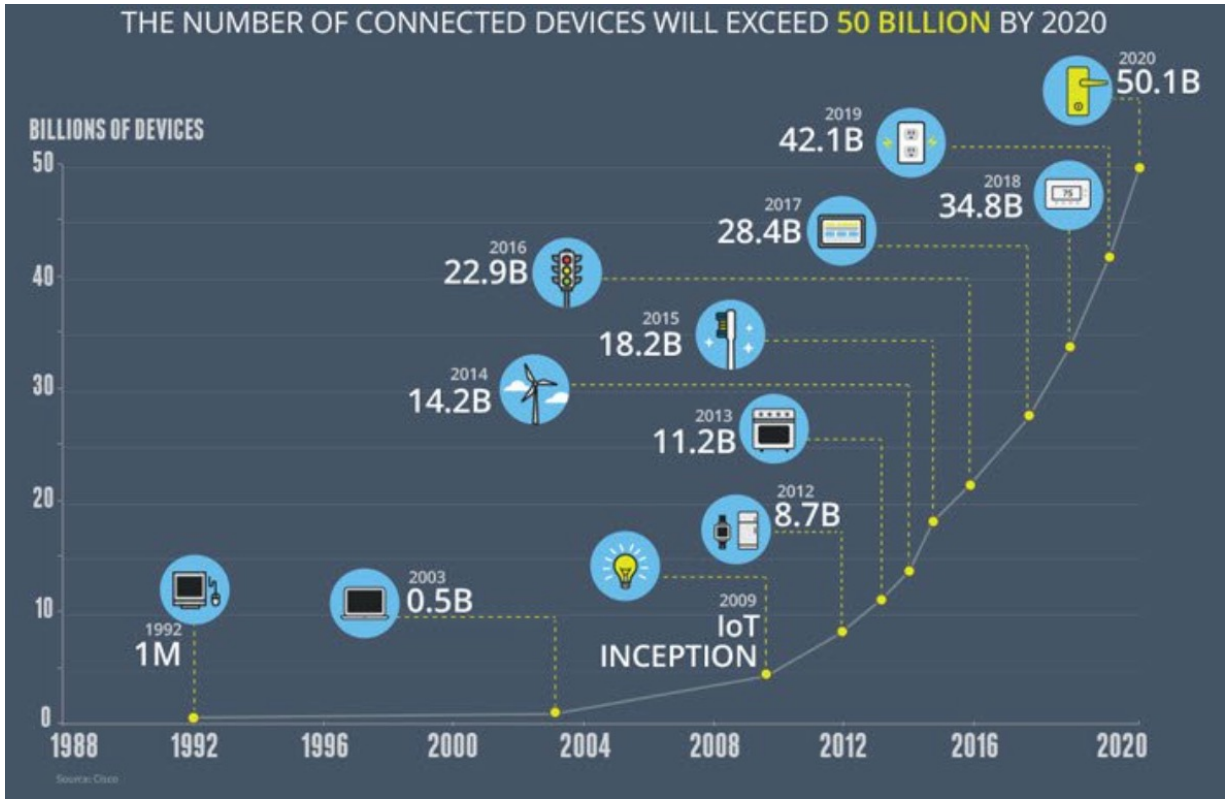
Crash Course on 5G Networks

IN5060: Quantitative Performance Analysis

UiO : University of Oslo

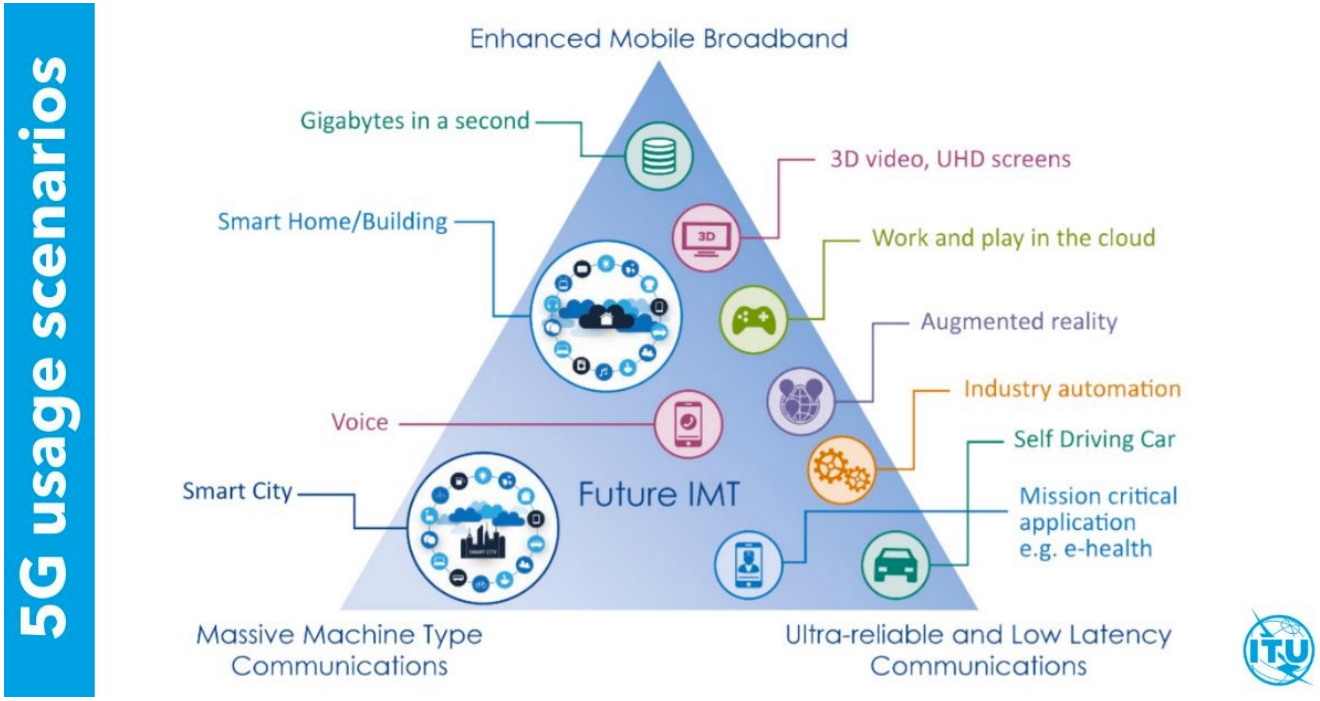
Growth in the number of connected devices



