

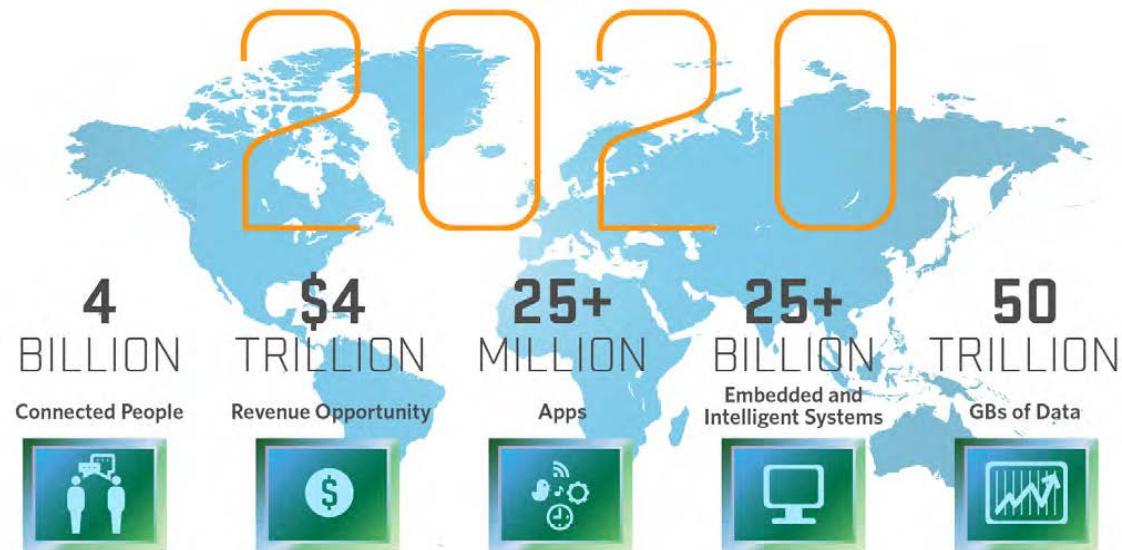
# Wireless Communication Systems

## @CS.NCTU

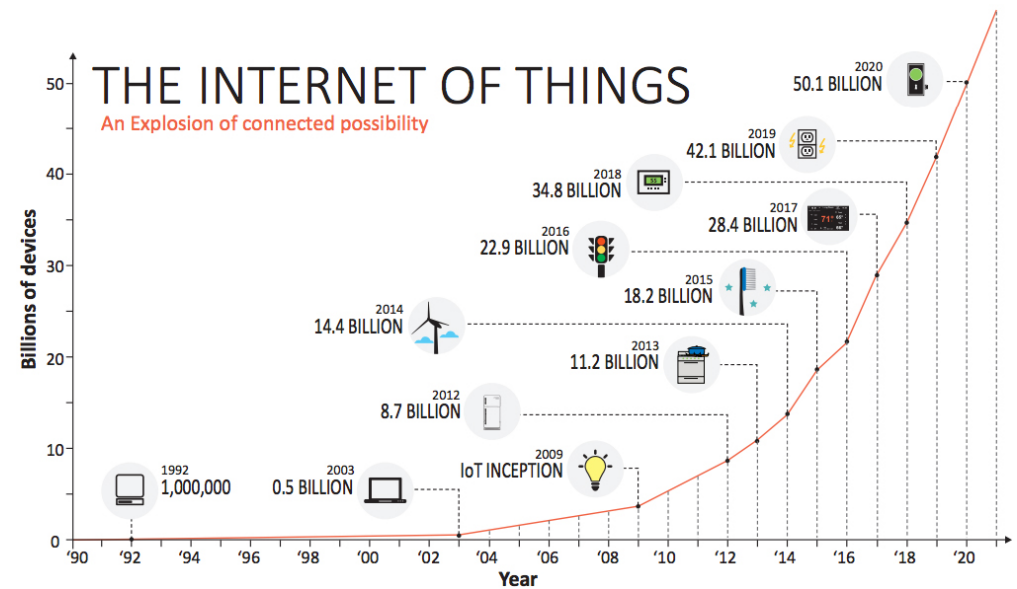
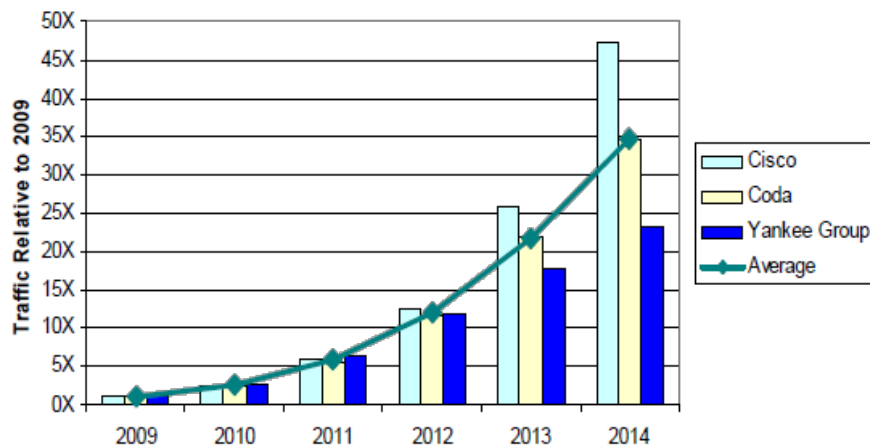
### Lecture 13: 5G

