5G Vison and Research on Massive Mimo

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Evolution of Wireless Access Technologies

Outline

1 Scenarios of 5G

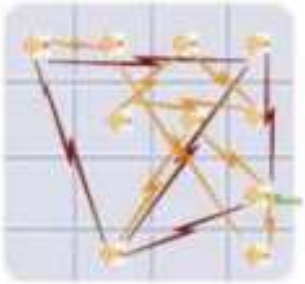
2 Research for 5G

3 Solid Step Toward 5G

5G- What Is the Industry Horizon

Amazingly Fast: Virtual Reality Office

Tele-Presence
As-if-they-were
here



Cloud Services and Applications

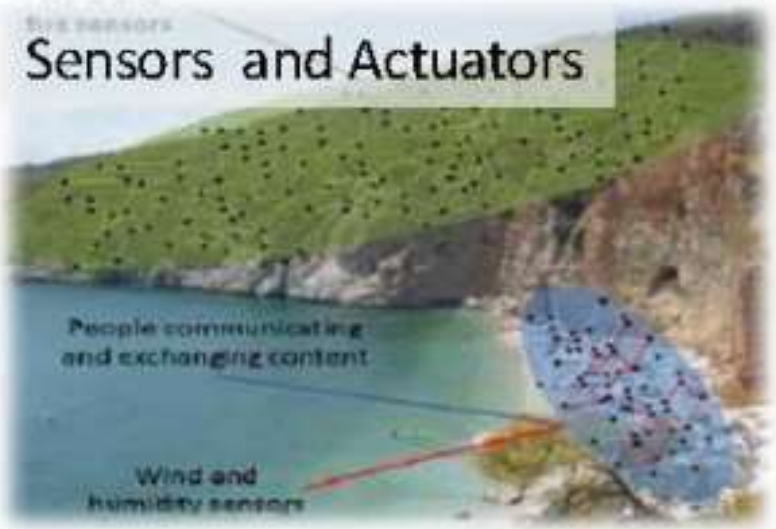
Tele-Immersion
As-if-you-were
there

Great Service in a Crowd:Stadium, Open Air Festival

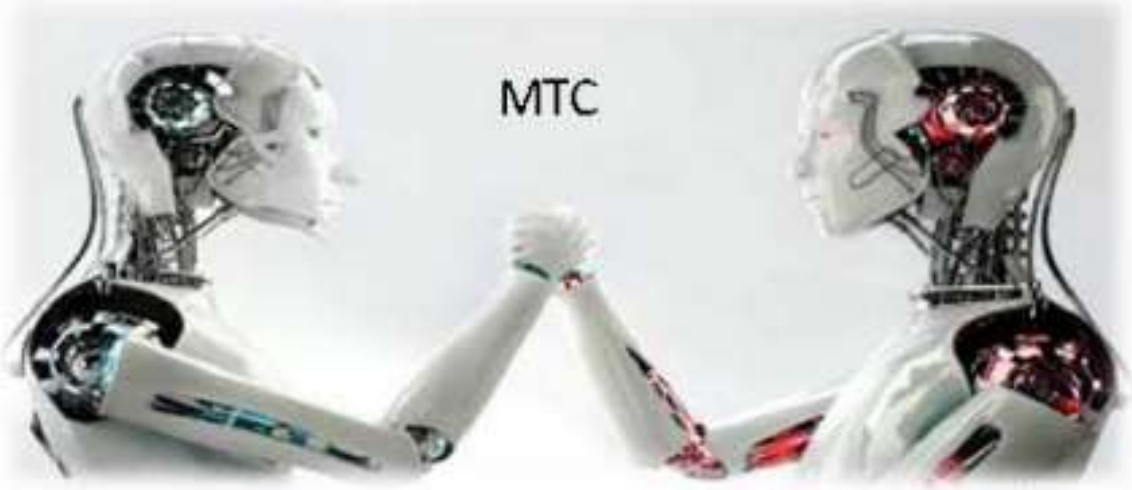
Watching, Exchanging Multi-Media Contents

Enjoy Infotainment Applications

Ubiquitous Things Communication:M2M



Wearable Device

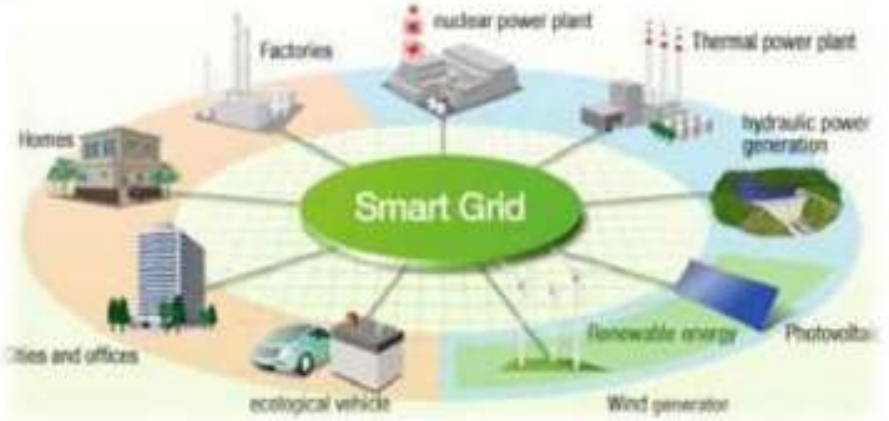


Intelligent Home Automation

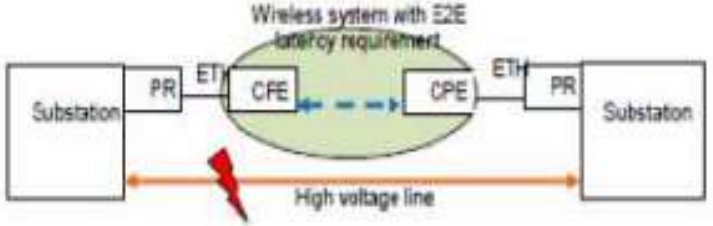
Best Experience Follows You:Ubiquitous MBB

Super Real -Time and Reliable Connection: Traffic Safety, Traffic Efficiency and Smart-Grid

Traffic Efficiency and Security



Tele-Protection of Smart Grid



PR: Protective Relay
CPE: Customer Premises Equipment
ETH: Ethernet

Failure/Damage info. send to other substations in a few ms to prevent cascading failure or damage.