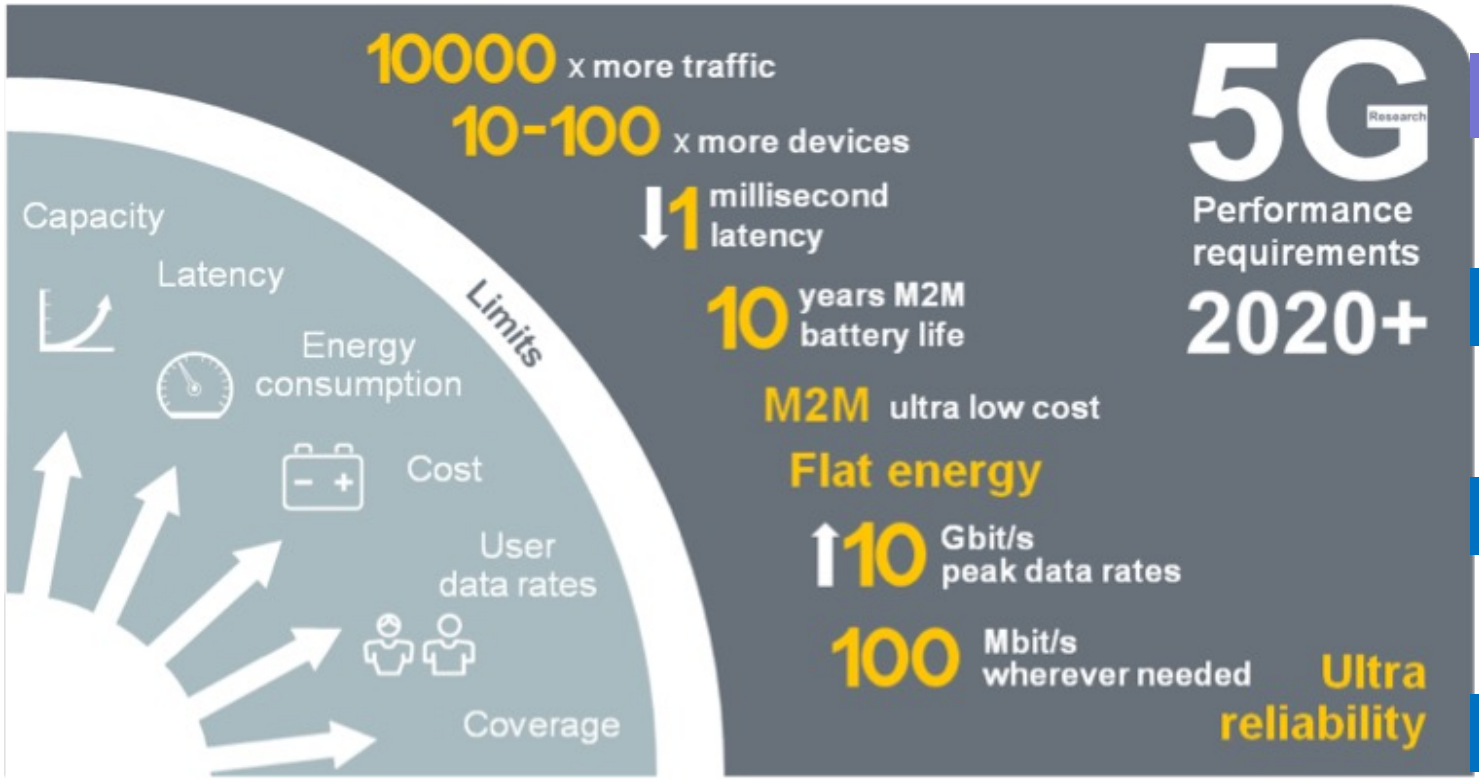
Connected devices in 2010

Connected devices today

How it all fits in 5G?



