

# Welcome to IEEE 5G World Forum

*Sanjay Jha, Santa Clara, July 9th*

# 3 Pillars of 5G

## EXTREME DATA



10+ Gbps peak data rate  
100+ Mbps on demand

## MISSION CRITICAL



<1 ms radio latency  
Zero mobility interruption

## DEVICE DENSITY



1,000,000 devices per km<sup>2</sup>  
10-yr battery life

Coverage & Capacity in sub-6GHz;  
Ultra-high capacity in mmWave

2022 for Machine Comms

# Advancing 4G to 5G

5G



Multiple Simultaneous connections



Network selection by service type



Complete Network in the Cloud

4G

One Radio Connection at a time

Common Network for broadband & machine type communications

First set of cloud services ushered in by 4G

**5G is the most dramatic advance in wireless technology since data**

# 5G Spectrum Allocation

## US

verizon✓



28GHz  
39GHz

2.5GHz  
600MHz  
3.5GHz

## Europe



Telefonica

3.5GHz  
26GHz  
700MHz

## China



中国移动通信  
CHINA MOBILE



3.5GHz

## Japan & Korea



3.5GHz  
4.5GHz  
28GHz  
39GHz

Harmonization across Europe, China and Korea to deploy 5G in 3.5GHz

# What applications will drive 5G deployment?

- Explosion of cameras and real-time understanding of image
  - Image becomes data: it can be analysed and understood
  - Autonomous vehicles, retail, healthcare, security...
- Explosion in Mobile display resolution
  - AR, VR, mixed-reality
- Explosion in real-time AI applications on the edge
- IOT
- Tactile Internet

**Lets not wait for the “killer app”**

**5G**

**will impact every industry**



**...and spark the innovation of unforeseen industries for decades to come**

# 5G Challenges: Devices

RF design:

- multiple carrier aggregation between 4G & 5G

- mmWave antenna arrays increasing cost, size & power consumption

- Selection diversity

Beam-forming & beam-tracking techniques to mitigate LOS issues in mmWave

New Radio (NR) waveform

# 5G Challenges: Network & Deployment

Capex for mmWave network buildout

Spectrum sharing (CBRS Alliance)

Balancing downlink with uplink

Phased rollout: NSA (LTE-assisted) followed by Standalone Mode (NR)

Prototyping, testing, global interoperability, network & services rollout



# IEEE Future Directions Initiatives



## SMART MATERIALS

Symbiotic Autonomous  
Systems



Maturity Level

Incubation

[ieee.org/futuredirections](http://ieee.org/futuredirections)

Phase 3

# In Conclusion...

- Spectrum allocations, RFP and RFQ process have already begun in the US
- US is leading in mmWave deployment
- 5G will enable a huge innovation in wireless application
- No need to wait for the killer app: the business case is here already!
- Some fundamental problems to be solved. Those who do will win big
- Lets get this done!