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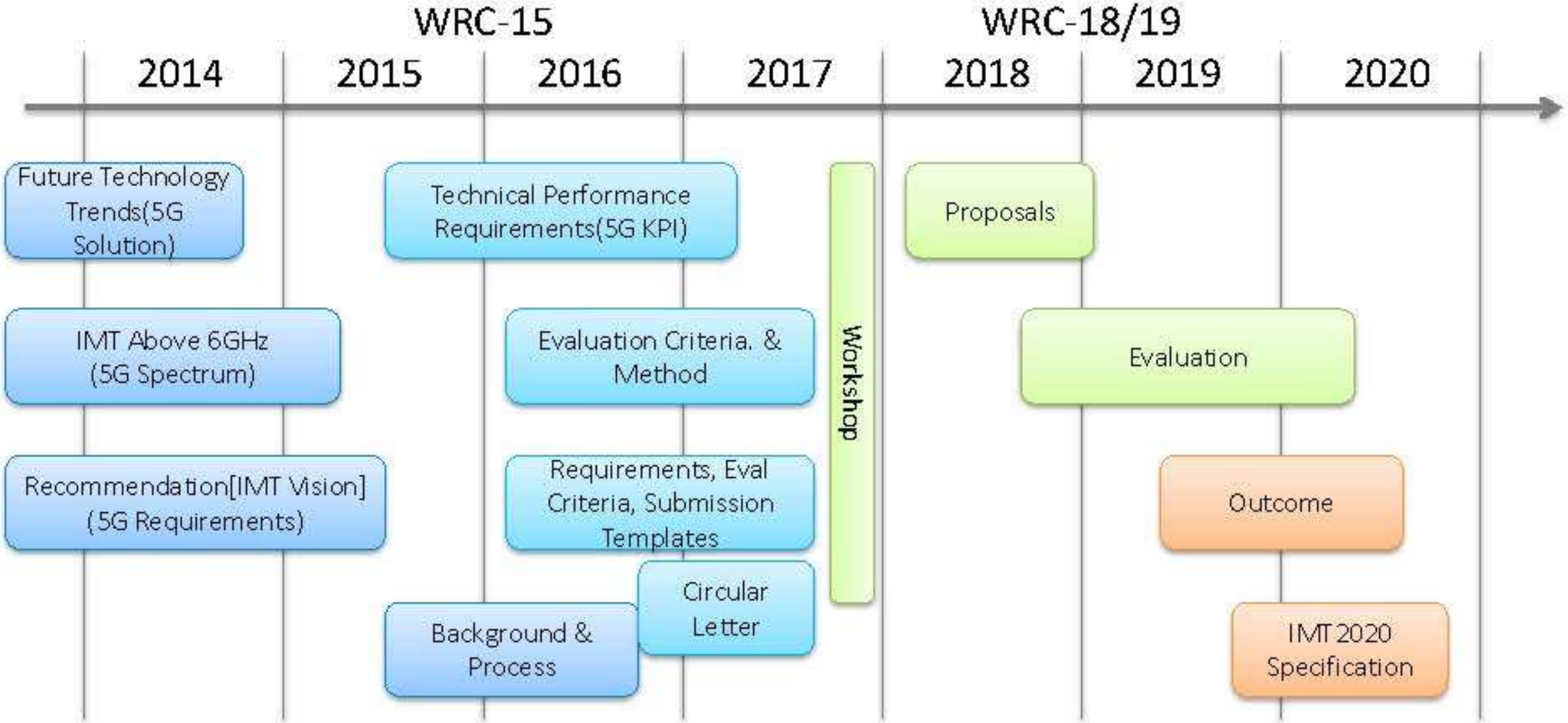
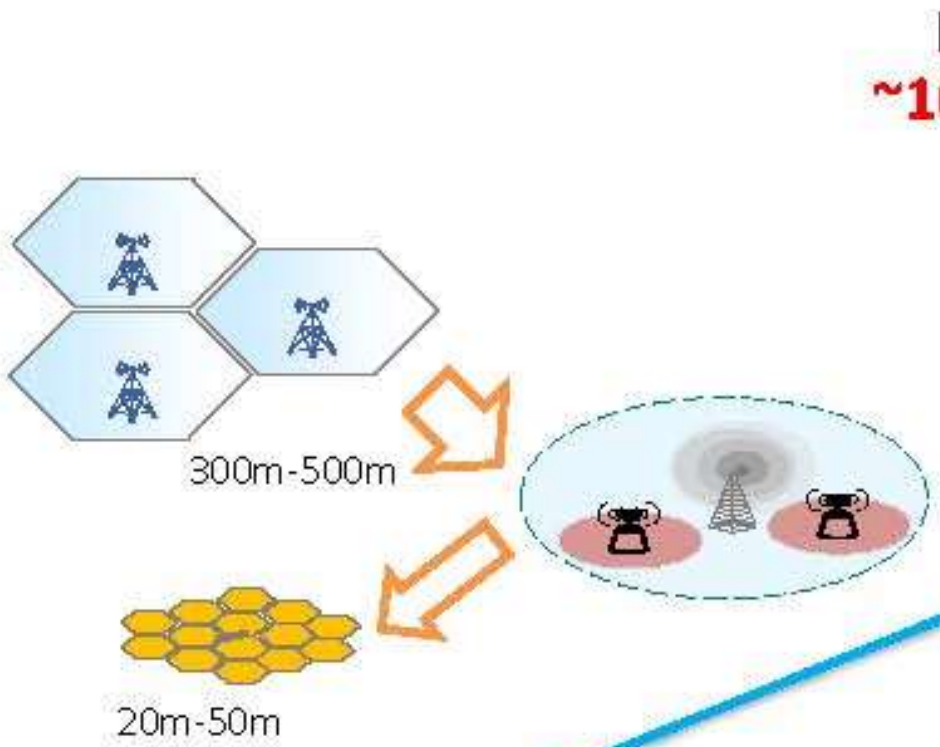
ITU 5G Standard Timetable

