



Economic & Business Impact of 5G Networks

(with a focus on automotive and healthcare)

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The Mobile Industry

- The mobile industry is now the world's largest innovation engine
- 5 billion people are mobile subscribers (~2/3 of world population)
- In many places, mobile is the leading means of internet access
- The future is not about connectivity – it's about opportunities *enabled by* connectivity

The Beginnings of Mobile

Mobile 1G established the foundation of mobile

1

Licensed Spectrum

Cleared spectrum for exclusive use by mobile technologies



Operator-deployed **base stations** provide access for subscribers

2

Frequency Reuse

Reusing frequencies without interference through geographical separation

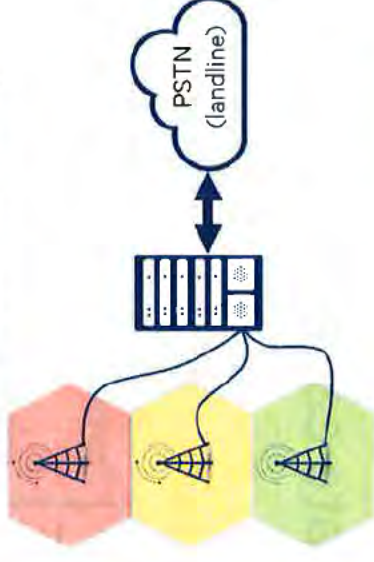


Neighboring **cells** operate on different frequencies to avoid interference

3

Mobile Network

Coordinated network for seamless access and seamless mobility



Integrated, transparent **backhaul network** provides seamless access

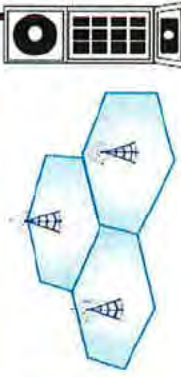
Mobile Technology's Evolution

Mobile 4G LTE is evolving to provide more data capacity
Delivering faster and better mobile broadband experiences

Mobile 1G

AMPS, NMT, TACS

Foundation of Mobile
Seamless Mobility



Mobile 2G

D-AMPS, GSM/GPRS,
cdmaOne

Mobile for the Masses
More Voice Capacity



Mobile 3G

CDMA2000/EV-DO,
WCDMA/HSPA+, TD-SCDMA

Mobile Broadband
Data Optimized



Mobile 4G LTE

LTE, LTE Advanced

Faster and Better Mobile Broadband
More Data Capacity



1980s

1990s

2000s

2010s

The 5G Revolution



New Capabilities and FLEXIBILITY

⇒ 5G is a Revolution vs. Evolution

- **New Capabilities:** LOW LATENCY, higher speeds, and improved spectral efficiency...
combines several technologies (MIMO, QAM, beamforming, full duplex, etc.)



➤ **Flexibility:**

- **Multiple Architectures:** Fixed (ala microwave), Mobile (ala 3G/4G), LP-WAN (ala LoRa), Meshed Networks (ala Zigbee/802.11ax).
- **Enables WIDE range of applications:** fixed line replacement, mobile, LAN, M2M, IoT, autonomous vehicles, sensor networks, etc.
- **Unified Radio Interface** (5G NR) across networks, products, devices, and applications (plus legacy support for some prior RF links).

- **Challenges:** much smaller cells (large infrastructure costs), very poor in-building coverage (obstacle/line-of-sight limits), lack of available spectrum, power consumption for mobile.

5G Performance Headlines

- At least 10x faster than 4G (makes current broadband speeds look sluggish)

<u>Network Type</u>	<u>Max Data Speeds</u>
3G	384 kbps
4G	100 Mbps
5G	1-10 Gbps

- Upload speeds also much faster (roughly half of simultaneous download speed)
- Verizon trials show 30-50x 4G/LTE speeds
- A high definition movie could be transmitted in a few seconds!