Instructor: Kate Ching-Ju Lin (林靖茹)

# Increasing Demand for Wireless Connectivity



Source: Mario Morales, IDC



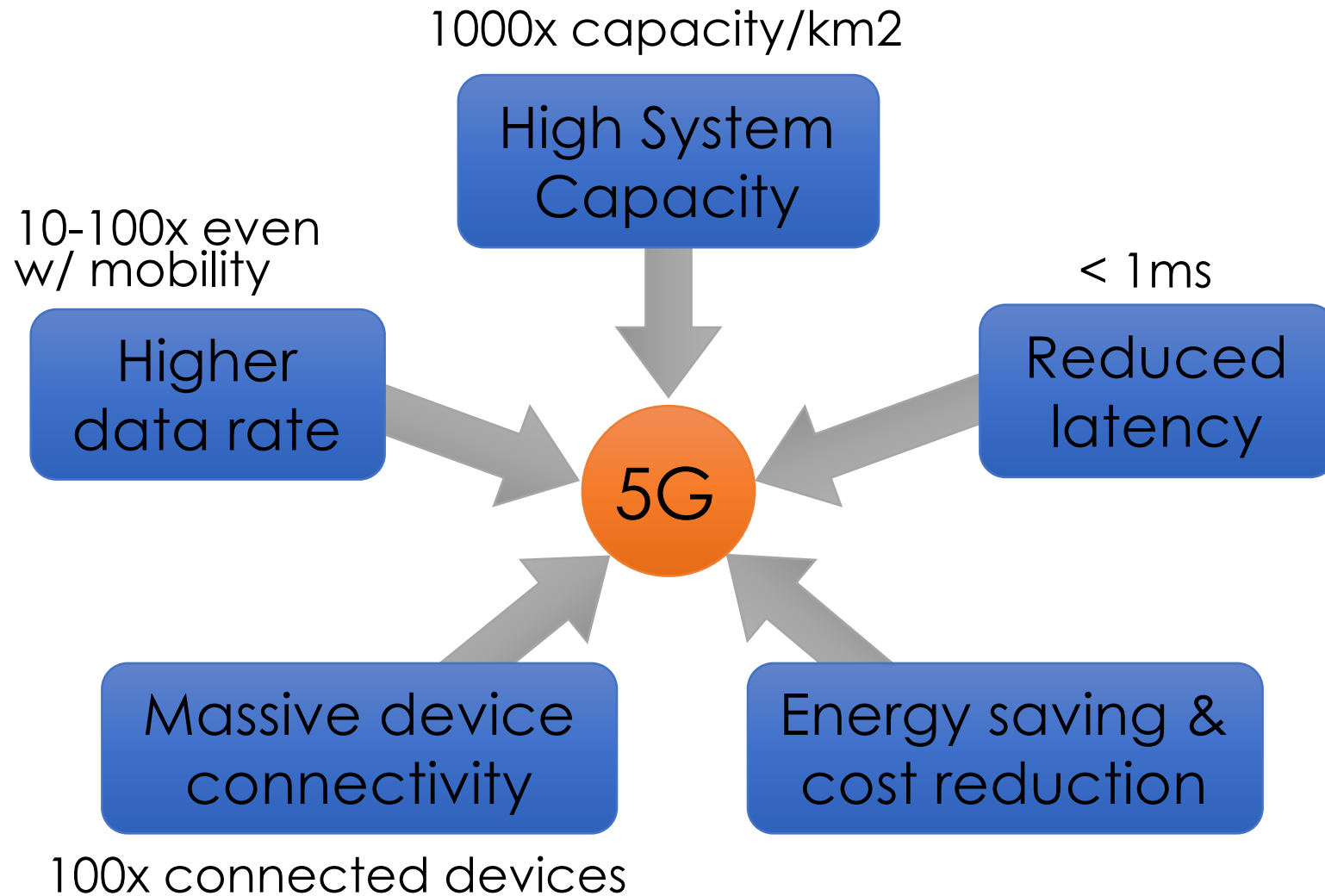
# Key Trend (2013-2025)