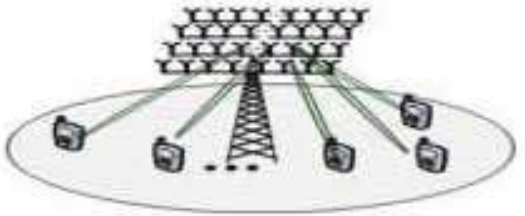


1000X -Spectrum/Efficiency/Sites



Higher Spectrum Efficiency

~10X



- Massive MIMO
- Multi-Site/Multi-Layer Coordination
- Advanced Interference Mitigation
- Co-time Co-Frequency Duplex, Network Coding

More Spectrum

~5X

Spectrum expansion: from 300~500MHz to 1500MHz

- Spectrum at High Frequency
- Larger Carrier Bandwidths, Enhanced CA
- Cognitive Radio, Authorized/Licensed Shared Access

More Sites

>20X

- Ultra Dense Network
- Multi-Connections
- Virtual Cell, D2D, Multi-hop

More Spectrum: New Spectrums Analysis

Existing Spectrum	Available Frequency	Comments
Existing Spectrum	IMT 1000M:700M-1G,1.7-2.4G,WiFi(2.42-2.4835G)	utilization<50%, maximum1.5 times availability
Television Spectrum	400M（470-790M）, varies in different countries	200M used , 100M left (TBD)

New Spectrum				
2.6G (2500-2690)	3.5G(3399.5-3431;3499-3531)	5G(4.9-5,5.03-5.09, 5.15-5.35, 5.47-5.725, 5.725-5.850)	6G-15G, 26-38G, 45G (40.5-47)	60G (57-64.7G)
190M	31.5M*2	740M	6.5G	7.7G

Very High Frequencies

- On top of the obvious capacity increase, very high frequencies (even at 28 GHz) would allow massive NxN MIMO fit into devices.

White Space

- Accurate geo-location databases would optimize spectrum geographic usage
- DSA (Dynamic Spectrum Access) may enable operator coordination for shared spectrum resource.

Ofcom

Cognitive Radios

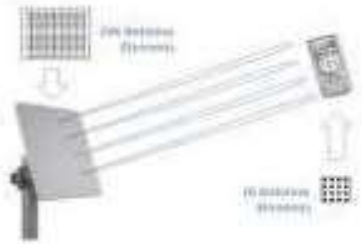
- Equipment sensing the radio environment and changing configuration thanks to SDR capability.
- Connected but not strictly required by DSA.

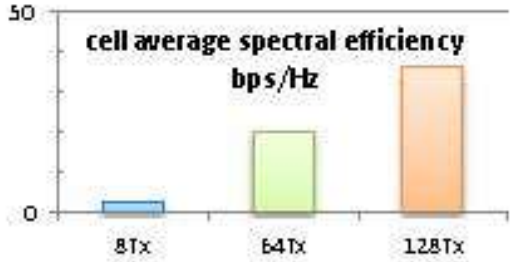
Spectrum Efficiency Improvement

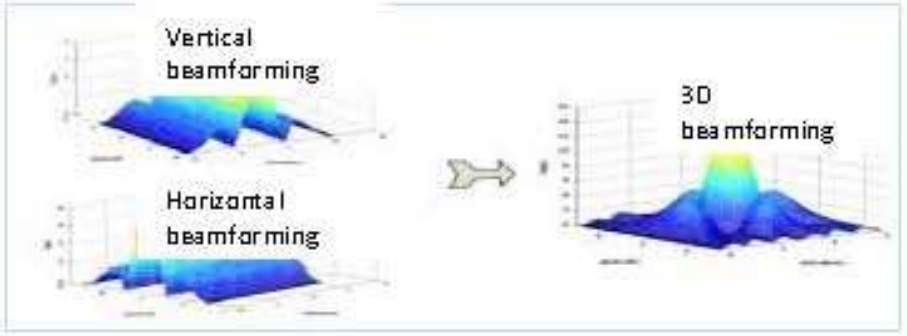
MASSIVE MIMO

◆**Capacity Boost**
- More antenna, more streams, higher capacity gain
- Precise beam-forming and interference cancelation

◆**Coverage Extension/Energy Saving**
- Power concentrated in desired direction
- User tracing and multipath diversity







Other Technologies

◆ **Different Technology for Different Applications**
- **Machine Type Communication: NOMA**
- **Cognitive Radio: FBMC**

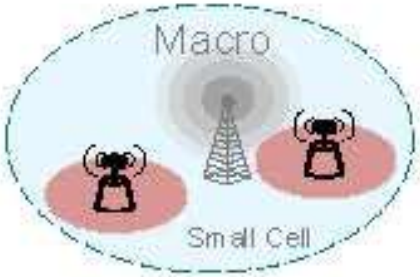
◆ **More Knowledge of Interference**
- **instantaneous and interactive**
- **More advanced nonlinear receiver**
- **Interference alignment**

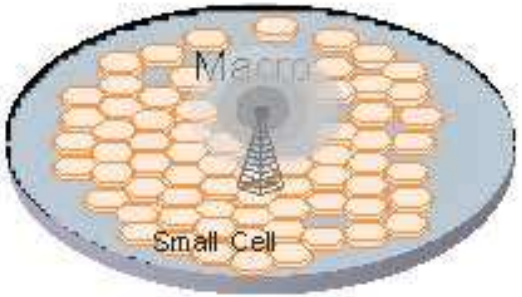
◆ **Advanced coding and modulation**
- **Network coding**

◆**Decoupled Control/User Plane**

◆**Co-time Co-frequency Full Duplex**

Super Dense Small Cells in Hot Points





Homogeneous network

- Only macro nodes, Independent processing
- Focus on coverage

Heterogeneous network

- Coverage and capacity Enhancement
- inter-cell coordination

Virtual cell network

- Huge capacity
- Cloud processing and in-depth coordination

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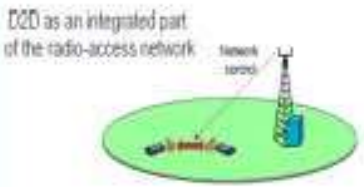
New Services and Applications of 5G

MTC

- Connection of huge wireless sensors/actuators/devices
- Diversity Requirements
- Typically Low data traffic
- Low cost and low energy consumption

D2D



- Direct D2D communication, Focus on network-assisted proximity-detection first
- Applications: Traffic safety, Local data transfer, social networking, proximity-enabled communication.

