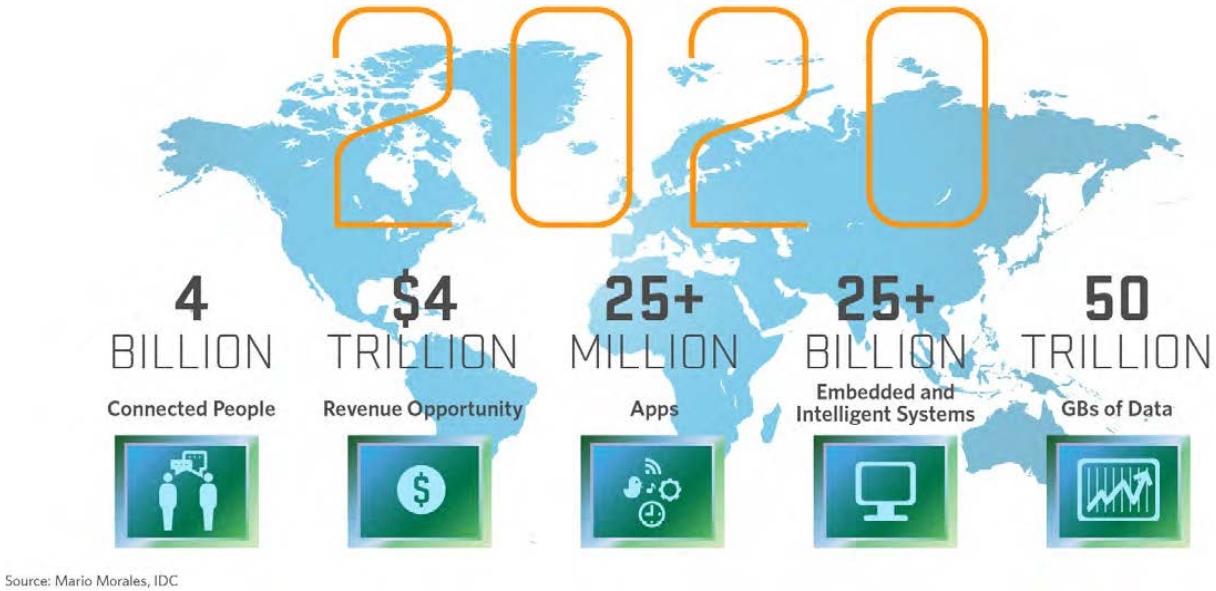
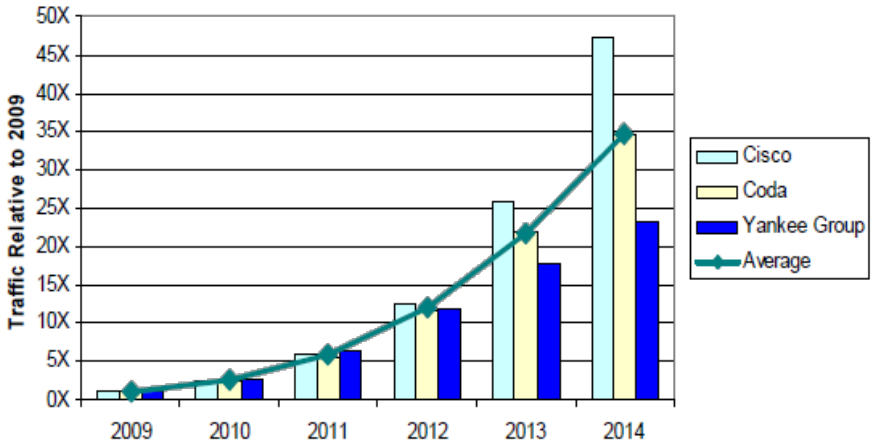
Wireless Communication Systems
@CS.NCTU