Technology-Driven Aspects of Mobile 5G



Millimeter Waves

- Uses a new swath of spectrum on higher frequency never before been used for mobile services
- Previously used wavelengths for mobile were centimeter-length
- While millimeter waves have been used before (fixed) base stations, using millimeter waves for mobile is revolutionary

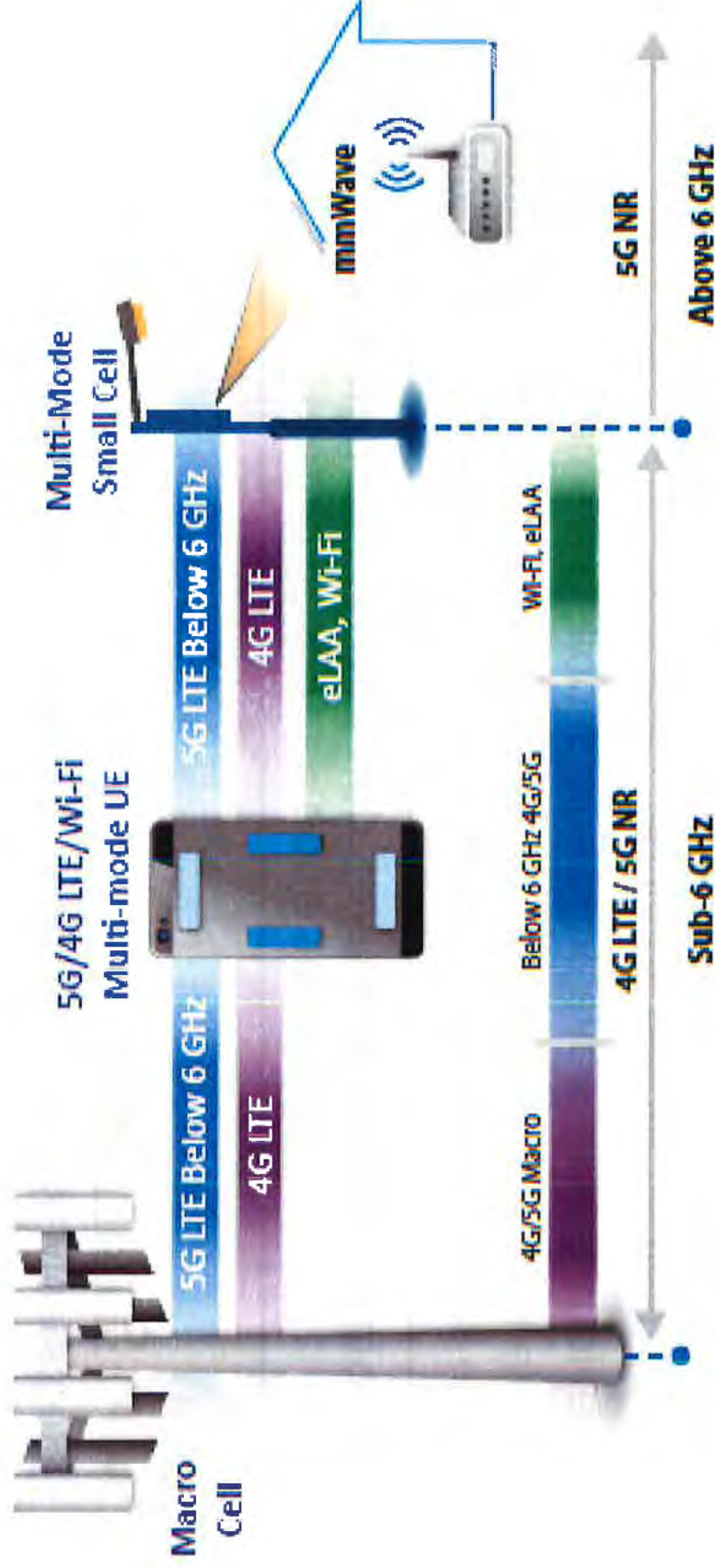
Problem: Millimeter waves don't travel through buildings or obstacles such as foliage or rain



Small Cells

- Helps solve the penetration problems associated with millimeter waves
- **Need to be placed every 250 meters or so**
- **Will lead to small cell proliferation**

Mobile 5G Overview



5G will (eventually) bring very high capacity/speed & ultra low latency (enabling “real-time” comm/control)