Moving Network

- Vehicle-to-X communications
- In-vehicle communication and networking
- Moving and Nomadic download or data sharing

URC

- Improve reliability through: Redundant topologies, robust transmission schemes, resilient protocols
- Make wireless as reliable as fixed network

New Service – MTC

Machine Type Communication/MMC(Massive Machine Communication)/M2M(Machine to Machine)

Various Scenarios

e-Healthy

Smart Grid

i-Industry

i-Agriculture

Smart Home

Smart Logistic

Diversity Requirements

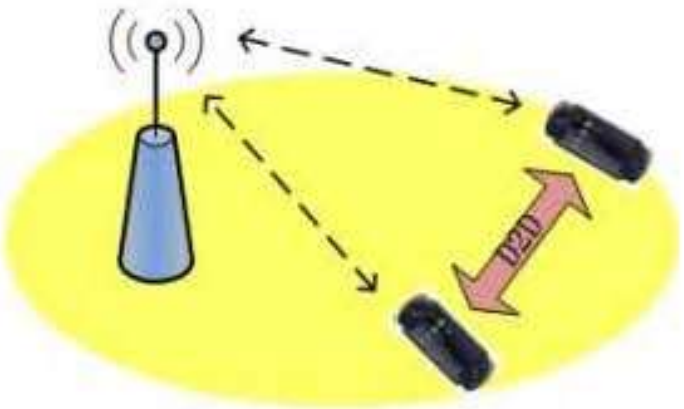
Optional Architecture

- Optimization of Macro Network
- M2M Gateway +Macro Network
- M2M Gateway +App Layer +Macro Network
- Multi-Hop, Mesh Network

New Service - D2D

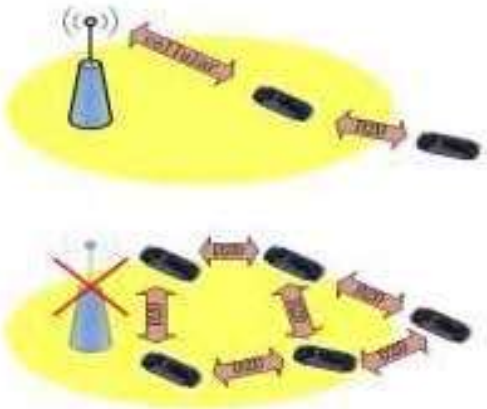
Local Service

Social Networking
Local Traffic
Cellular Offloading



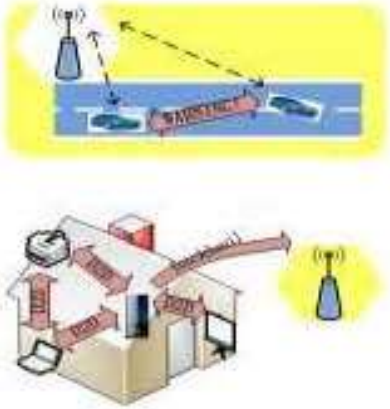
Communication in case of Emergency

relaying
Mesh Network



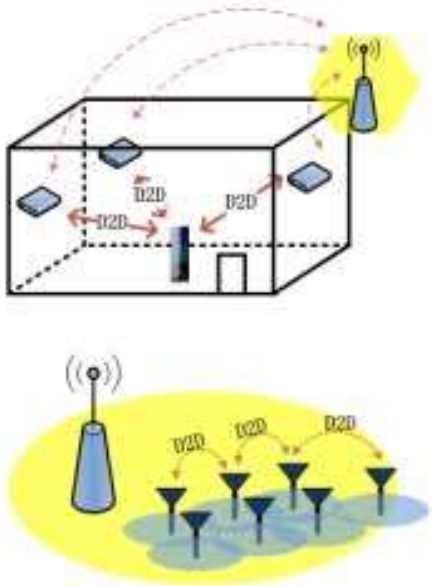
Enhanced IoT

V2V
Smart Home
Electronic Payment



Others

Indoor positioning
...

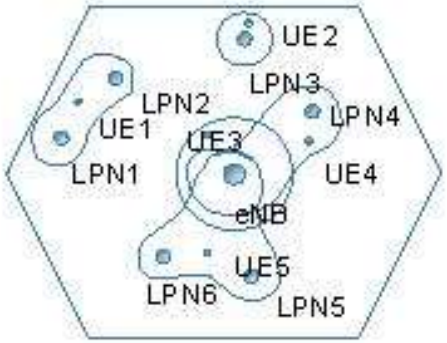


Direct Device Communication → Multi-Hop, Mesh Network → Optimization for Specific application

New Service – Moving Network

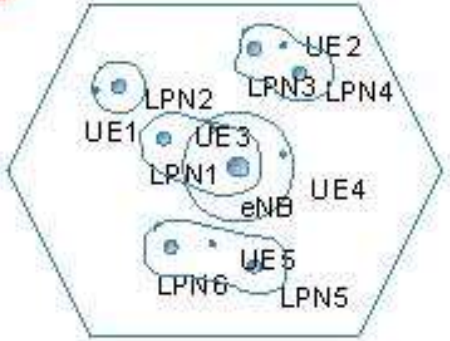
From Fixed BS to Mobile BS
From Fixed RN to Mobile RN