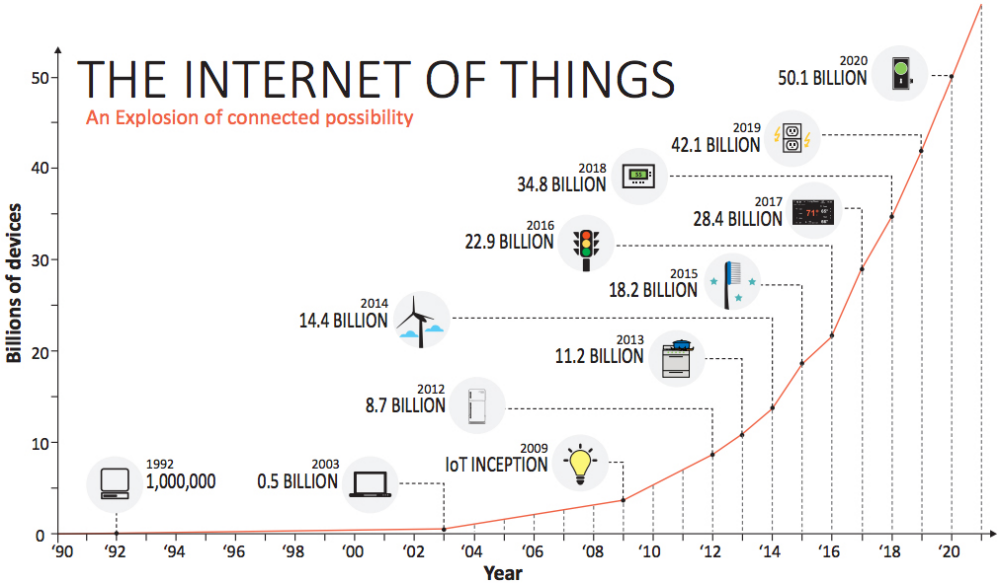
Lecture 13: 5G

Instructor: Kate Ching-Ju Lin (林靖茹)

Increasing Demand for Wireless Connectivity





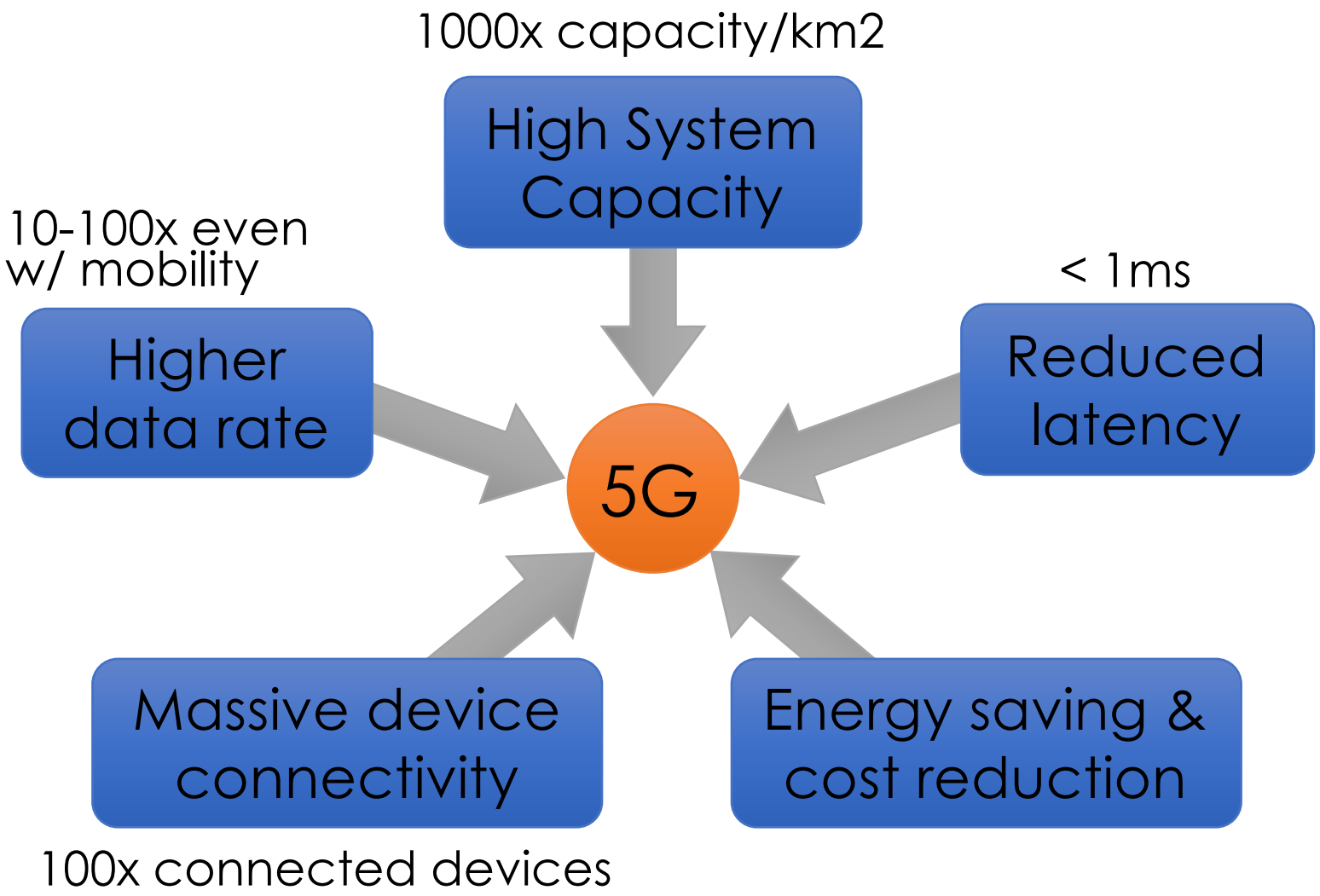


Key Trend (2013-2025)

