Microsoft

Millimeter Wave Wireless Networks: Potentials and Challenges

Sundeep Rangan

Microsoft Research
Faculty Summit
2015

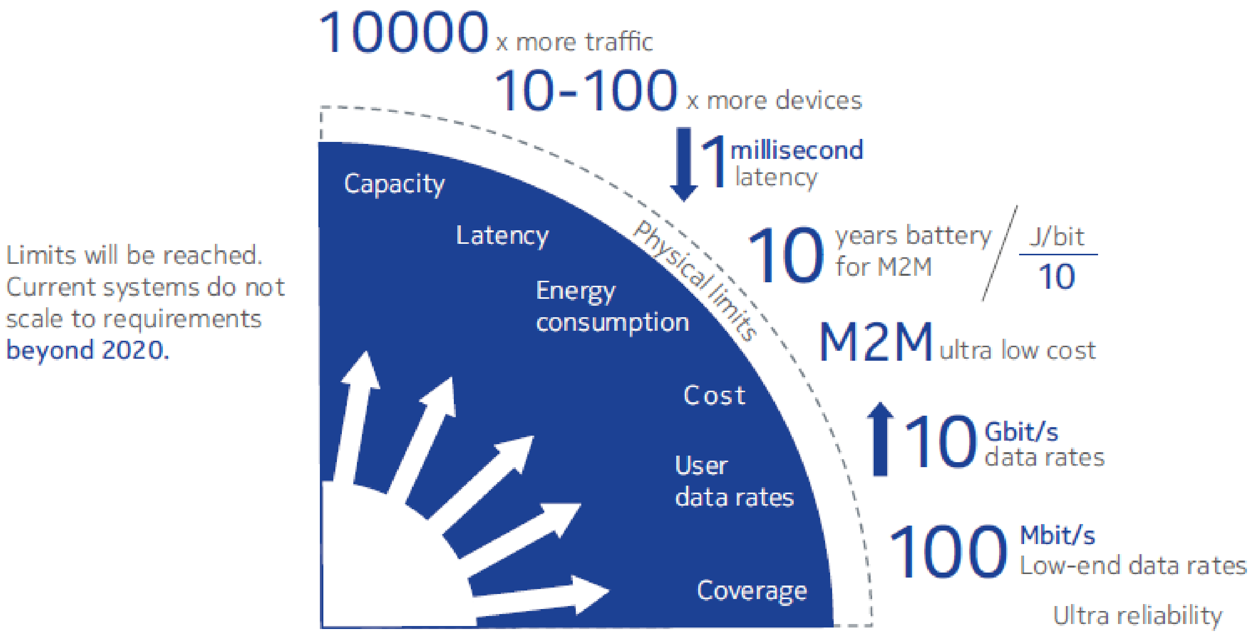
Millimeter Wave Wireless Networks: Potentials and Challenges

Sundeep Rangan, NYU-Poly
Joint work with Ted Rappaport, Elza Erkip

July 8, 2015

Microsoft Faculty Summit

5G Requirements

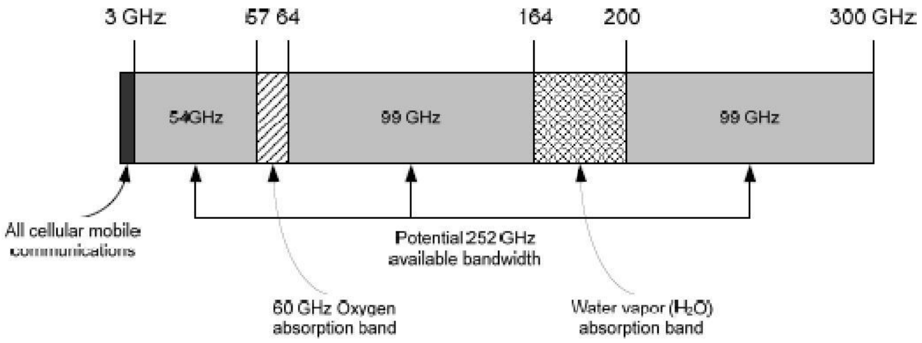


- From Nokia whitepaper, "Looking ahead to 5G. Building a virtual zero latency gigabit experience"

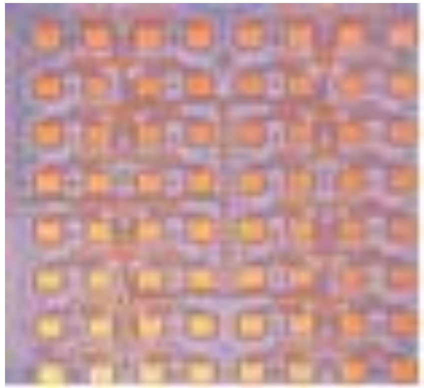
NYU WIRELESS

MmWave: The New Frontier for Cellular

- Massive increase in bandwidth
  - Up to 200x total over long-time
- Spatial degrees of freedom from large antenna arrays