Out of Band Relay



Time 1

Amorphous cells



Time 2

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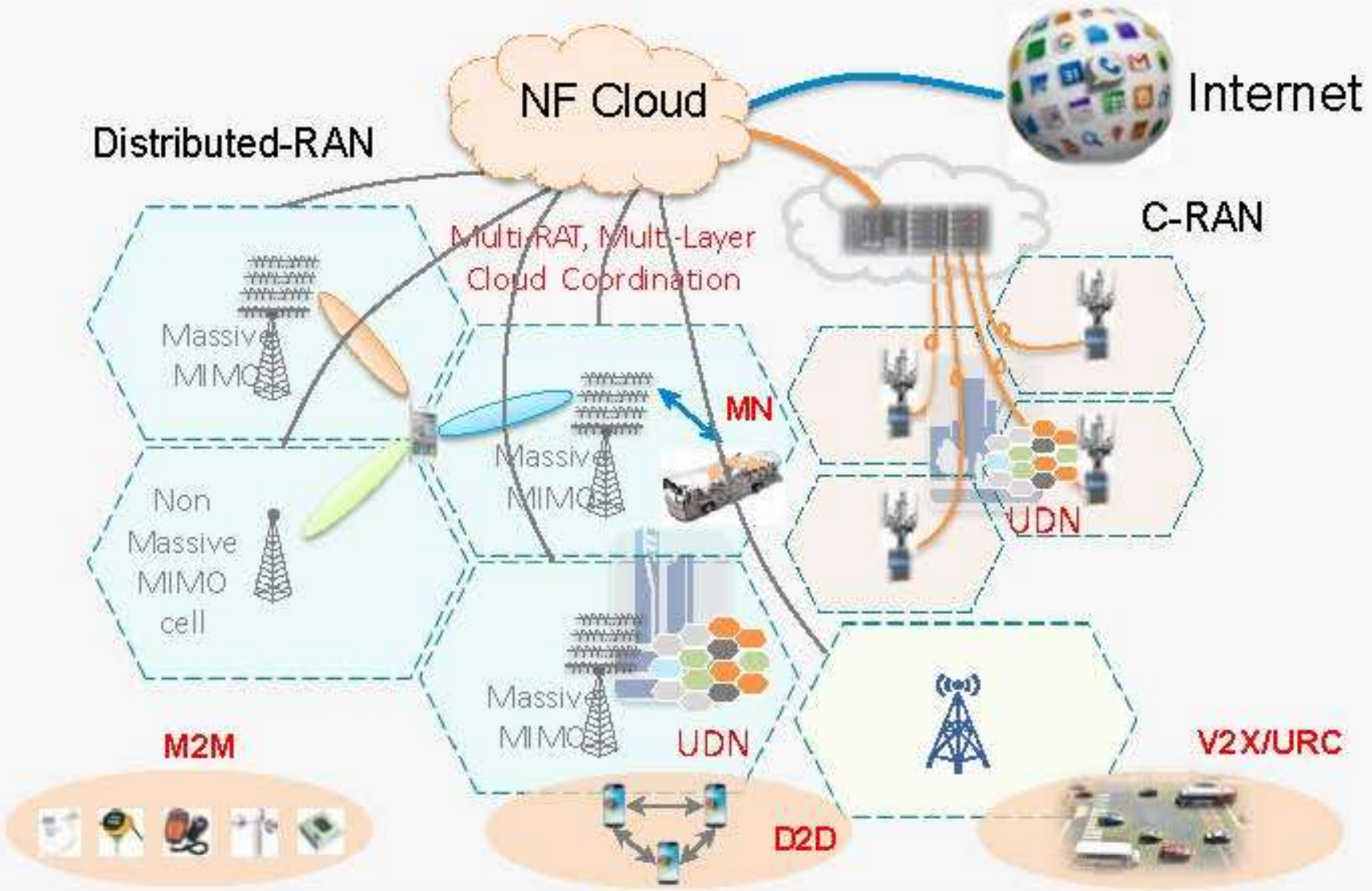
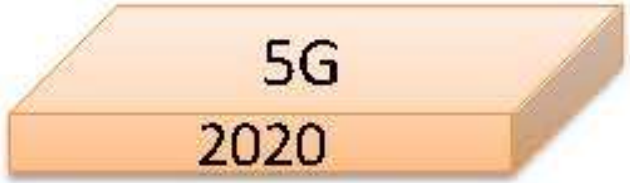
5G RAN Architecture

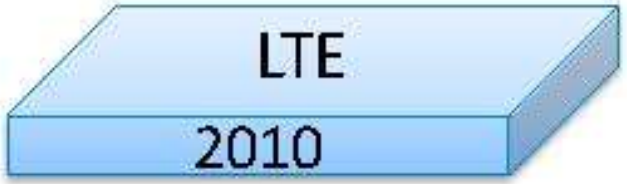


- Mixed Legacy Macro cell and Massive MIMO Cell
- Both Distributed and Centralized deployment
- Mixed macro cell, small cell and Ultra-Dense Cells (UDN)

Smooth Evolution From LTE to 5G



- Offer 5G-like Experience
- Using 5G Technologies
- Compatible with 4G UE
- Available from 2015



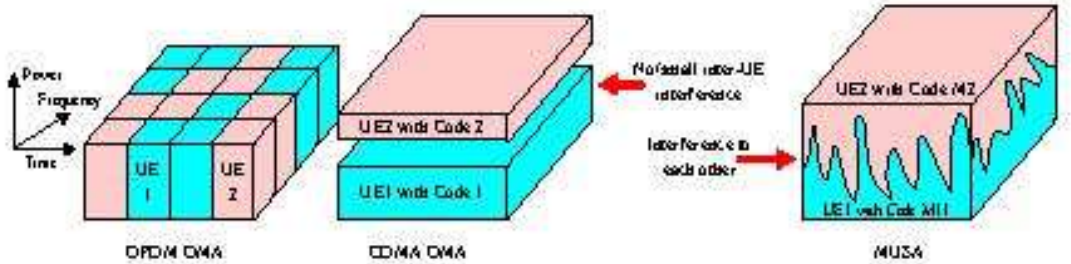
Pre-5G Brings Great Innovations

Regarding 64T64R Demo

- up to 8X Spectrum Efficiency
- Precise Beam-forming
- 4G UE Compatible

Massive MIMO

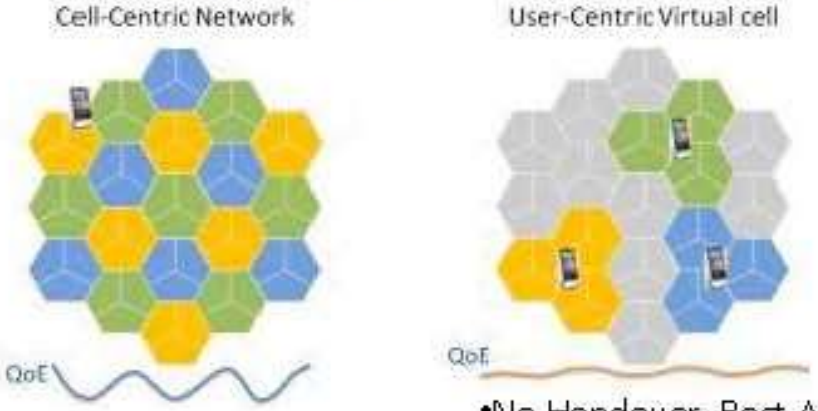
- Multiple User Reuse the Same DOF
- Over 300% Overload (Scheduler Free)