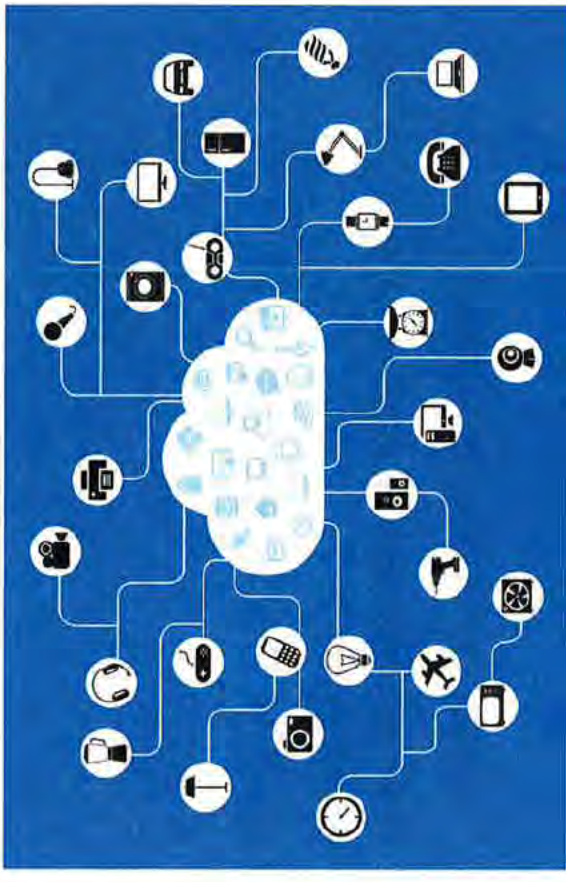
General Economic Impact of 5G

- Mobile technology will be the backbone of the “internet of things” (IoT); meets GPT (General Purpose Technology) criteria:
 - Economy-wide use
 - Drives complementary innovation in other sectors
 - Drives economy-wide innovation and productivity
- 5G will make mobile technology the key medium through which:
 - Devices are connected
 - Information is transmitted
 - Transactions are facilitated
 - How connected activities are enabled
- 5G will also help support mobility as a system (MaaS) business models

IoT Enablement

➤ 5G = essential enabling technology for IoT-related applications:

- LP-WAN: enables very low power devices to remain connected to the WAN
- Mesh networking: enables lower bandwidth communication between devices, sensors, and even mobile devices (e.g., vehicles)
- Low latency: enables control of critical, real-time systems
- High capacity/bandwidth: enables massive networks (very high device densities), e.g., sensors
- Unified Radio + heterogeneous RF support: enables a universal interface for “all” devices.



Economy wide Benefits



A tremendous economic surplus will be generated. IHS market simulation model: 5G will create incremental global output of \$3.5 trillion, equivalent to adding an economy the size of India to today's global resources.

Automotive

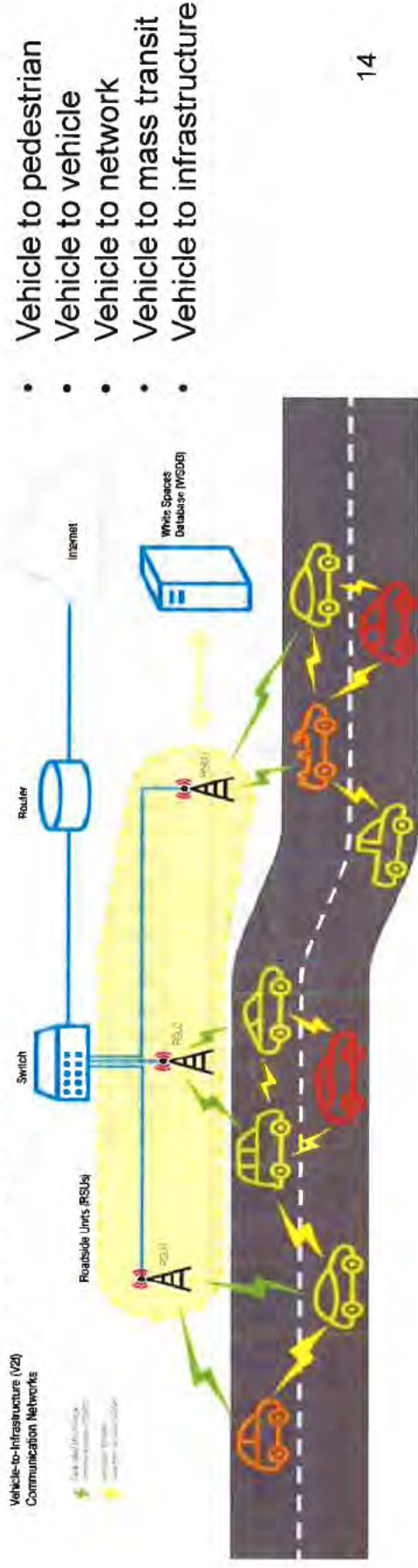


5G will help disrupt and improve the automotive sector

- 5G will help in the reengineering of the transportation sector
- Cars will become connected computers on wheels
- IHS automotive sector: includes sales enablement in transportation and logistics (taxis, trucking, etc.)
- Benefits from 5G also include better use of infrastructure and savings of time from improvement in traffic flow, reduced emissions, reduced collision and fatalities, and better use of car occupants (especially drivers' time)