- Exponential traffic growth
- Wireless traffic dominated by video multimedia
- Expectation of ubiquitous broadband access
- Expectation of Gbps, low latency access
- Emerging internet of things devices

source: Intel, Sept. 2013

5G Targets



source: NTT DoCoMo, Inc. 2014

Disruptive Technologies

- Massive MIMO
- Device-to-device (D2D) communications
- Heterogeneous networks
- Full-duplex communication
- Millimeter wave (mmWave)

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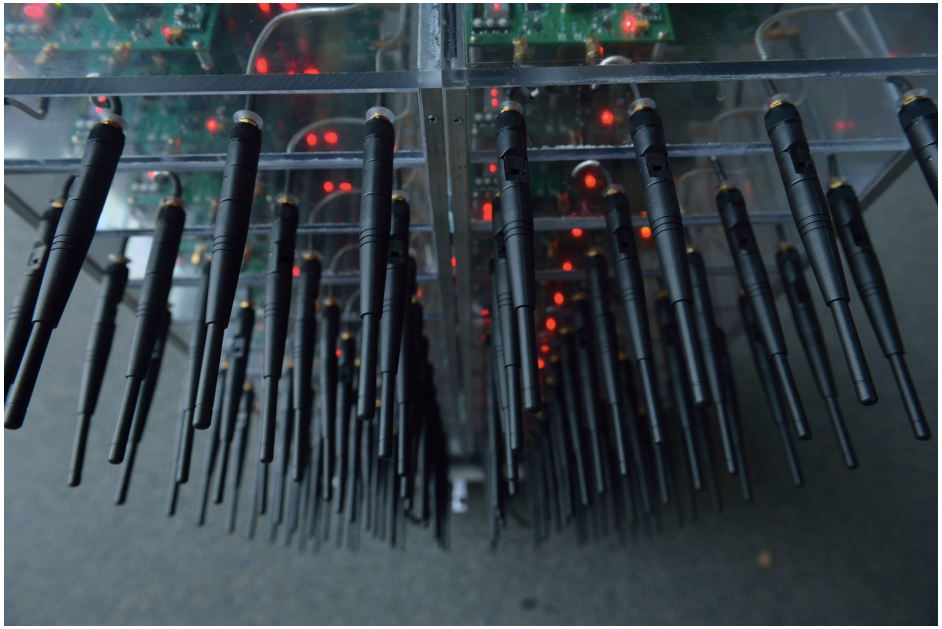