Multi-User Shared Access

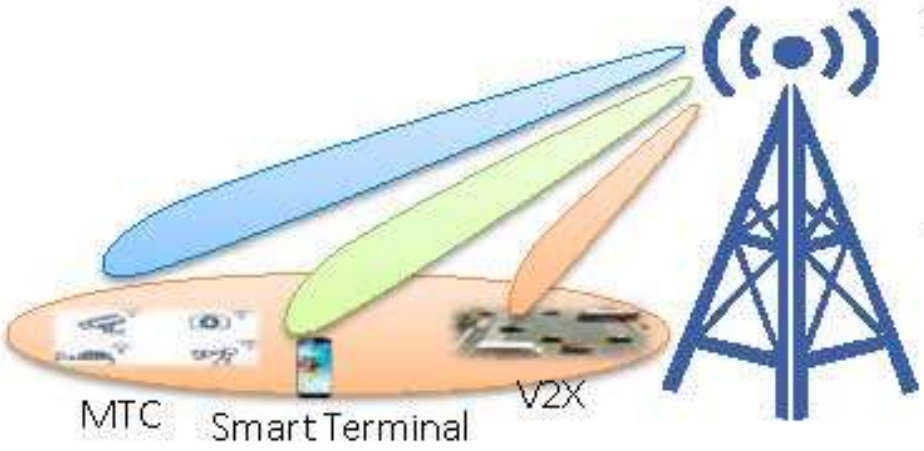
Pre-5G

Virtual Cell



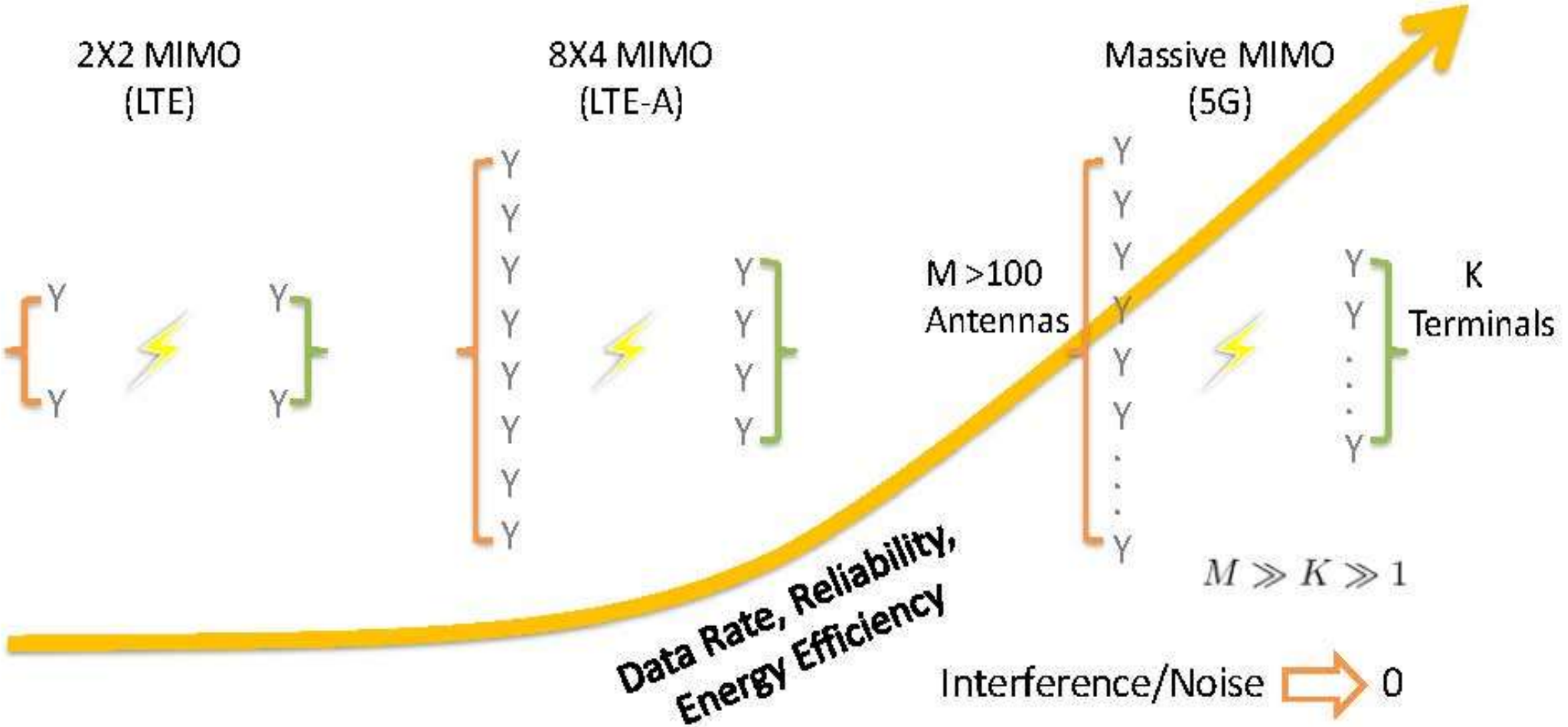
- No Handover, Best Access Service wherever You are

Software Defined Air Interface



- Flexible Combination of ANY Standard
- One N.W. for Diversity 5G Applications

From 2X2 MIMO to Massive MIMO



What's Massive MIMO ?