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- 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

# 5G Targets

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source: NTT DoCoMo, Inc. 2014



# Disruptive Technologies

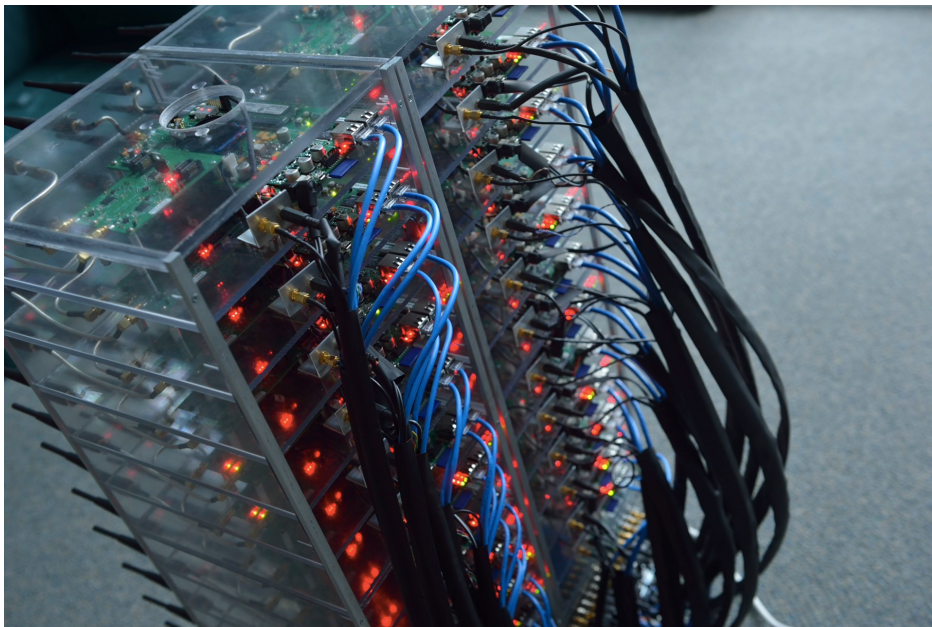
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- Massive MIMO
- Device-to-device (D2D) communications
- Heterogeneous networks
- Full-duplex communication
- Millimeter wave (mmWave)

# Disruptive Technologies

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- **Massive MIMO**
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<http://argos.rice.edu/>

# Massive MIMO

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- 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

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- 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

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- <http://www.idc.Int.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>



