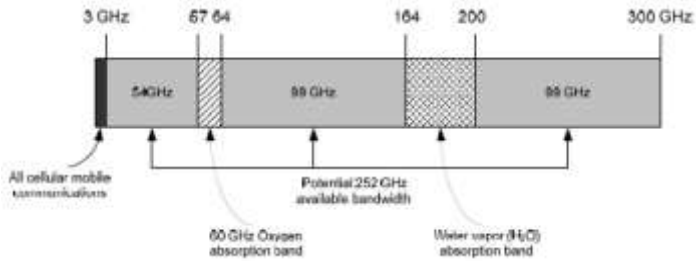


COSMOS Millimeter Wave

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Millimeter Wave Communications



From Khan, Pi "Millimeter Wave Mobile Broadband: Unleashing 3-300 GHz spectrum," 2011

- Vast untapped spectrum above 6 GHz
 - Up to 100x more bandwidth
 - High-dim antenna arrays
- But, many challenges for mobile cellular
 - Path loss, blocking, ...



Initial NYU MmWave Measurements



- Millimeter wave: It can work!
 - First measurements in urban canyon environment
 - Distances up to 200m
 - Propagation via reflections
- Proved feasibility of cellular systems
 - Measurements made urban macro-cell type deployment
 - Rooftops 2-5 stories to street-level

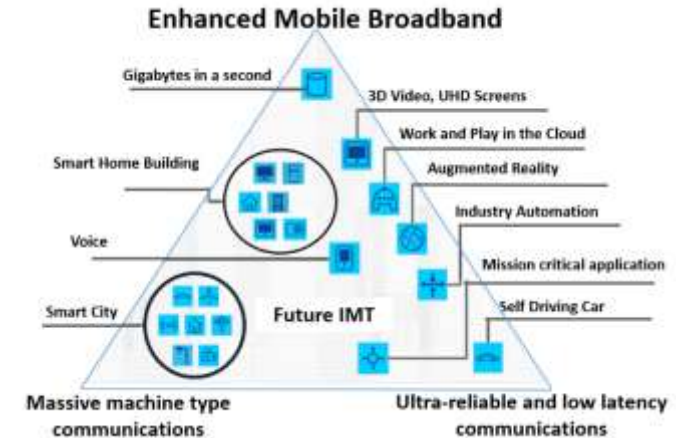
Rappaport, Theodore S., et al. "Millimeter wave mobile communications for 5G cellular: It will work!." *IEEE access* 1 (2013): 335-349.

Significant Gains Over LTE

| System antenna | Duplex BW | fc (GHz) | Antenna | Cell throughput (Mbps/cell) | | Cell edge rate (Mbps/user, 5%) | |
|----------------|---------------|----------|---------------------|-----------------------------|------|--------------------------------|------|
| | | | | DL | UL | DL | UL |
| mmW | 1 GHz TDD | 28 | 4x4 UE 8x8 eNB | 1514 | 1468 | 28.5 | 19.9 |
| | | 73 | 8x8 UE 8x8 eNB | 1435 | 1465 | 24.8 | 19.8 |
| Current LTE | 20+20 MHz FDD | 2.5 | (2x2 DL, 2x4 UL) | 53.8 | 47.2 | 1.80 | 1.94 |

~ 25x gain
~ 10x gain

- mmWave delivers IMT Vision

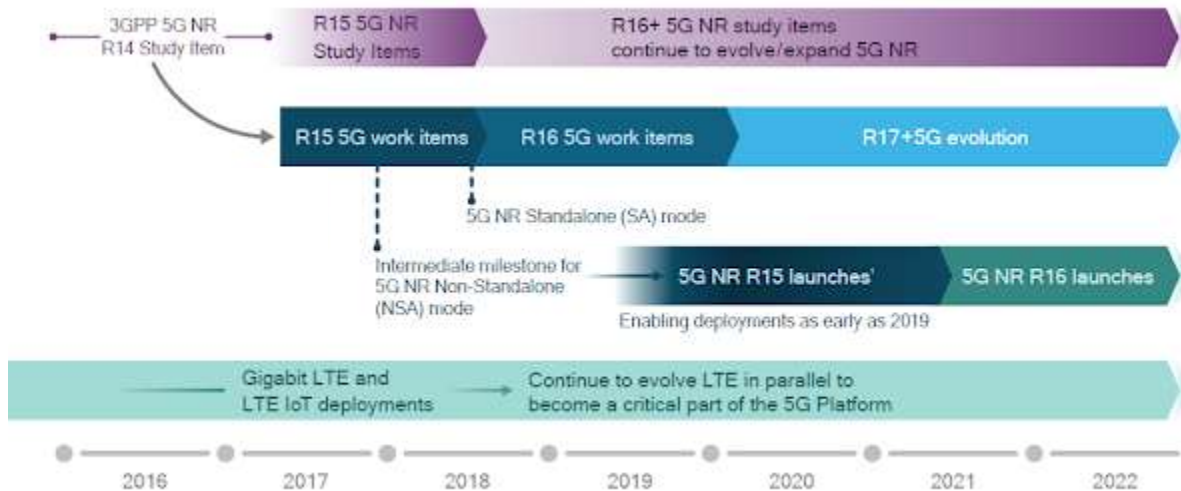


Akdeniz, Mustafa Riza, et al. "Millimeter wave channel modeling and cellular capacity evaluation", 2014