Pre-5G Base Station

Include Antenna, RF, and Baseband

Over 100 Antennas

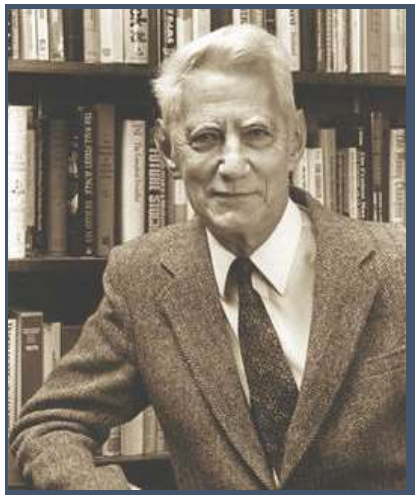
- User-level Beam-forming
- Low Interference
- Energy Saving

More Streams

- Higher System Capacity
- Higher User Throughput

Legacy UE Compatible

- Fast Time-to-Market
- Smooth Evolution to 5G



Shannon Limit

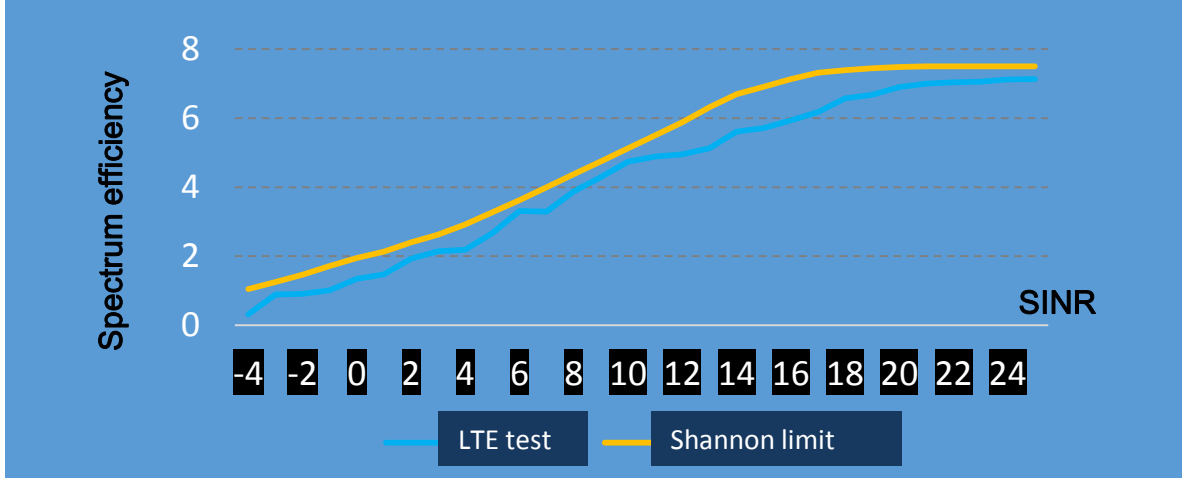
$$C = \log_2 (1 + P_T / N_0) \ \text{bits/Hz/s}$$