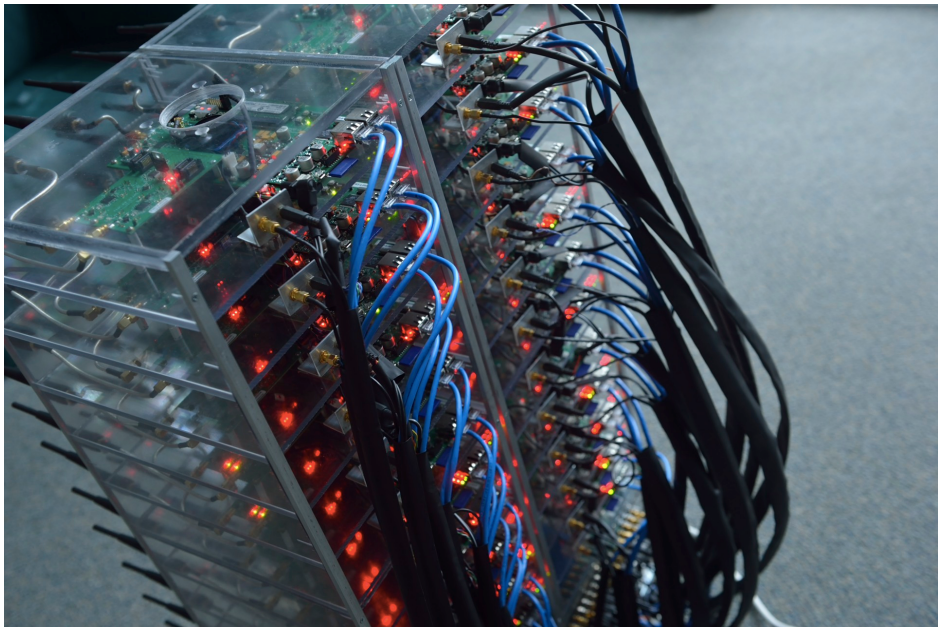

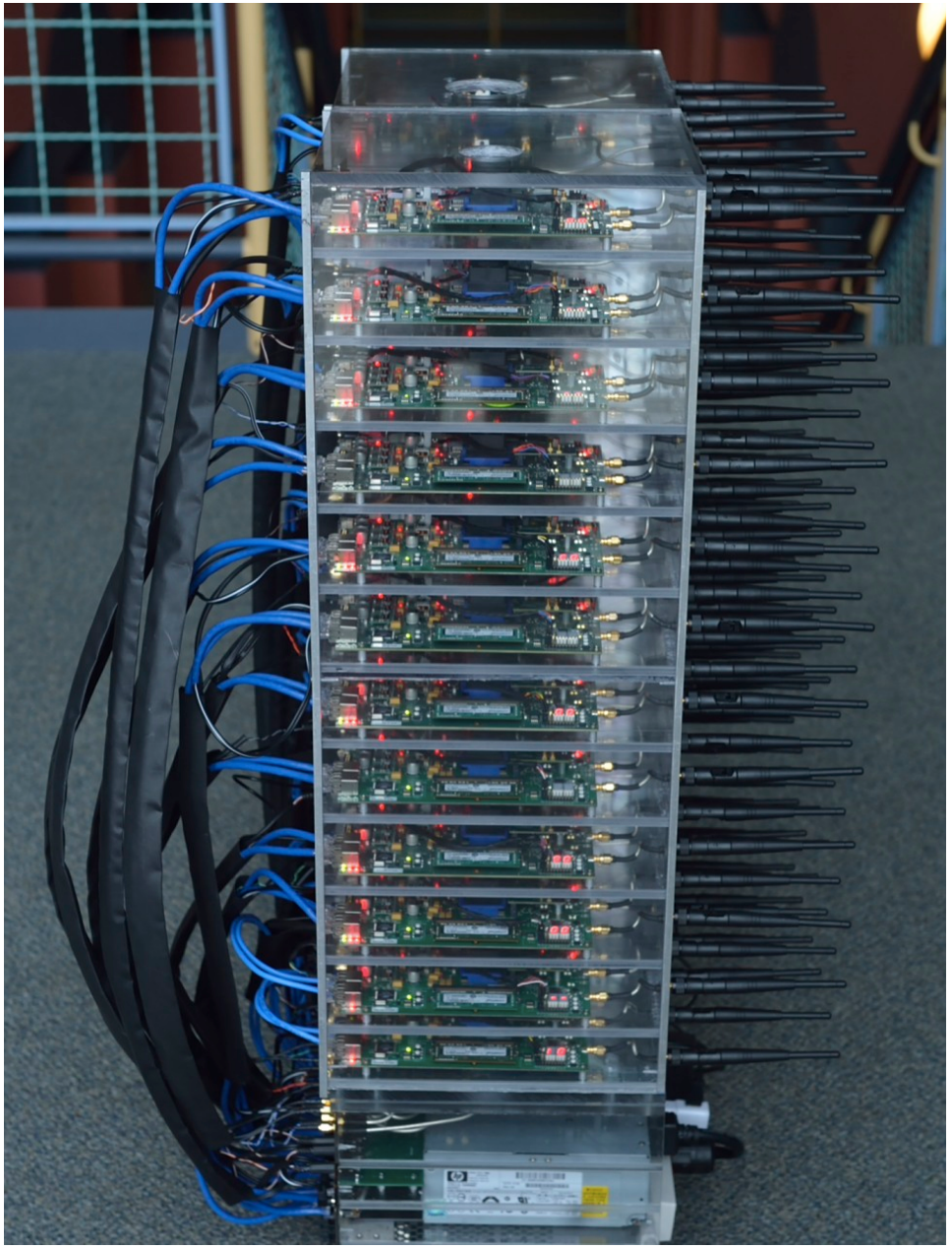

http://argos.rice.edu/

Massive MIMO

- Support a much larger number of antennas, e.g., one hundred or more
- Also known as Large-Scale Antenna Systems, Very Large MIMO, Hyper MIMO, Full-Dimension MIMO
- If N grows large and all other system parameters are assumed constant, the transmit power per user can be reduced proportionally to 1/N and $1/\sqrt{N}$ for perfect and imperfect CSI knowledge, respectively

H. Q. Ngo, E.G. Larsson, T.L. Marzetta, "Energy and Spectral Efficiency of Very Large Multiuser MIMO Systems," IEEE Trans. on Comm., vol. 61, no. 4, pp. 1436--1449, Apr. 2013.