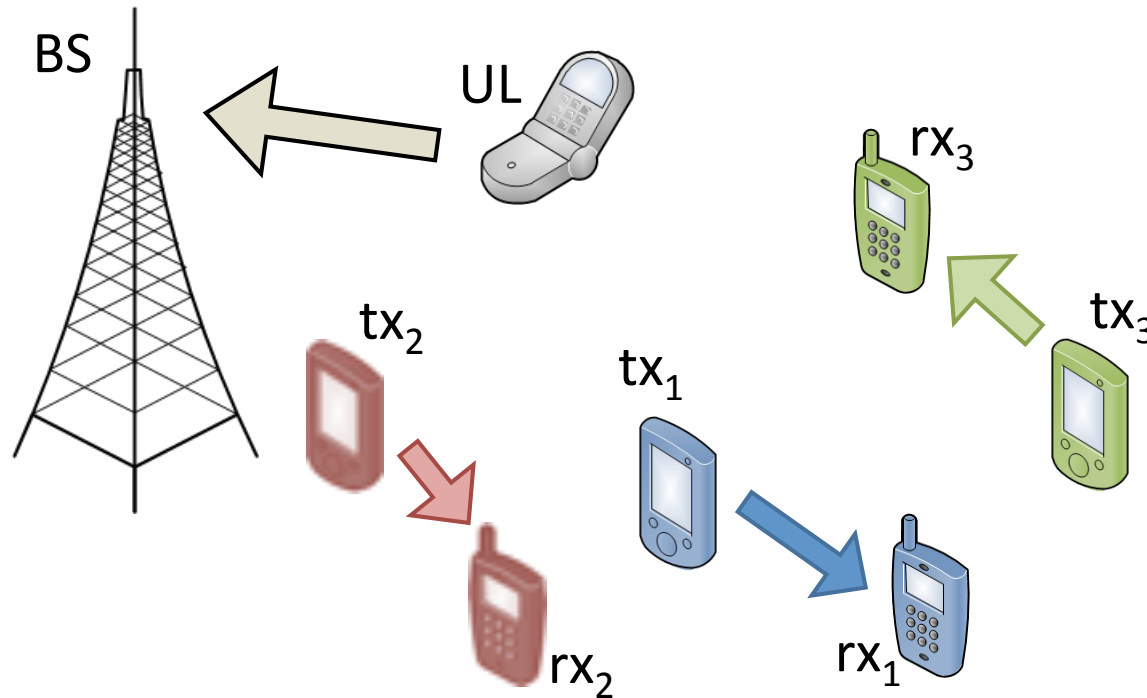
# Disruptive Technologies

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# D2D Communications

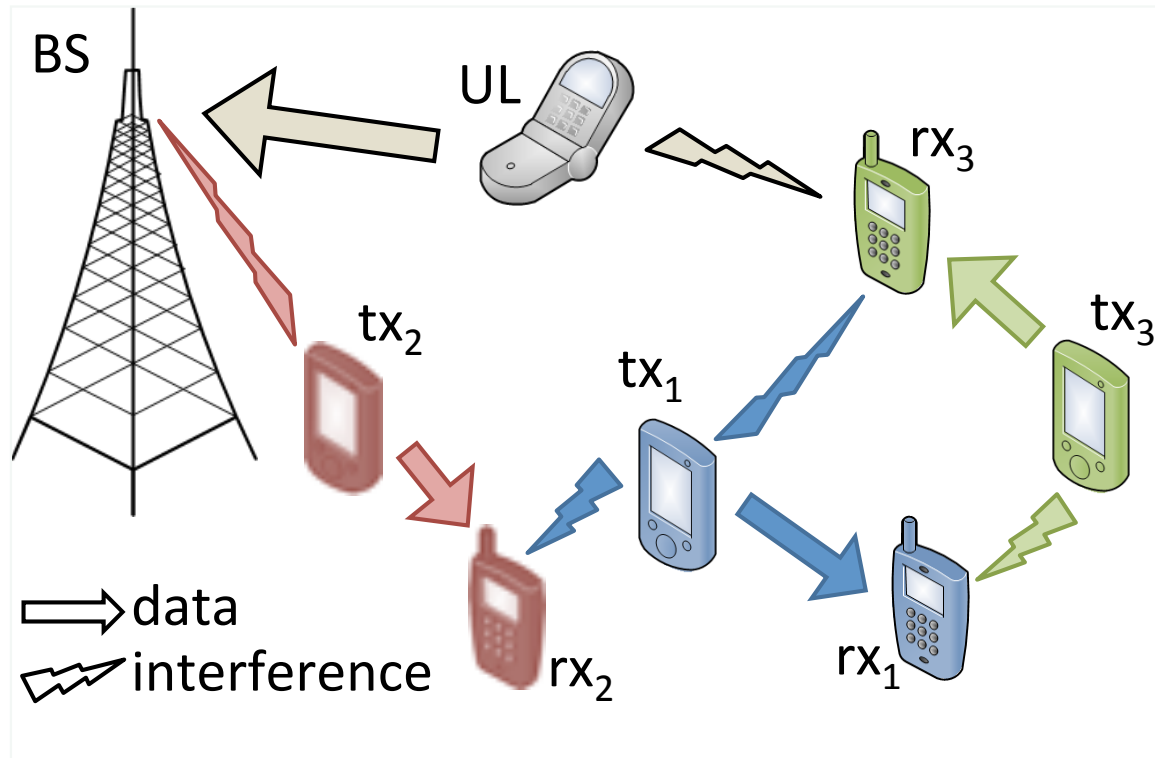
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- Co-located devices share content directly, without going through a base station
- Offload proximity data exchange from a congested cellular system