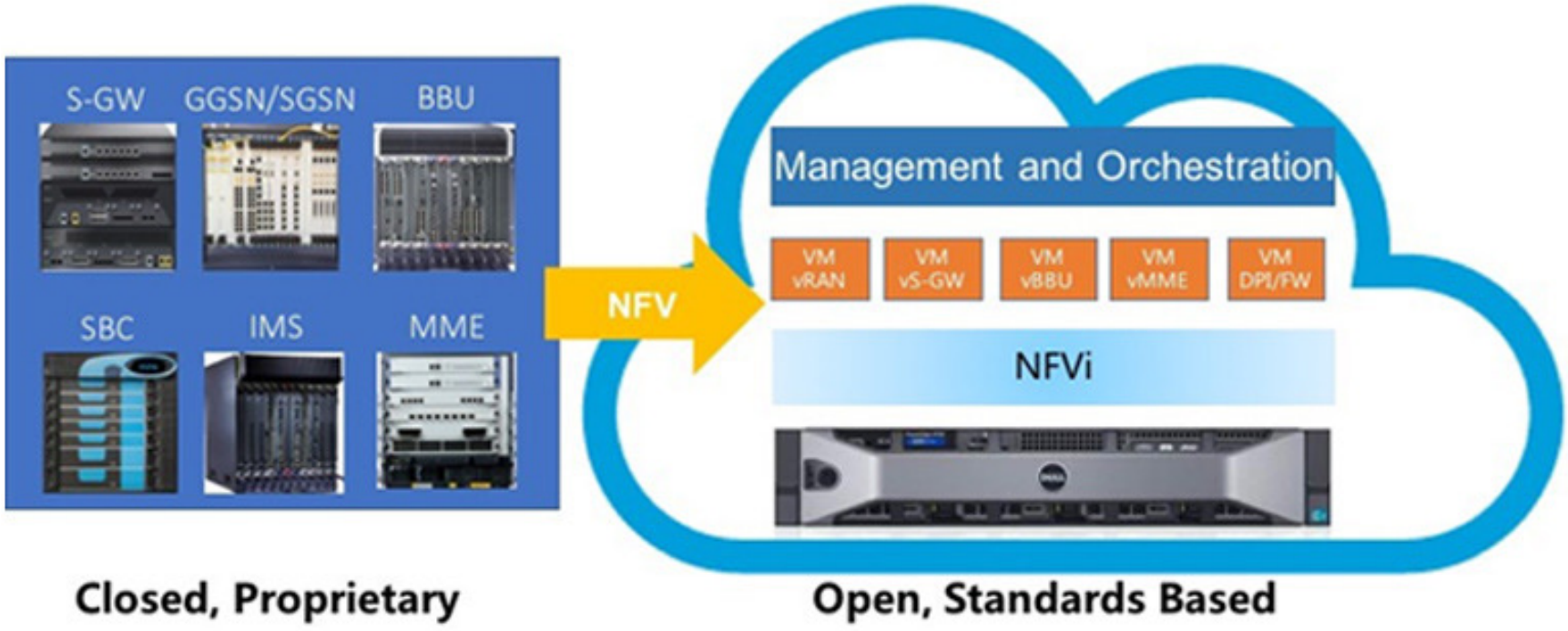
5G Mobile Network Expected Performance

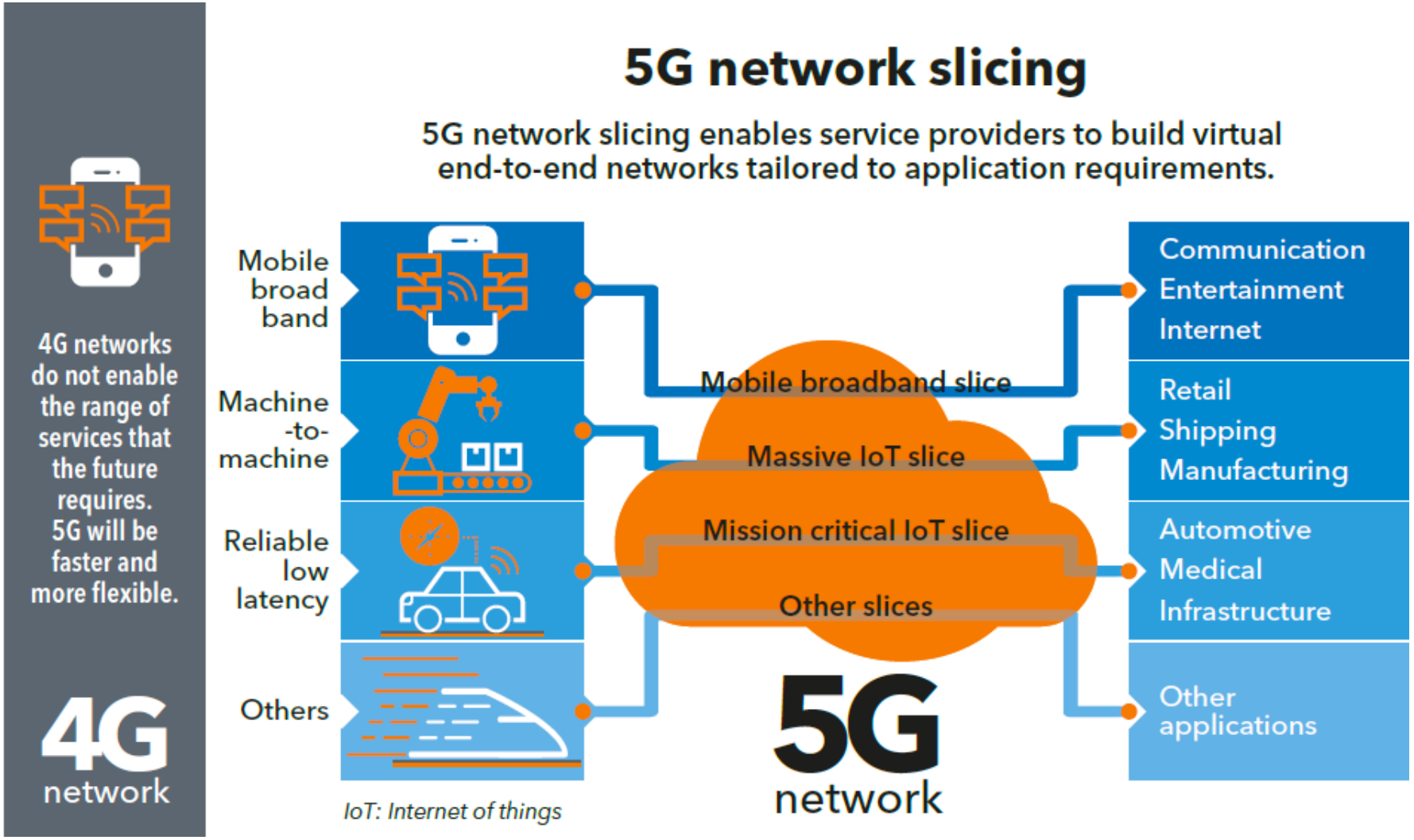


Back in the day...