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



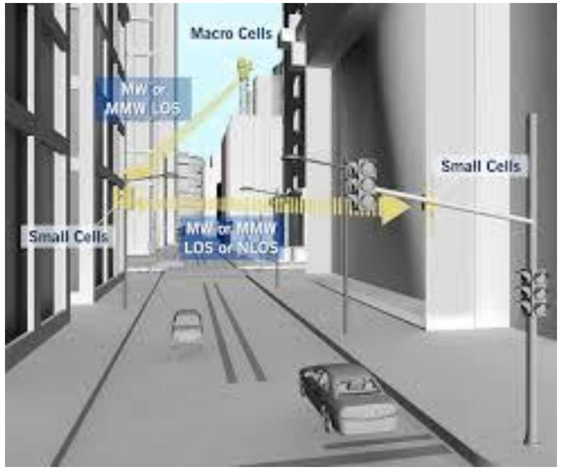
Commercial 64 antenna element array

Key Challenges for Mobile Cellular

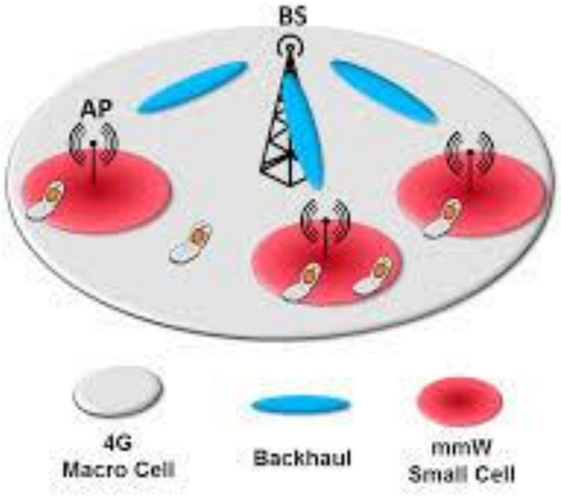
- All transmissions are directional:
  - Friis' Law: $\frac{P_r}{P_t} = G_t G_r \left(\frac{\lambda}{4\pi r}\right)^2 \Rightarrow$ Path loss $\propto \lambda^{-2}$
  - Can be overcome with beamforming: $G_t, G_r \propto \lambda^{-2}$
  - But requires directional search, tracking to support mobility

- Shadowing
  - Mortar, brick, concrete > 150 dB
  - Human body: Up to 35 dB
  - NLOS propagation relies on reflections and scattering