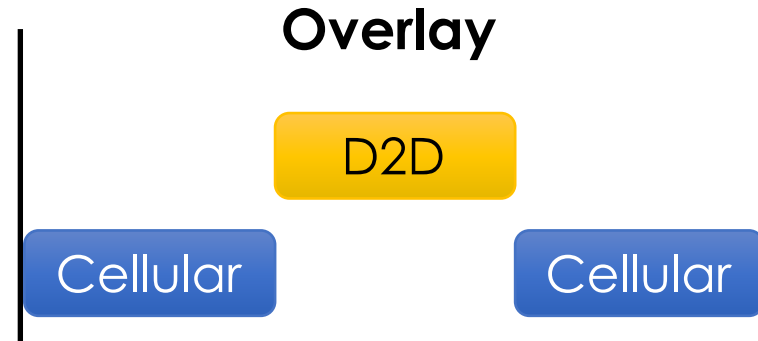
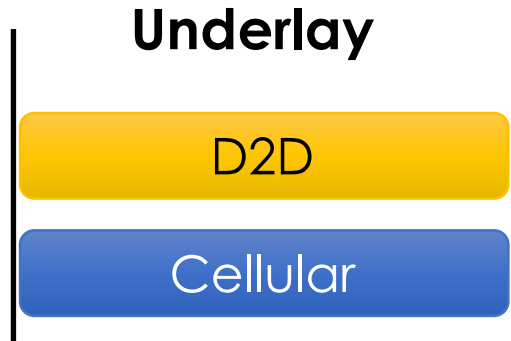
# Inter-link Interference in D2D



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

# Overlay and Underlay D2D

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- 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