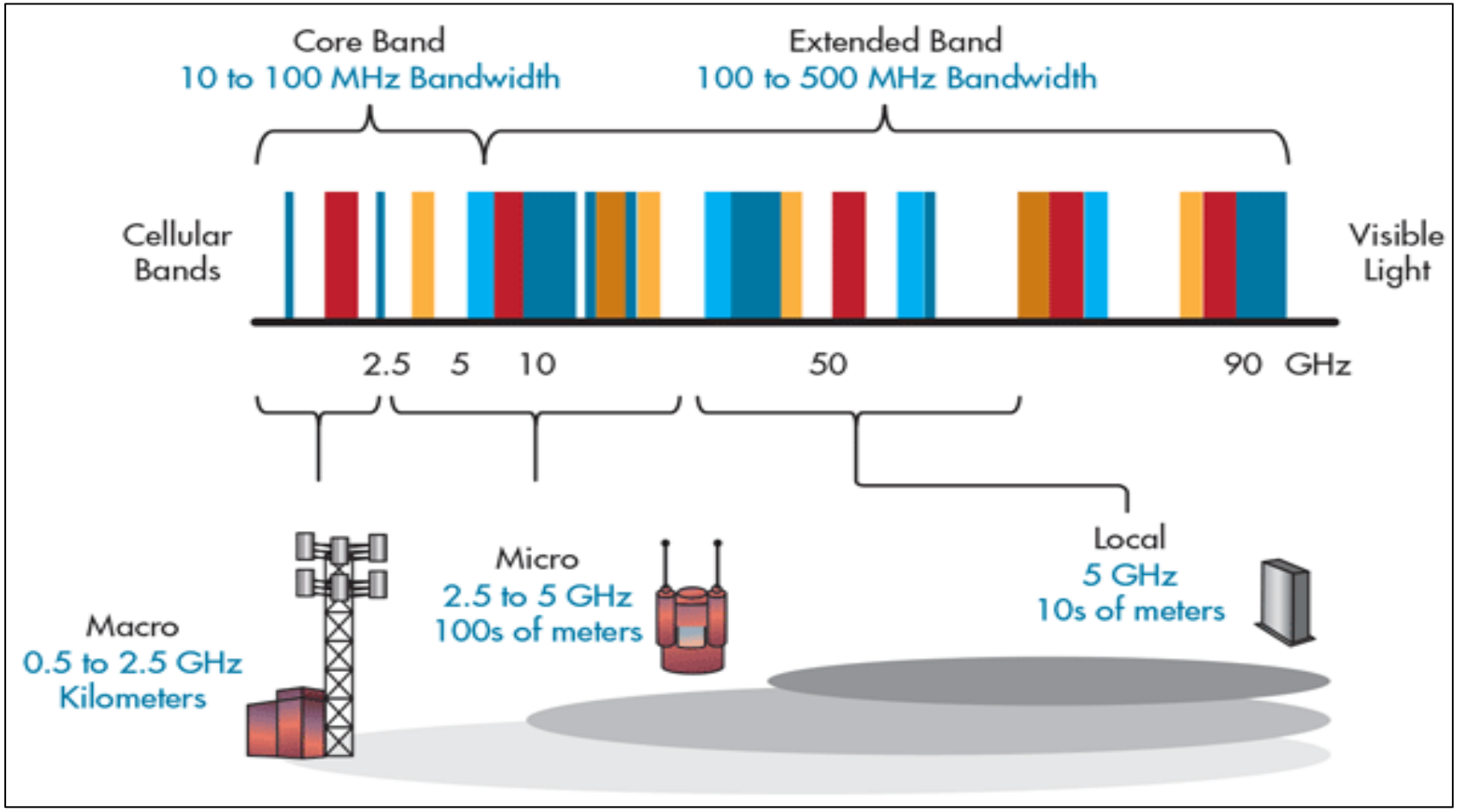
1994

Network Flexibility: Virtualization

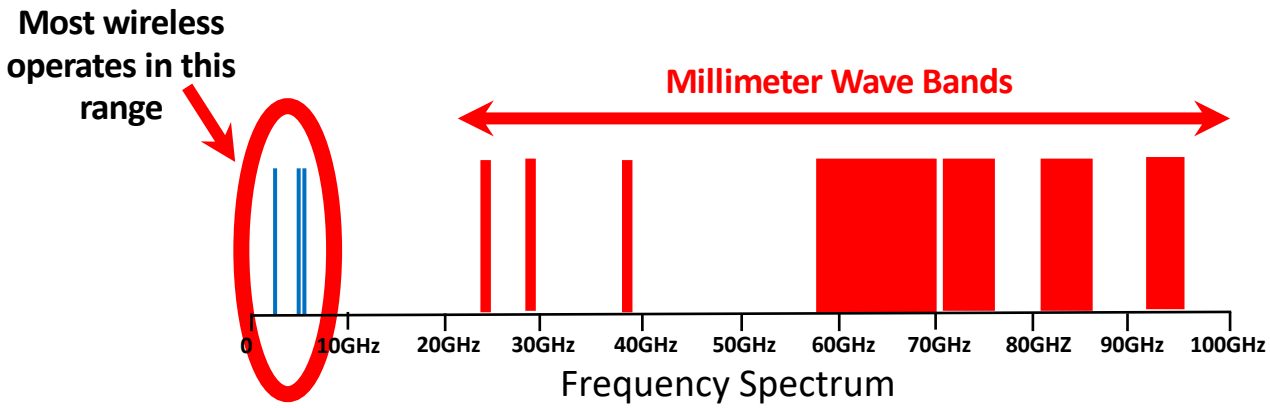



4G networks do not enable the range of services that the future requires. 5G will be faster and more flexible.
4G network
5G network slicing
5G network slicing enables service providers to build virtual end-to-end networks tailored to application requirements.
Mobile broad band
Machine -to- machine
Reliable low latency
Others
Mobile broadband slice
Massive IoT slice
Mission critical IoT slice
Other slices
5G network
Communication Entertainment Internet
Retail Shipping Manufacturing
Automotive Medical Infrastructure
Other applications
IoT: Internet of things

5G Bands and its impact on Cell size



What is mmWave?



Why mmWave?

Shannon-Hartley Theorem

$$C = B \log_2 \left(1 + \frac{S}{N}\right)$$

- C—channel capacity (bps),
- B—channel bandwidth (Hz),
- S—average signal power, and
- N— average noise and interference power.

At higher carrier rates, larger B -> higher rates.

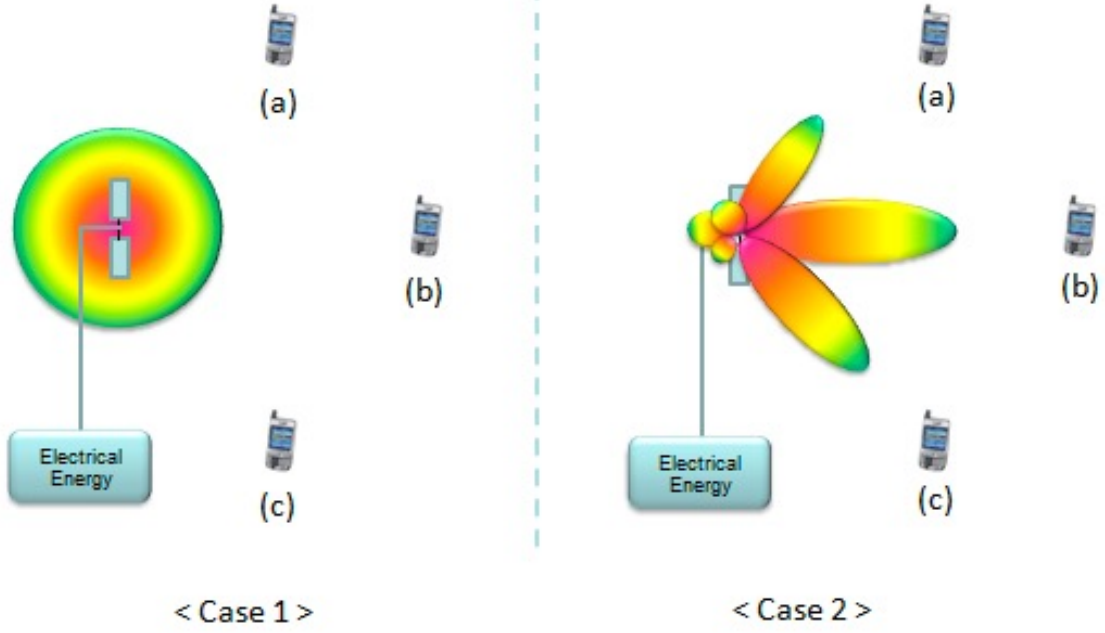
100-1000 times faster than existing wireless networks

How does mmWave work?