Massive MIMO: Challenges

- Scalability of precoding and detection
  - Traditional zero-forcing beamforming requires non-trivial baseband processing
- CSI estimation
  - How to efficiently collect full CSI?
- Accurate synchronization
- Cost, size, and power consumption

Reading list

- http://www.idc.lnt.de/en/forschung/massive-mimo-systems/
- http://www.massivemimo.eu/research-library
- http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6798744
- http://www.comsoc.org/best-readings/topics/massive-mimo

Disruptive Technologies

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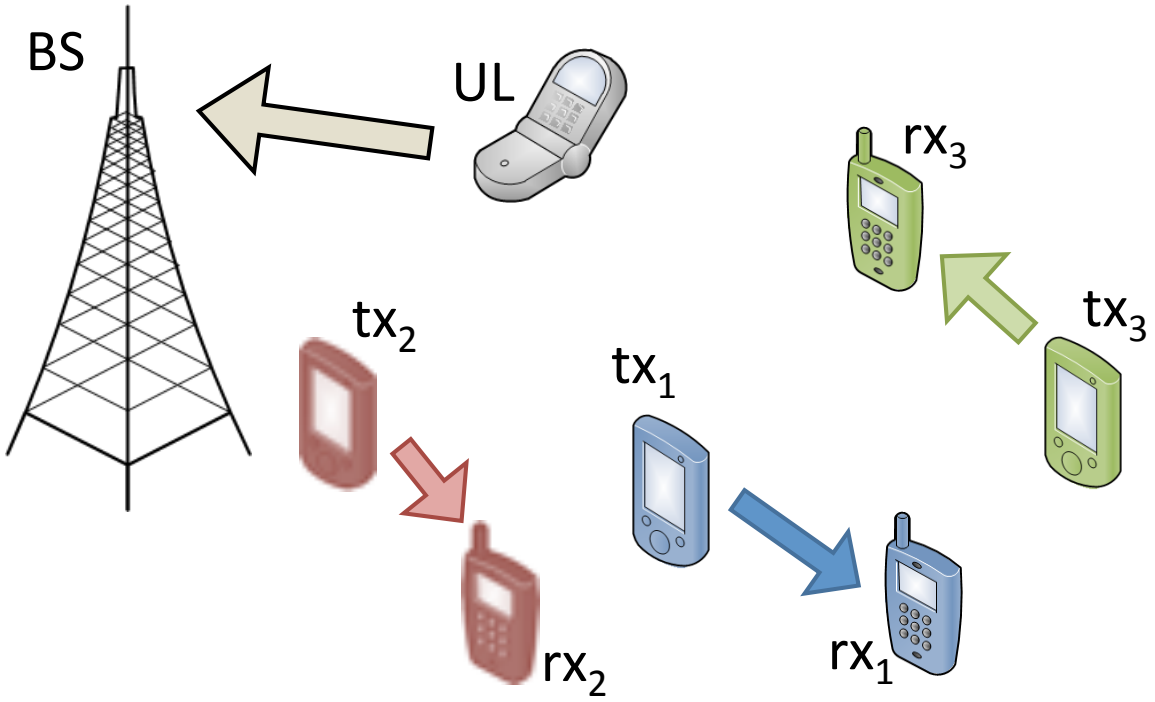
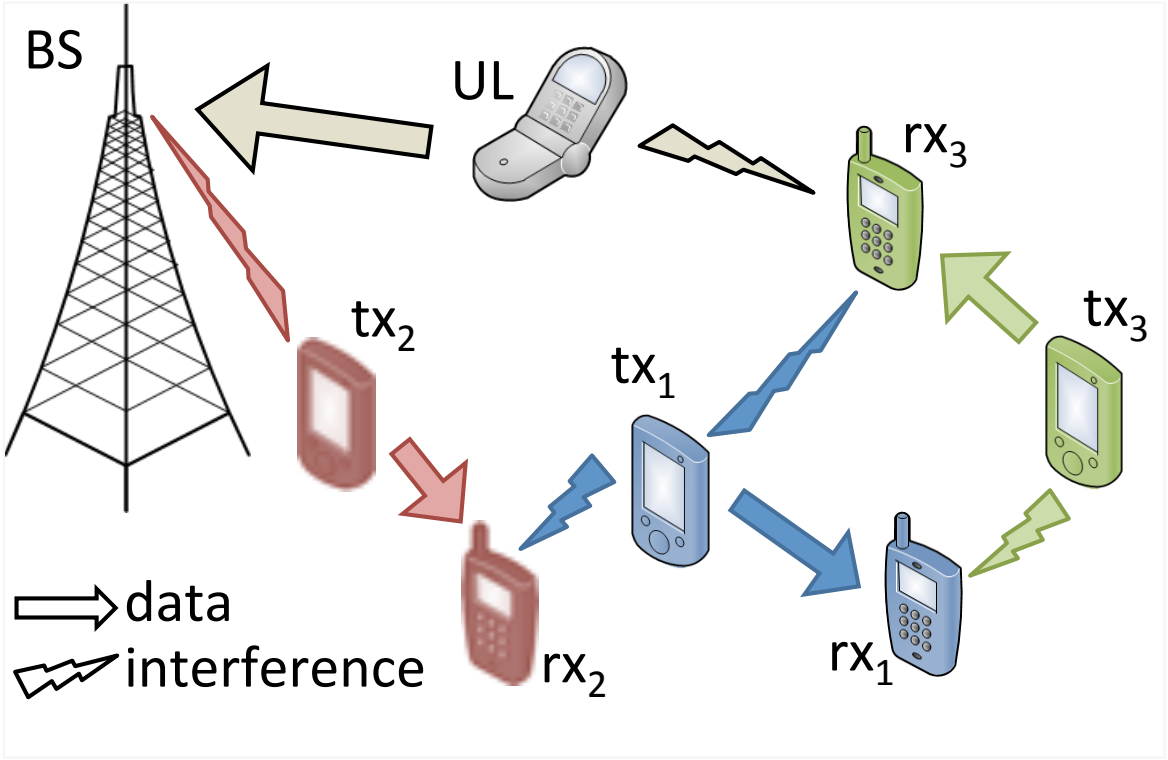
D2D Communications