-- 10 UEs / cell; 100 m ISD

Source: ITU-R IMT-2020 Vision

Rapid Progress in 3GPP



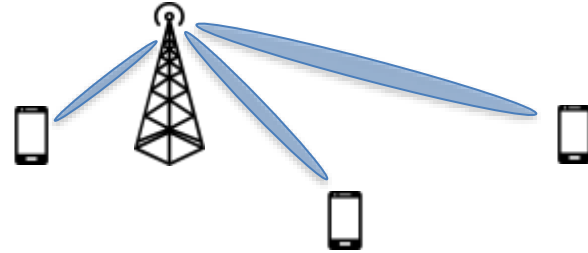
- Advanced demos
- Several trials underway
 - VZ, Sprint, AT&T
- FCC allocation of 28 and 37 GHz bands
- Commercial chip sets

Qualcomm, “Making 5G NR a Reality”

Key Challenges for mmWave

- **Directionality**

- High isotropic path loss
- Compensated by directional beams
- Impacts all aspects of cellular design



- **Blockage**

- mmWave signals blocked by many common materials
- Brick > 80 dB, human body > 25 dB
- Leads to highly intermittent channels

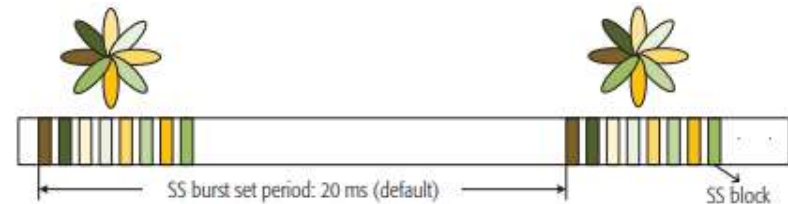
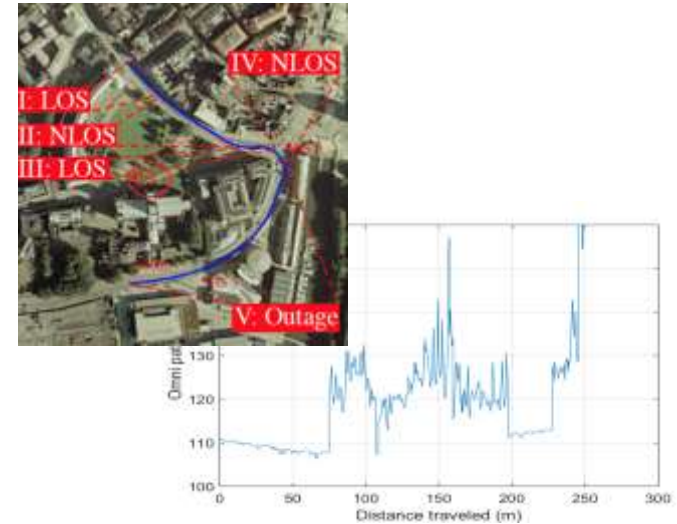
- **What COSMOS can answer:**

- Can mmWave work on a large scale?
- How?

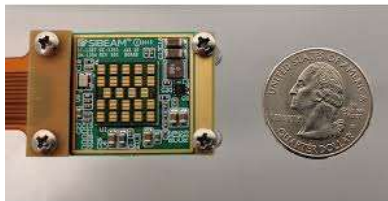


COSMOS mmWave Research

- Wide Area Channel Measurements
 - Multi-sites, macro-diversity, blocking, dynamics
- Beam forming, adaptive arrays
- Beam search, initial access
- Scheduling, MAC, idle mode
- Networking
 - Congestion control, multi-path routing, edge networking
- Integrated Access / Backhaul
- Low latency, high-throughput applications
 - VR/AR, connected car



COSMOS mmWave Nodes



SiBeam 60 GHz
phased array

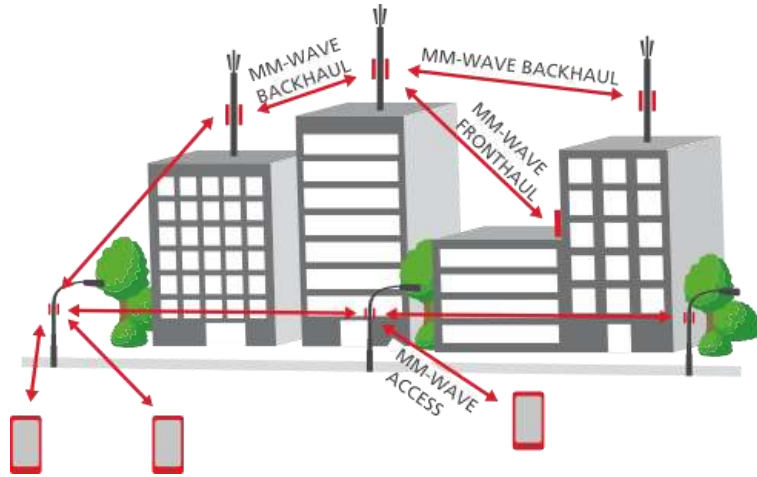
- 12 steerable elements
- 23 dBi gain



NI 5G SDR based on PixE platform

- Build powerful SDR platform
 - Massive baseband processing
 - Multi-Gbps throughput (large nodes)
- 28 GHz phased arrays
 - Vendor to be decided
- Programmable, open interface
 - Experimentation for beamforming, directional MAC layer, ...
- Built on 5G OFDM New Radio
 - Can connect to 5G devices when available

COSMOS mmWave Backhaul



MiWebra, "MmWave Evolution for backhaul and access"

- Cellular backhaul for small cells
 - Currently extremely costly (up to 50% OPEX)
 - Bottleneck for deployments
- mmWave provides low-cost alternative
 - Potential use in same frequency as access
- COSMOS could integrate mmWave backhaul nodes

Interdigital 60 GHz
EdgeLink antenna

- 38 dBi gain
- 802.11ad based