mmWave: High attenuation at high frequencies -> very short range

To address high attenuation: Beamforming

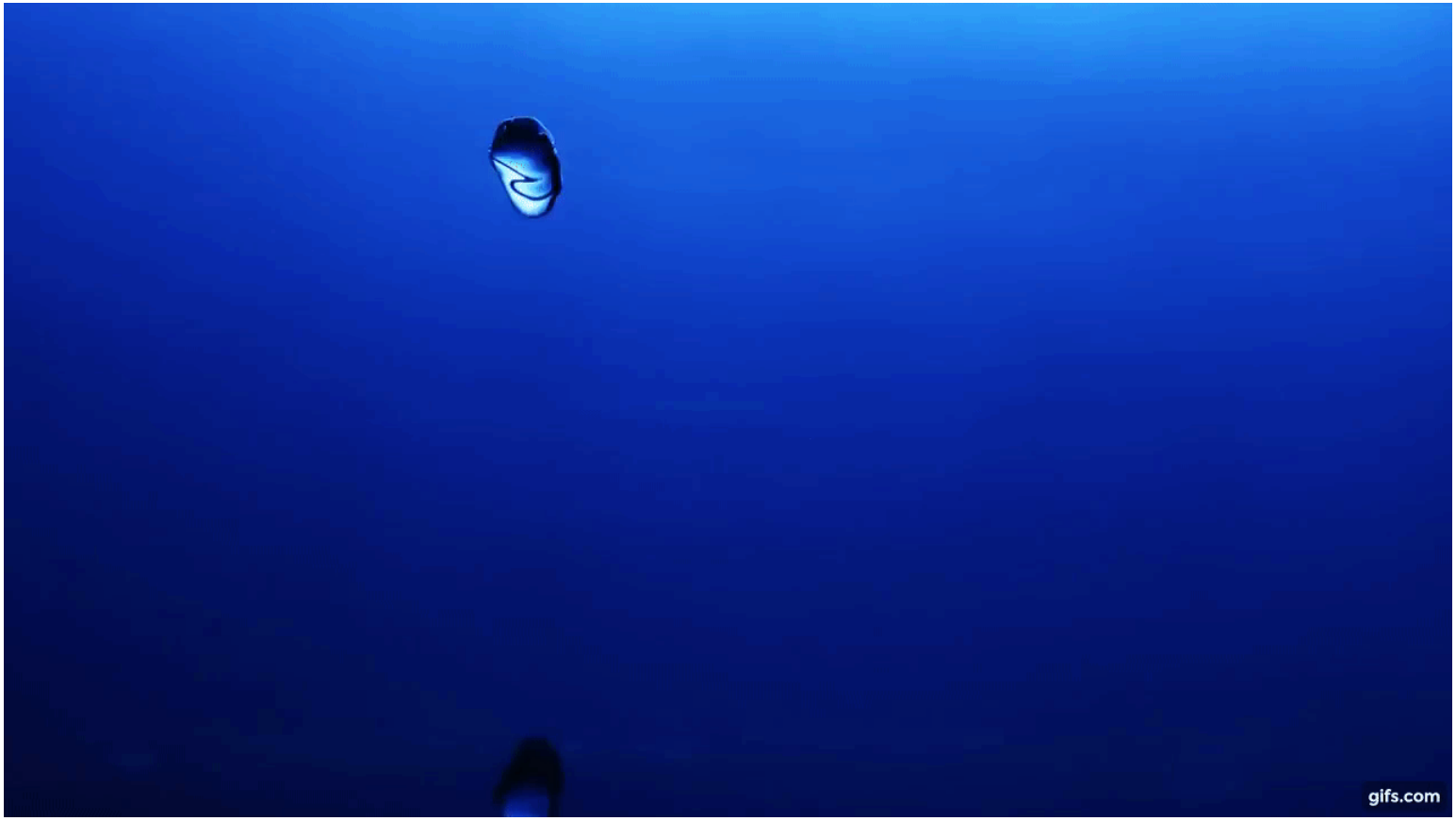
- **Beamforming** is a signal processing technique used for directional signal transmission or reception.
- Elements of an antenna array is combined in such a way that signals at particular angles experience constructive interference while others experience destructive interference.



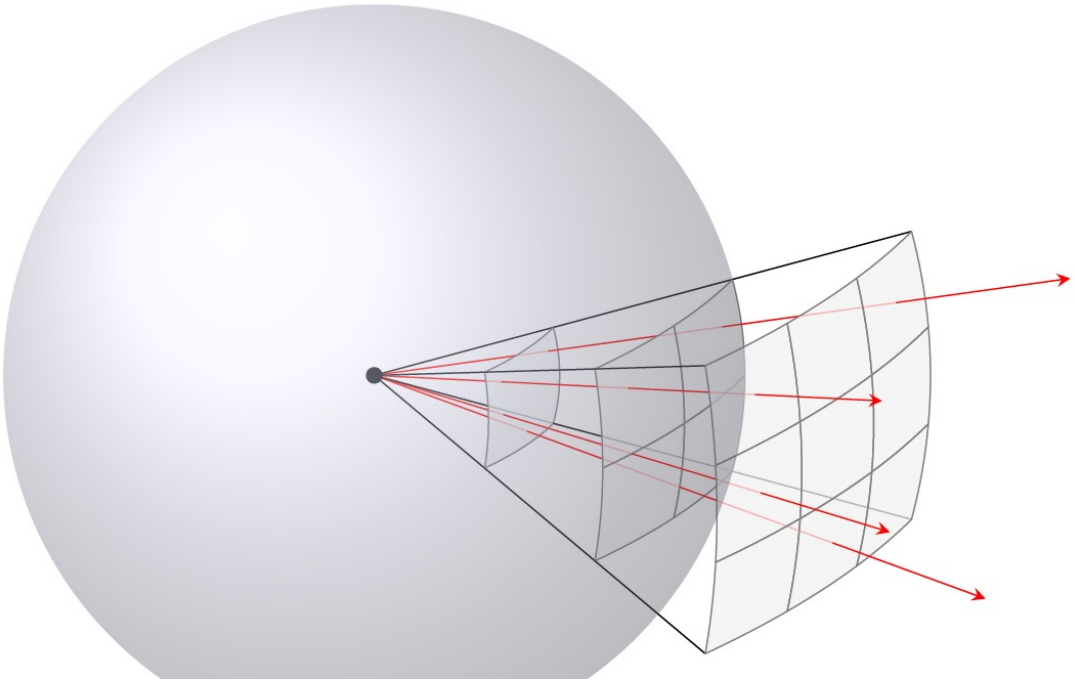
An antenna radiates energy like....