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

# Disruptive Technologies

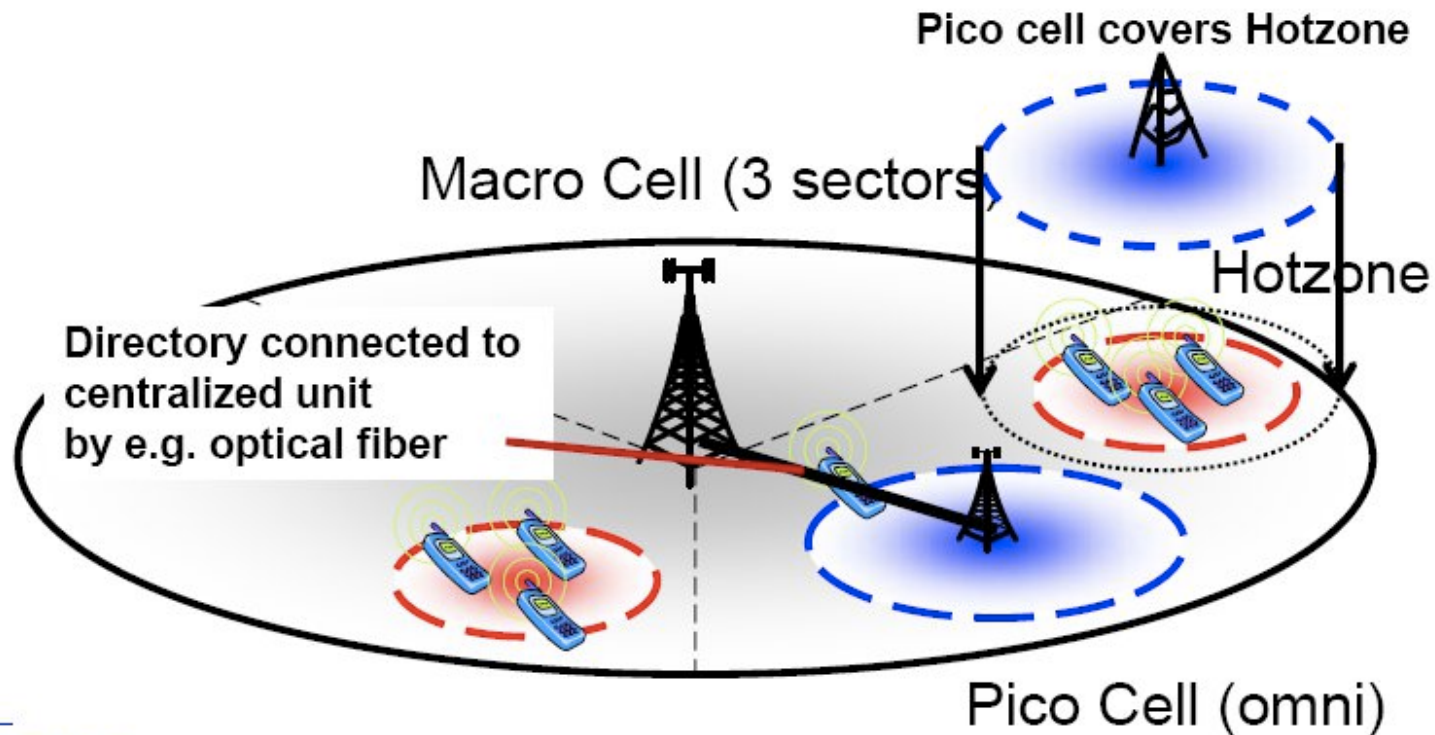
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- Massive MIMO
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# Heterogeneous Networks

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macro cell + pico cell + femto cell



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

# Comparison

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<b>Aspect</b>	<b>Picocell</b>	<b>Femtocell</b>
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

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- 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

# Disruptive Technologies

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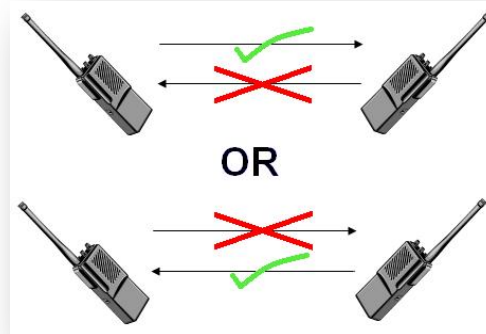
# What is Duplex?

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- Simplex



- Half-duplex



- Full-duplex



# Disruptive Technologies

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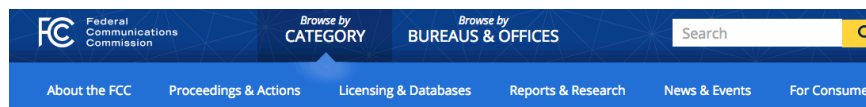
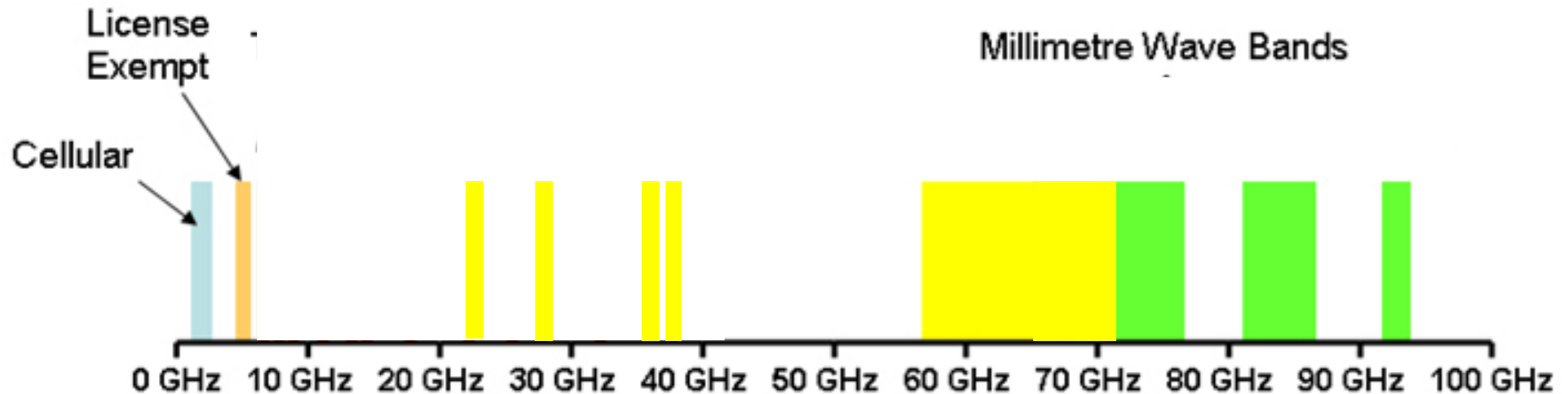
# Disruptive Technologies