Vehicle to Infrastructure Networks

- 5G standard is being developed with ultra-reliable and low latency communications (URLLC) in mind
- Existing 3G and 4G standards were developed with human voice and data in mind (vs. M2M for 5G)
- DSRC (Dedicated Short-Range Communications) is the proposed standard for intelligent transportation systems
- 5G is tuned to low latency and high bit-rate communications—to facilitate all kinds of V2X communications



Scale and Scope in Technology Development



- 5G has momentum to become dominant in part because it offers economies of scale and scope
- 5G is likely to underpin V2X as it can support:
 - a. High density platooning... closely spaced multiple vehicle chains on highways
 - b. Coordinated lane changes and intersection navigation
 - c. Automatic parking
 - d. Reduction in insurance premiums
 - e. Acceleration of mobility as a system (MaaS)

Mobility As A System (MaaS)

- Trials in Helsinki offer travelers the chance to specify their travel needs and integrate across platforms to achieve lowest cost, highest convenience travel route.
- MaaS success likely to impact to reduce car ownership not just in cities but also in suburbs.
- 5G will advance “the sharing economy” and allow better utilization of existing capital stock... a big savings for society.



Healthcare



5G & Healthcare: Medical Use Case

Individual has a stroke at home:

- Patient monitoring device sends a distress signal to an ambulance
- Ambulance picks up patient, and streams ultra reliable high resolution images and data on vital signs to the hospital
- Doctors spring into planned action immediately upon ambulance's arrival

Point of Care will be wherever you are

- Tremendous cost savings while improving quality of life
- Shifting the focus of care from hospitals to homes will save billions and improve quality of life (e.g., diabetics connected to sensors will receive real-time personalized feedback on courses of action)
- Outcome-based business models will be able to displace inefficient and ineffective volume-based models

**Connected health creates
self-management opportunity.**

The “Internet of Medical Things” (IoMT) Will Be Enabled by 5G

- Medical devices
- Wearables
- Remote sensors
- Enhanced broadband data rates
- Enhanced security (e.g., biometric identification)
- Reduced risk of breach of HIPAA rules



Current cost-containment infrastructure is often based around micromanaging doctors; future cost containment can be focused on outcome-based healthcare.

How does 5G wireless Innovation get supported?



5G as a Standards-Driven Technology



- Much of 5G-related technology will be embedded in standards
- Standards allow:
 - development of platforms
 - implementers to invest with confidence that products will be compatible
- Standards enable innovations in other application areas to be transferred over to the medical device sector

Phased Roll Out



- Licensing = primary business model by which developers of 5G technology are rewarded
- There is an onus to ensure that FRAND is indeed “fair,” not de minimus... otherwise innovation will stall, and later phases may fail to materialize.
- Now discrimination issues will arise: similarly situated licensees should receive similar terms.

Important Findings by the US Treasury **(re: Broadcom/Qualcomm Acquisition)**

Qualcomm's investment and history has positioned it as the "current leading company in 5G technology development and standard setting."

CFIUS, March 2018

The risk of a diminished Qualcomm capabilities "would significantly impact our national security."

A diminished Qualcomm capabilities would likewise produce a reduced economic benefit for the economy and society.

If excessive debt would stall innovation (CFIUS concerns), then low royalties would do the same.

Generic Value Capture Problem

- Standard technologies need to be licensed
- FRAND regimes: FR means fair, not free nor de minimis
 - Holdup theories are too often used by implementers to deny upstream inventors their just desserts
 - ‘Political’ issues; few portfolio inventors; cacophony of implementers
 - Antitrust agencies and courts concerned about holdup but often blind to hold out? (ie infringement)
 - Antitrust agencies and courts without global understanding and vision will impair technological development and reduce commercial opportunities and hence also consumer welfare

Makan Delrahim and the DOJ's pivot towards Schumpeter*?

“This exciting new environment means that now, more than ever, the promotion and protection of patent rights is critical.”

Beijing Speech,
Feb 1, 2018



“Unfortunately, in recent years, competition policy has focused too heavily on the so-called unilateral hold up problem...every incremental shift in bargaining leverage toward implementers...can undermine incentives to innovate.”

USC Speech
Nov 10, 2017

* “Pivoting Towards Schumpeter, Makan Delrahim & the Recasting of US Antitrust Towards Innovation, Competitiveness, & Growth”
March 30 2018 DJ Teece working paper, UC Berkeley