from Mark Hickle https://youtu.be/vtPPAnvJS6c

Forming a beam



Transmit beam and receive strength



All directions

$$P_r \propto \frac{P_{tx}}{4\pi r^2}$$

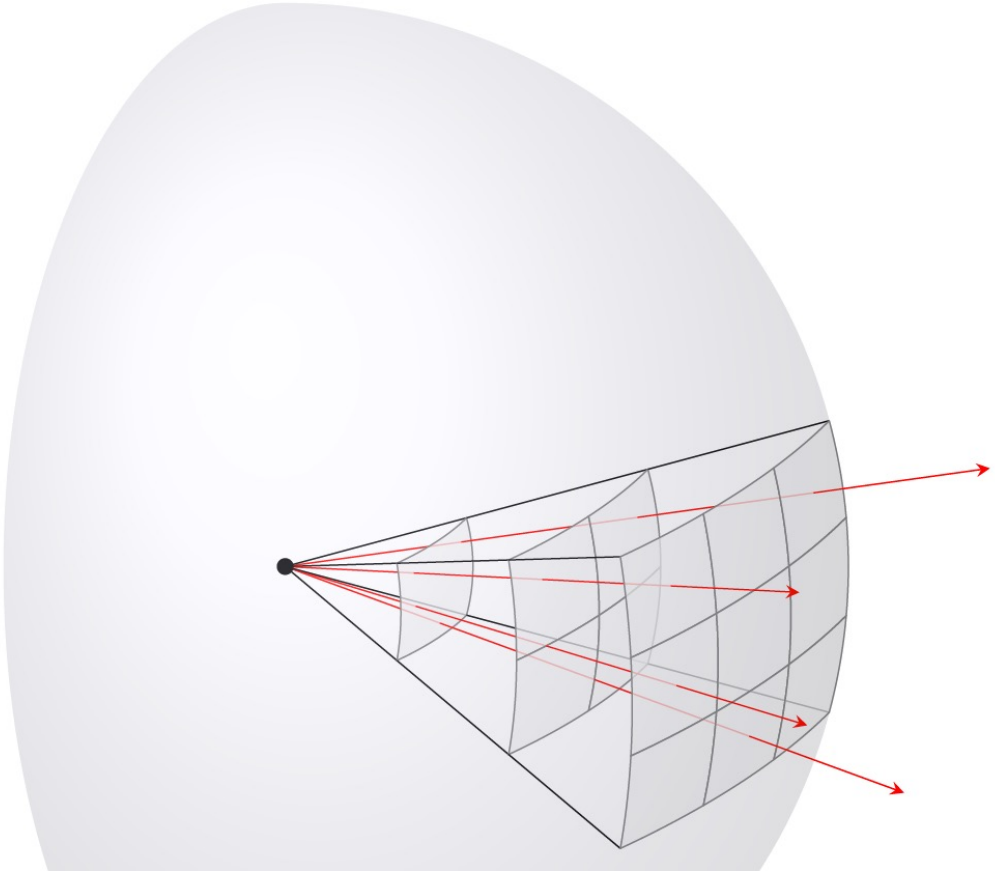
one side

$$P_r \propto \frac{2P_{tx}}{4\pi r^2}$$

2 deg conical beam

$$P_r \propto \frac{1300P_{tx}}{4\pi r^2}$$

Transmit beam and receive strength



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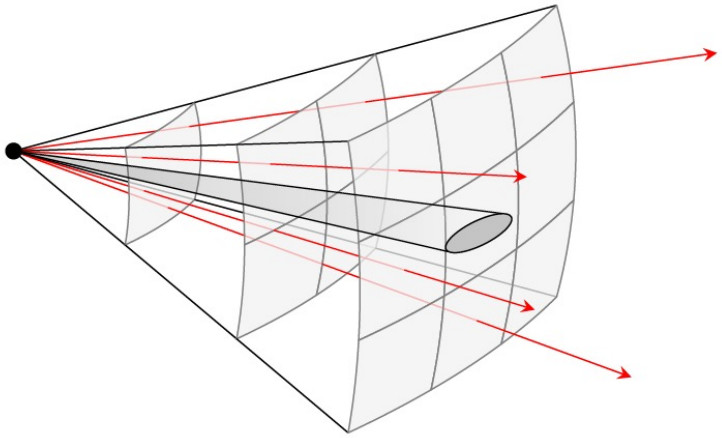

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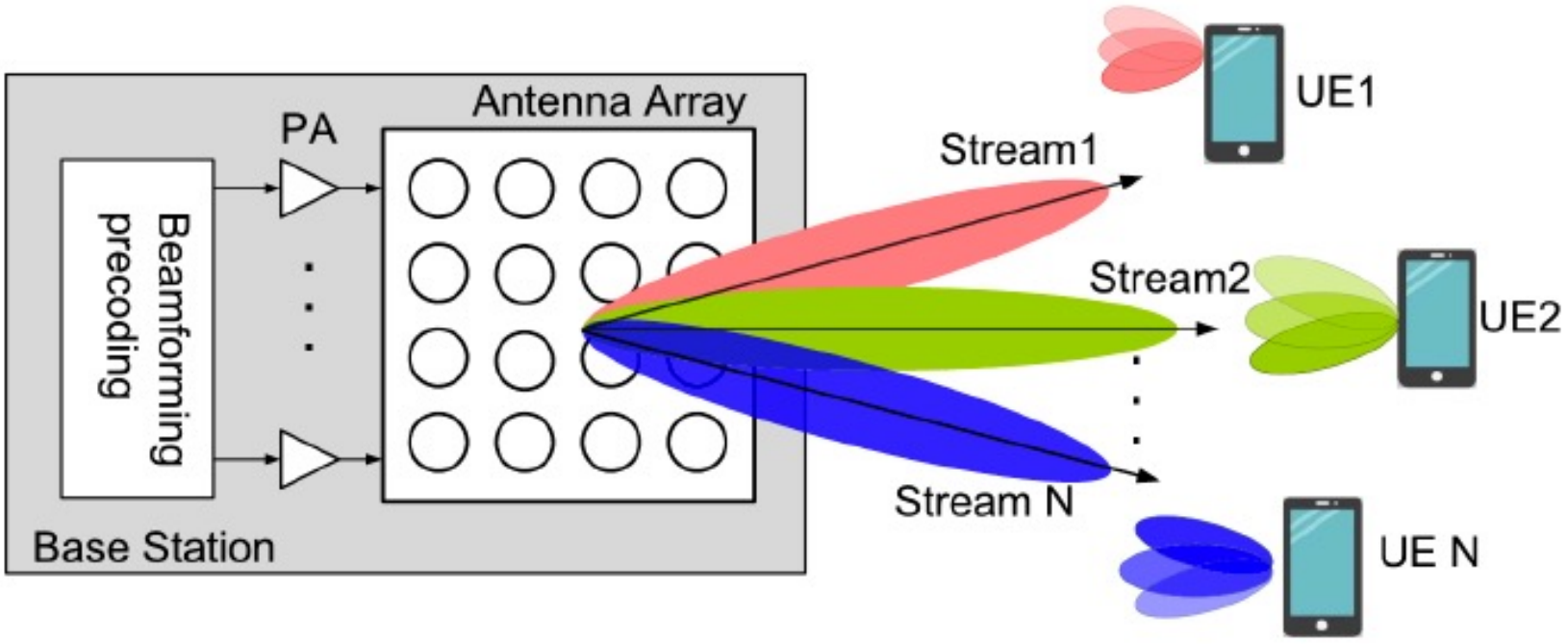
Beamforming and Steering



How does mmWave work?

To address high attenuation, beamforming is used!