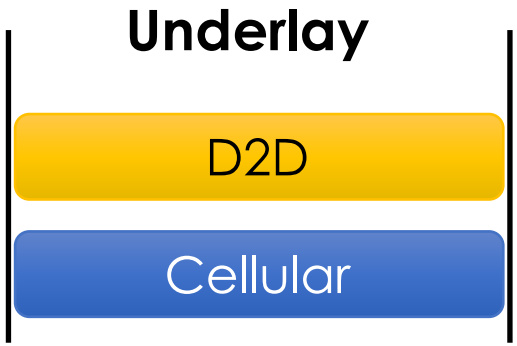
- Co-located devices share content directly, without going through a base station
- Offload proximity data exchange from a congested cellular system

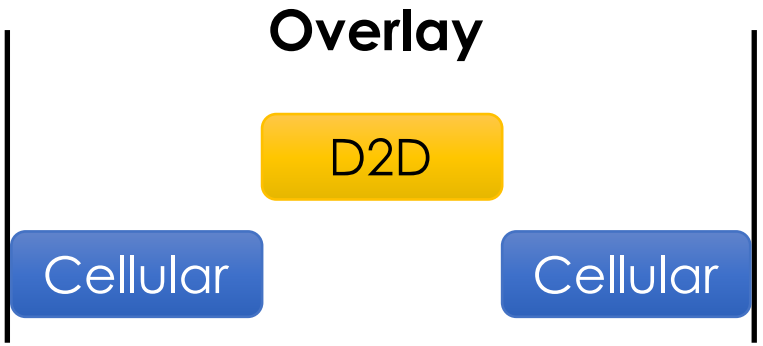
Inter-link Interference in D2D



- D2D links might interfere with each other
- D2D clients might also interfere cellular transmissions

Overlay and Underlay D2D





- Higher spectrum efficiency by spatial reuse
- Need to cope with interference

- Dedicated resources for D2D
- Reduce the concern about interference
- Need explicit resource allocation

D2D Interference Management

- Possible solutions
  - Resource allocation (OFDMA)
    - Throughput maximization
    - Revenue maximization
    - Energy consumption
    - Incentive
  - MIMO techniques, such as interference alignment

