (Jan ‘14)
- 1st modem to support LTE Unlicensed (Feb’15)
Solving the 1000x data challenge
Innovative small cells and spectrum solutions

Creating the connectivity fabric for everything
Intelligently connect everything/everyone, empower new services, drive convergence

Bringing cognitive technologies to life
Devices and things that perceive, reason, and act intuitively

An essential innovator and accelerator of mobile and beyond

Small cells and self organizing technology
LTE in unlicensed spectrum, MuLTEfire™
LTE Advanced carrier aggregation, dual connectivity
Advanced receivers and interference management
Spectrum innovations like LSA
Wi-Fi – 11ac, 11ad, MU-MIMO, OCE, 11ax
3G

More capacity

LTE-M (Machine-Type Communications), NB-IOT
LTE Direct device-to-device
LTE Broadcast
LTE – Wi-Fi Convergence
Wi-Fi – 11ah, 11ad, Wi-Fi Aware, Wi-Fi Direct, DSRC
Bluetooth Smart
OneWeb
5G

Next level of intelligence

Machine learning
Computer vision
Always-on sensing
Immersive multimedia
Cognitive connectivity
Intuitive security
Heterogeneous computing
Meeting expanded connectivity needs for next decade

- Uniform fiber-like mobile broadband with deep awareness
- New services like ultra-reliable mission critical control
- Connecting everything from simple sensors to complex robots
5G: not just a new generation, but a new kind of network

Connecting new industries and devices
Enabling new services
Empowering new user experiences

For more information: www.qualcomm.com/5G
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