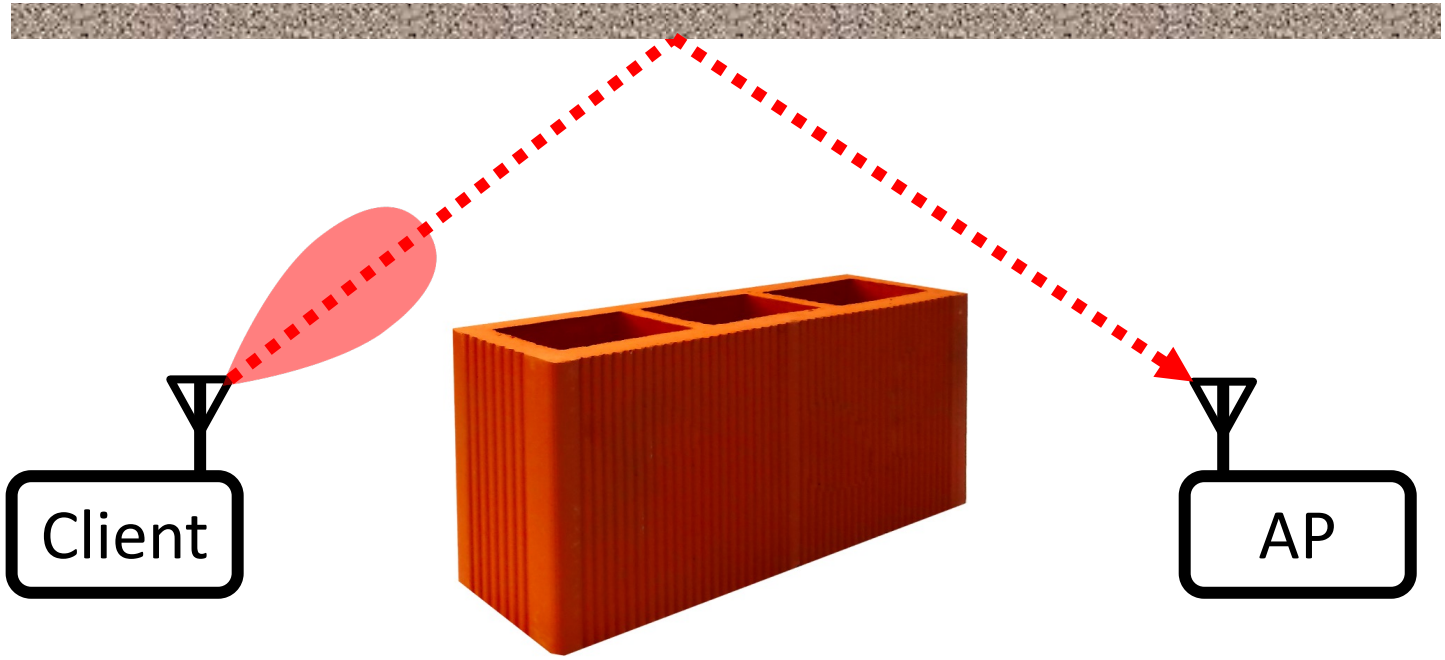
Challenge: Beam alignment

How does mmWave work?

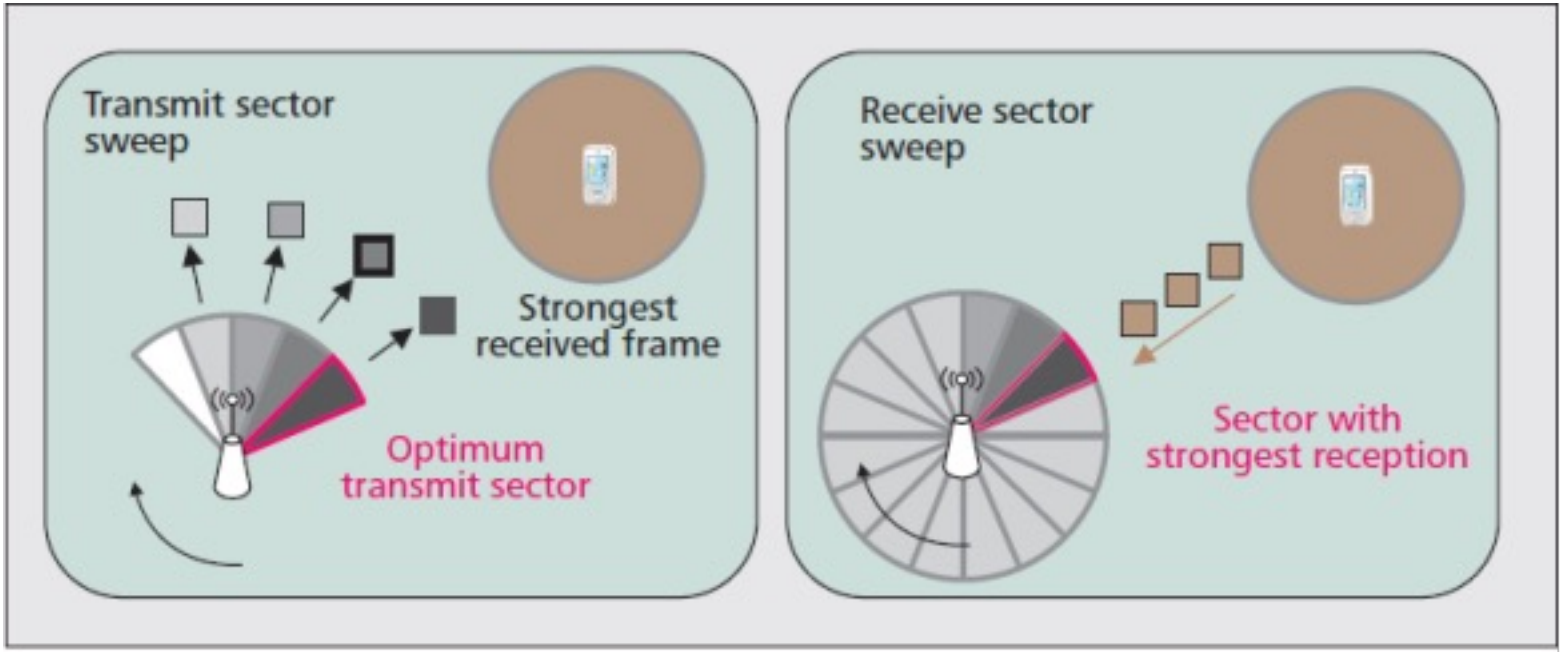
Line of sight exists

How does mmWave work?