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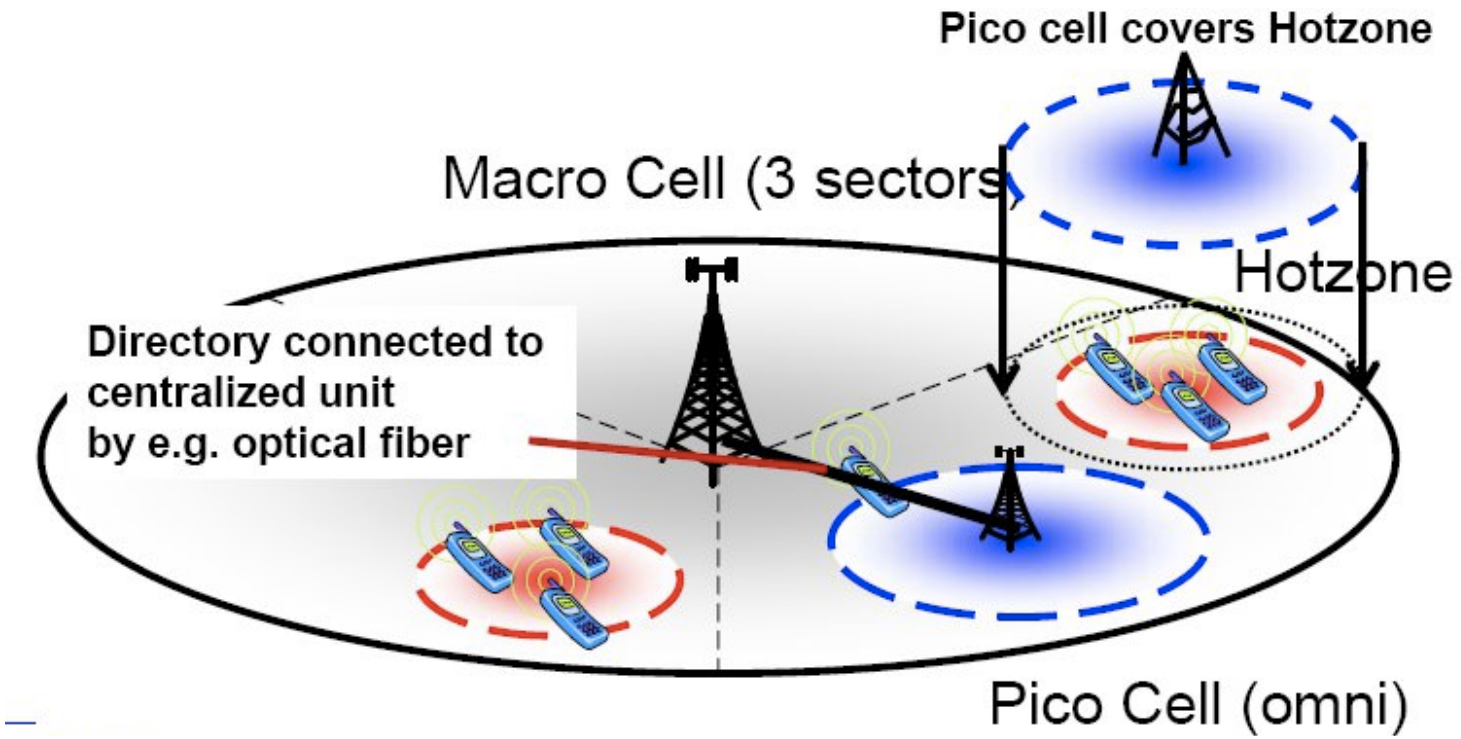
Heterogeneous Networks

macro cell + pico cell + femto cell



source: http://blog.3g4g.co.uk/

Comparison

Aspect	**Picocell**	**Femtocell**
Installation	Operator	Customer
Transmission to operator's network	Operator	Customer
Frequency/radio parameters	Centrally planned	Locally determined
Site rental	Operator	Customer

Source: https://www.thinksmallcell.com/FAQs/whats-the-difference-between-picocells-and-femtocells.html

Advantages and Challenges

- Reduce the cell size, and improve spatial reuse
  - larger capacity per device
- Challenges
  - Resource allocation and interference management
  - Backhaul bandwidth management
  - Latency and QoS guarantee
  - Pricing

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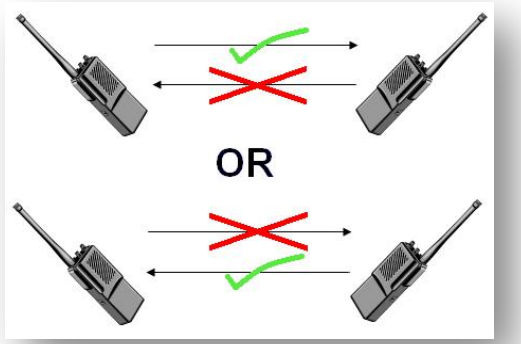
What is Duplex?