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# Millimeter Wave Bands

- Huge amount of available bandwidth



Home / Commission Documents /

## FCC Promotes Higher Frequency Spectrum for Future Wireless Technology

Full Title

Use of Spectrum Bands Above 24 GHz For Mobile Radio Services

Description

FCC proposes new rules to make spectrum bands above 24 GHz available for mobile and other services

Document Type: Notice of Proposed Rulemaking

Document Dates

Released On: Oct 23, 2015

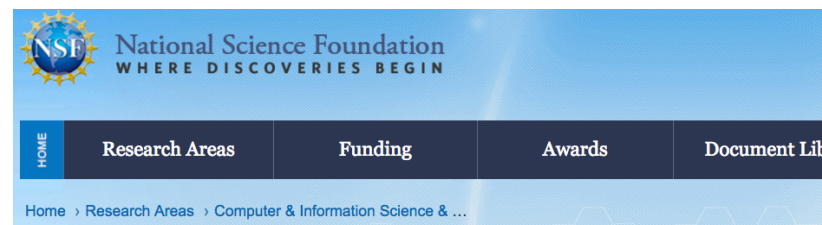
Comment: Jan 26, 2016

Adopted On: Oct 22, 2015

Issued On: Oct 23, 2015

Document Numbers

DA/FCC: FCC-15-138



Home > Research Areas > Computer & Information Science & ...

## Advanced Wireless Research Initiative @ NSF

The [Advanced Wireless Research Initiative](#) will sustain United States leadership in wireless communications and tech and development.

The National Science Foundation's (NSF) [leadership of this Initiative](#) has three intertwined components:

- Establishing **platforms for advanced wireless research** enabled by a new industry consortium and engagement
- Supporting **fundamental research enabling advanced wireless technologies**; and
- Catalyzing **academic, industry, and community leaders** to work together to prototype innovative wireless app

These efforts will provide new insights capable of making wireless communication faster, smarter, more responsive, a

# mmWave Wireless Applications



5G Cellular Networks



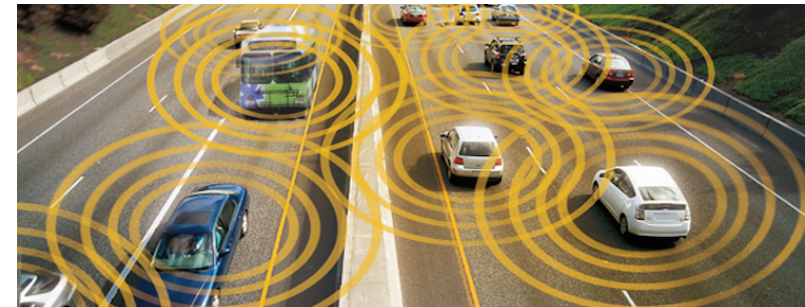
Wireless Data Centers



Wireless LANs 802.11ad



Wireless Virtual/ Augmented Reality



Connected Vehicles



Gesture Recognition