Line of sight blocked



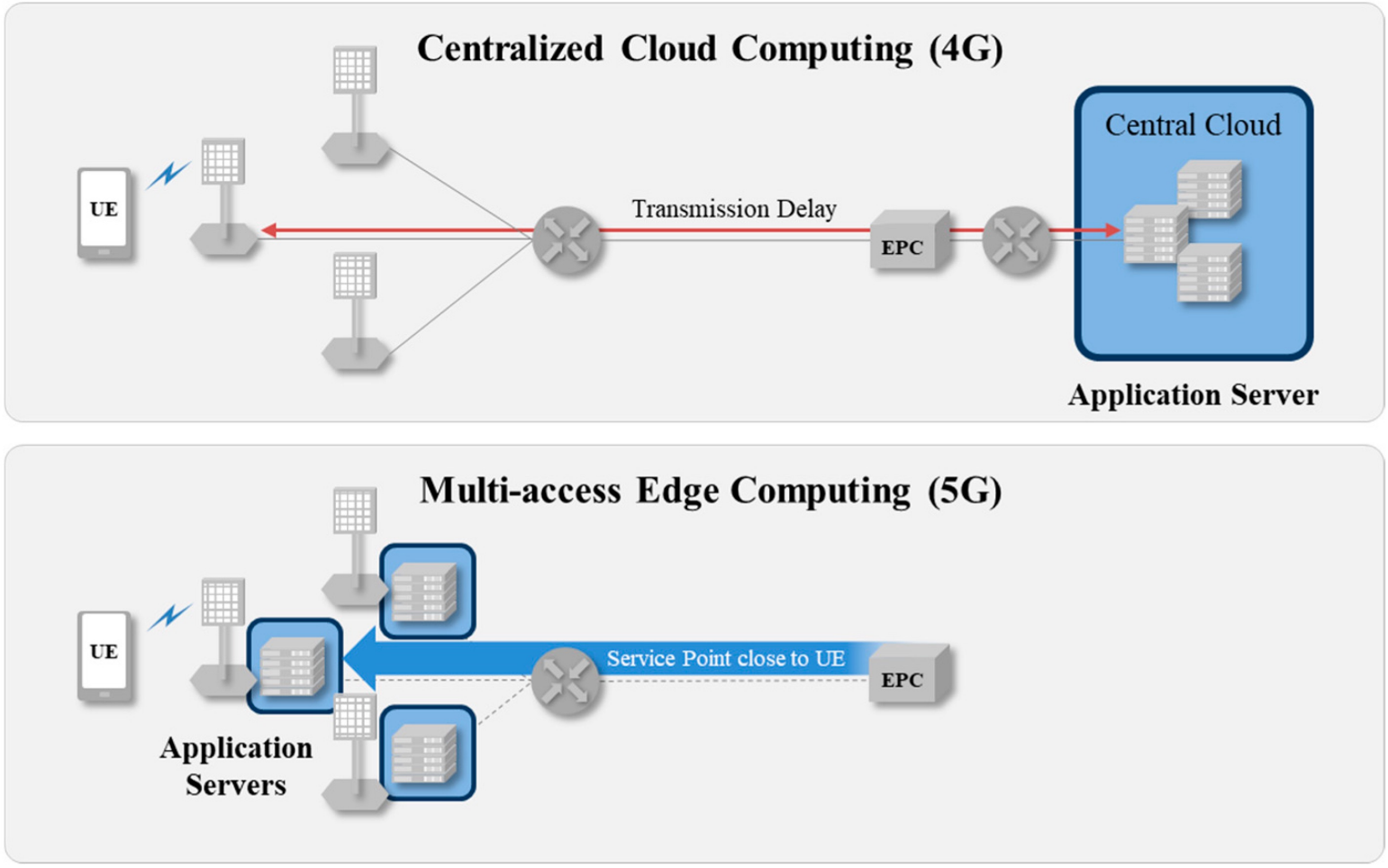
Beamforming Training



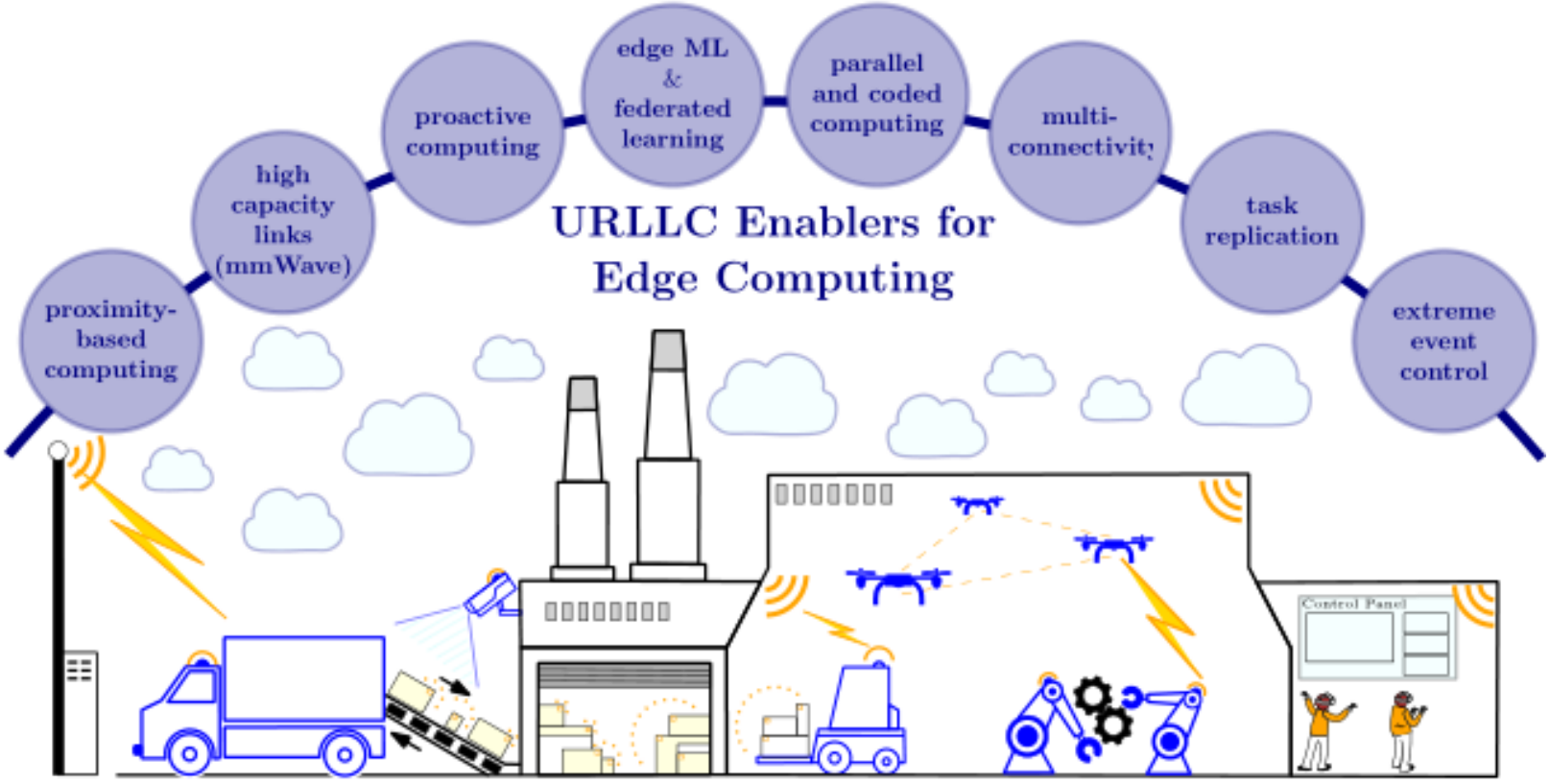
Still quite a challenging problem especially under mobility scenarios!

Spectrum Sharing: Multi-connectivity

Ultra high reliability and Low Latency



Ultra high reliability and Low Latency



Summary and Conclusion

- 5G is a paradigm shift in the networking ecosystem: Network as a Programmable Platform
- Flexible software based architecture to support many different applications with diverse requirements
- Several techologies are proposed: network function virtualization, network slicing, edge computing, mmwave, etc...
- Does this flexibility and virtualization comes at a cost?