- Simplex

- Half-duplex



- Full-duplex

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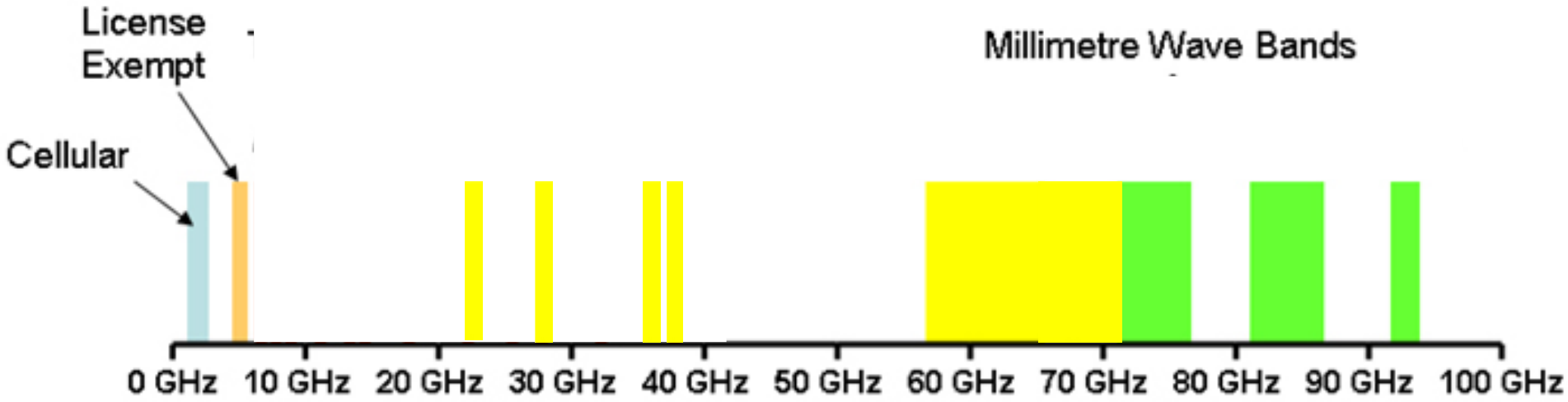
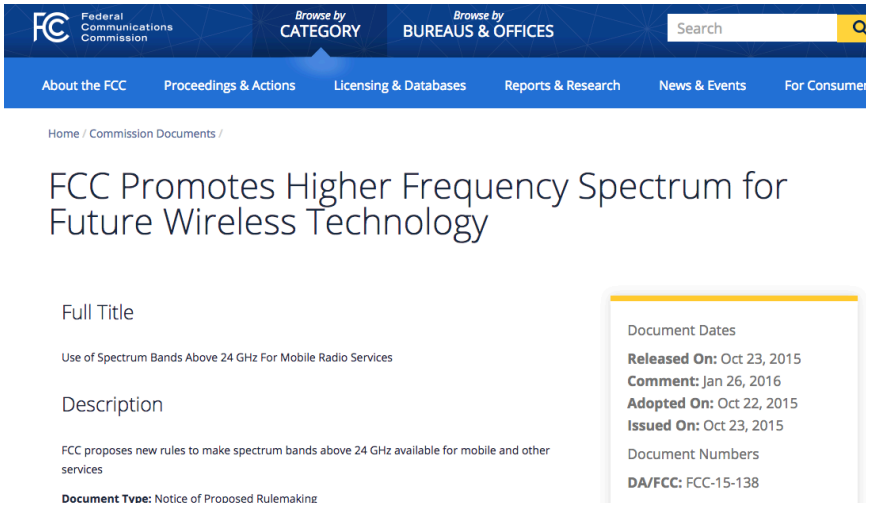
Millimeter Wave Bands

- Huge amount of available bandwidth





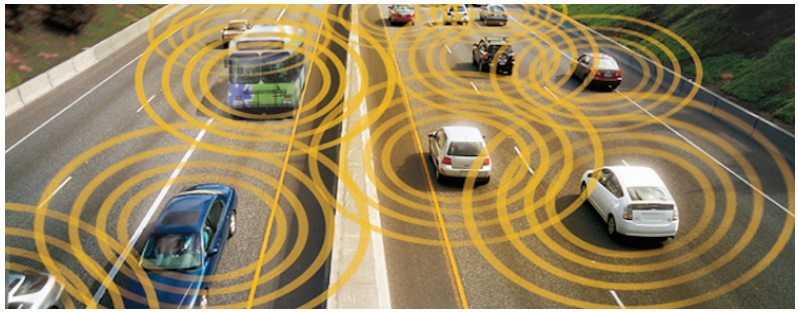
mmWave Wireless Applications

5G Cellular Networks

Wireless Data Centers

Wireless LANs 802.11ad

Wireless Virtual/ Augmented Reality



Connected Vehicles

Gesture Recognition