Millimeter Wave Cellular Vision



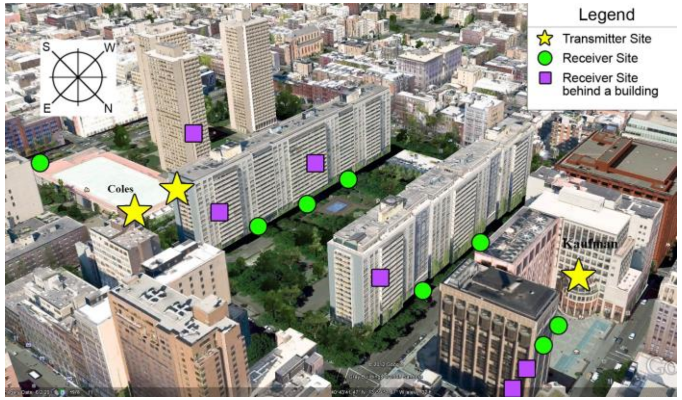
Uday Mudoi, Electronic Design, 2012

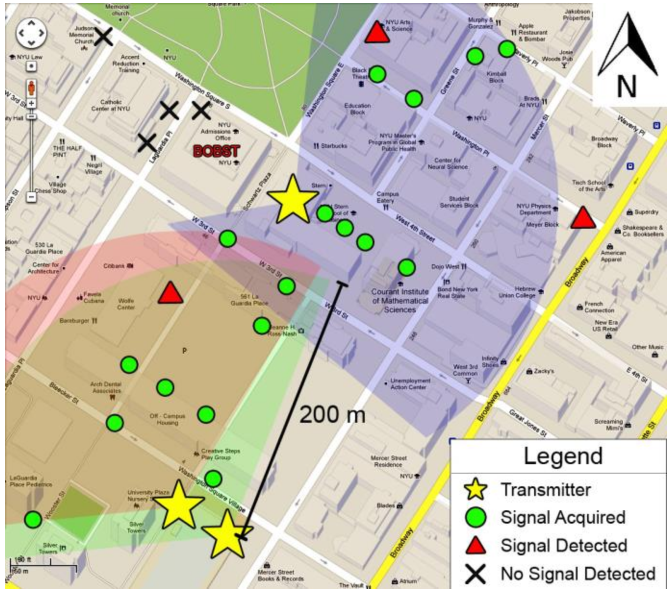


http://www.miwaves.eu/

- Small cells
- Directional transmissions
- Relaying / mesh topology

NYC 28 and 73 GHz Measurements



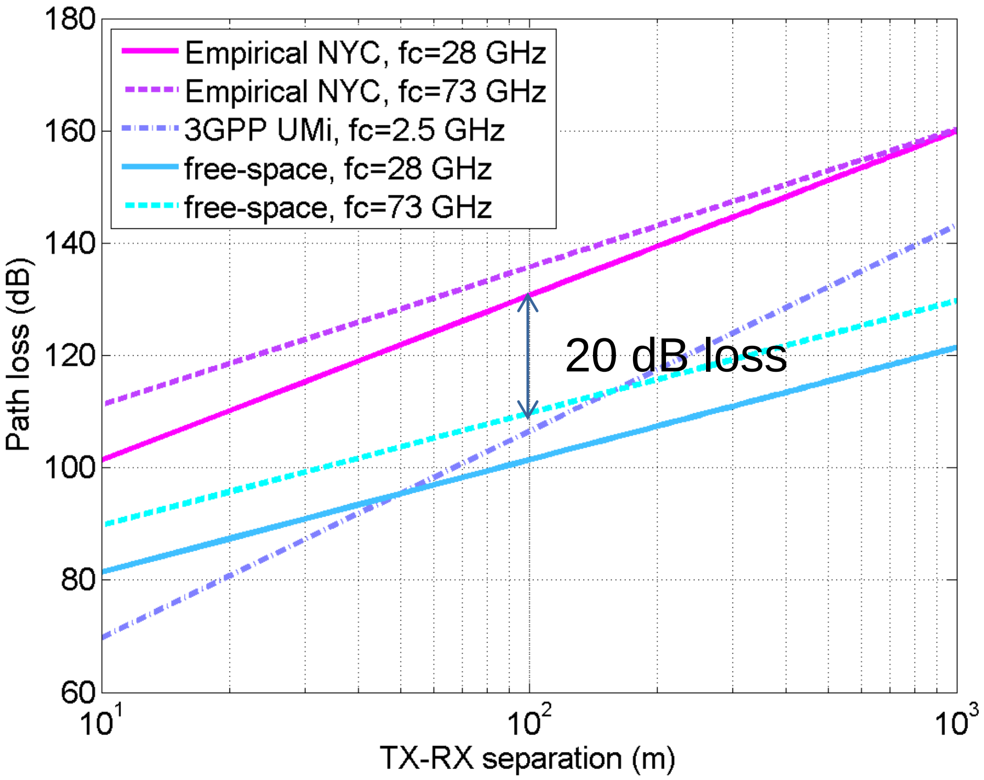


- Focus on urban canyon environment
  - Likely initial use case
  - Mostly NLOS
  - "Worst-case" setting
- Measurements mimic microcell type deployment:
  - Rooftops 2-5 stories to street-level
- Distances up to 200m

All images here from Rappaport's measurements:

Azar et al, "28 GHz Propagation Measurements for Outdoor Cellular Communications Using Steerable Beam Antennas in New York City," ICC 2013

Isotropic Path Loss Comparison



- Isotropic NLOS path loss measured in NYC
  - ~ 20 - 25 dB worse than 3GPP urban micro model for fc=2.5 GHz
- But beamforming will offset this loss.
- Bottom line:
  mmW has no effective increase in path loss

Comparison to Current LTE

- Initial results show significant gain over LTE
  - Further gains with spatial mux, subband scheduling and wider bandwidths

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

10 UEs per cell, ISD=200m,
hex cell layout
LTE capacity estimates from 36.814

~ 25x gain (cell throughput)

~ 10x gain (cell edge rate)

A Big Question
What is the killer app for mmWave?

- What applications can drive huge amounts of data?
  - Video?
  - Machine to machine?
  - Many users bursty vs. few users continuous?

- What will drive very low latency (e.g. ~1ms)?
  - Network delays?
  - Mobile vs. cloud partition?
  - Where will data be located?

- Power, form factor, cost?