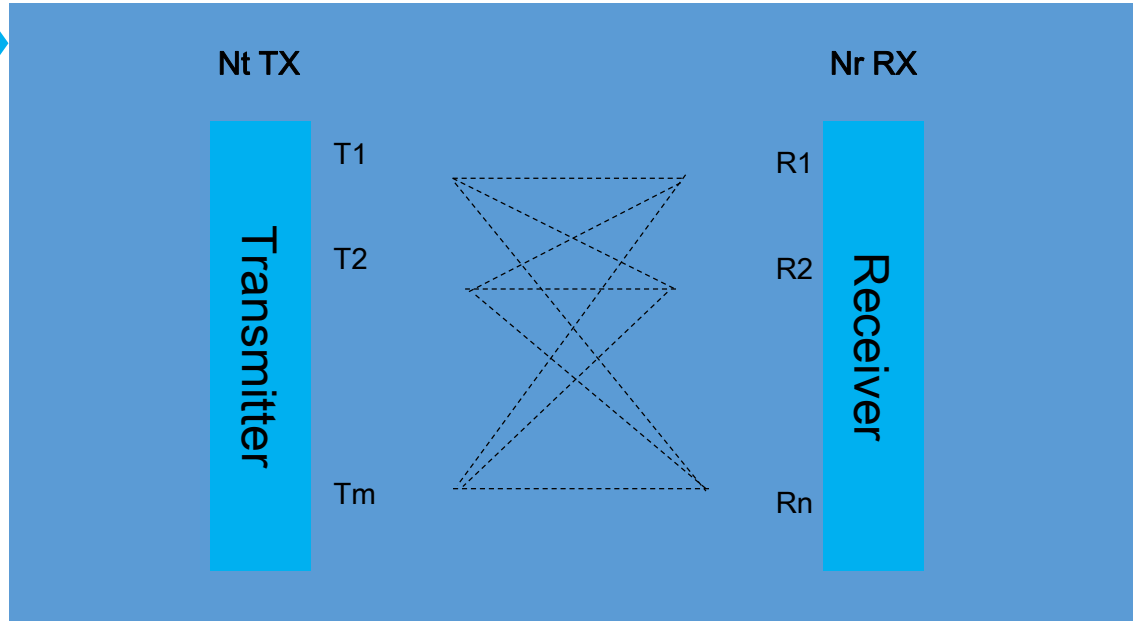
More capacity is possible

by Massive MIMO with spatial multiplexing

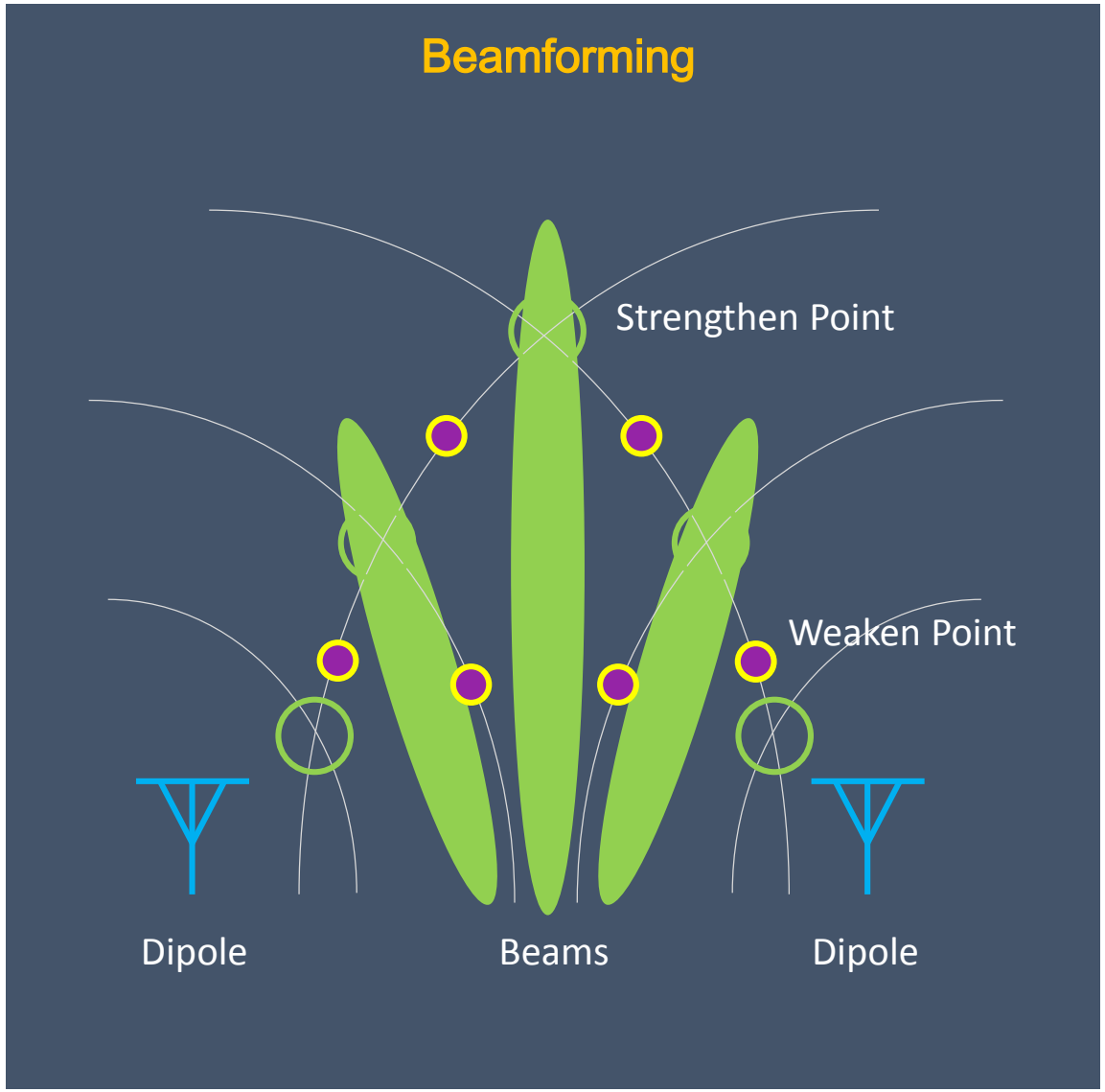
$$C = \min(n_t, n_r) \log_2 (1 + P_T / N_0)$$

LTE performance is close to Shannon Limit with given number of TRX

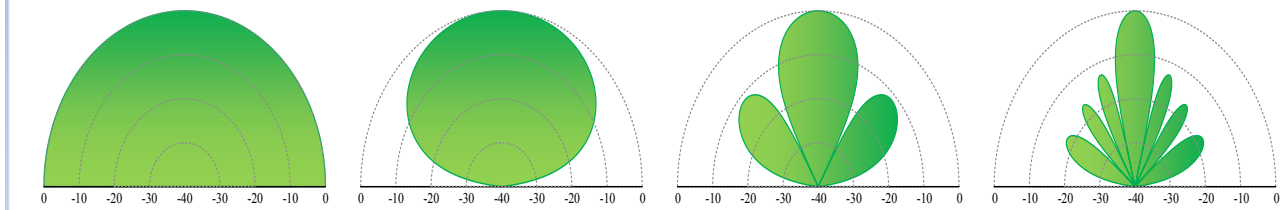




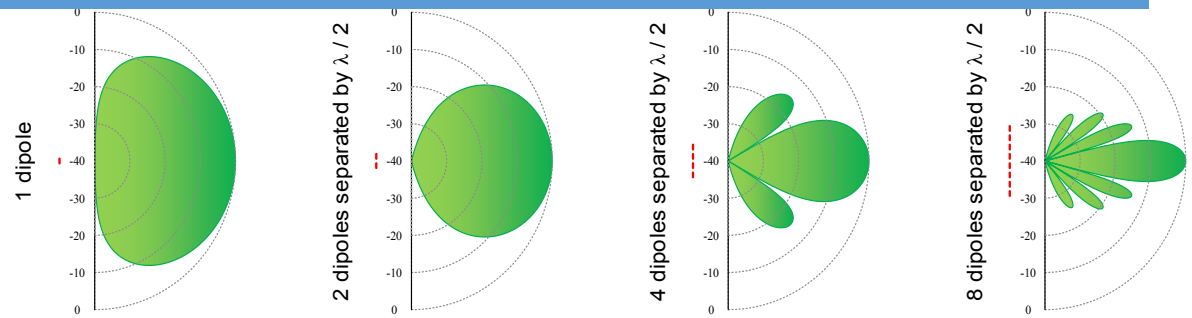
Beamforming Made Possible with



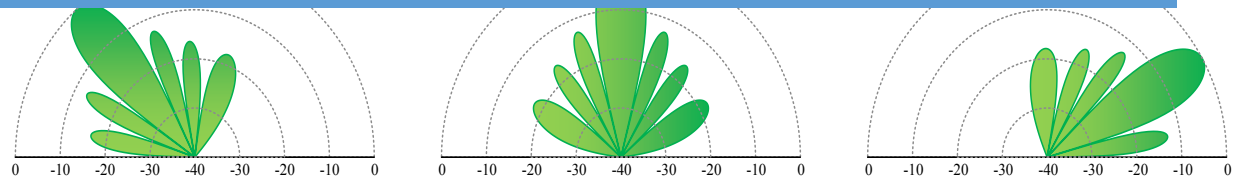
Horizontal Pattern of 1/2/4/8 Half Wavelength Dipole



Vertical Pattern of 1/2/4/8 Half Wavelength Dipole



Different Beam Direction with Phase Shift

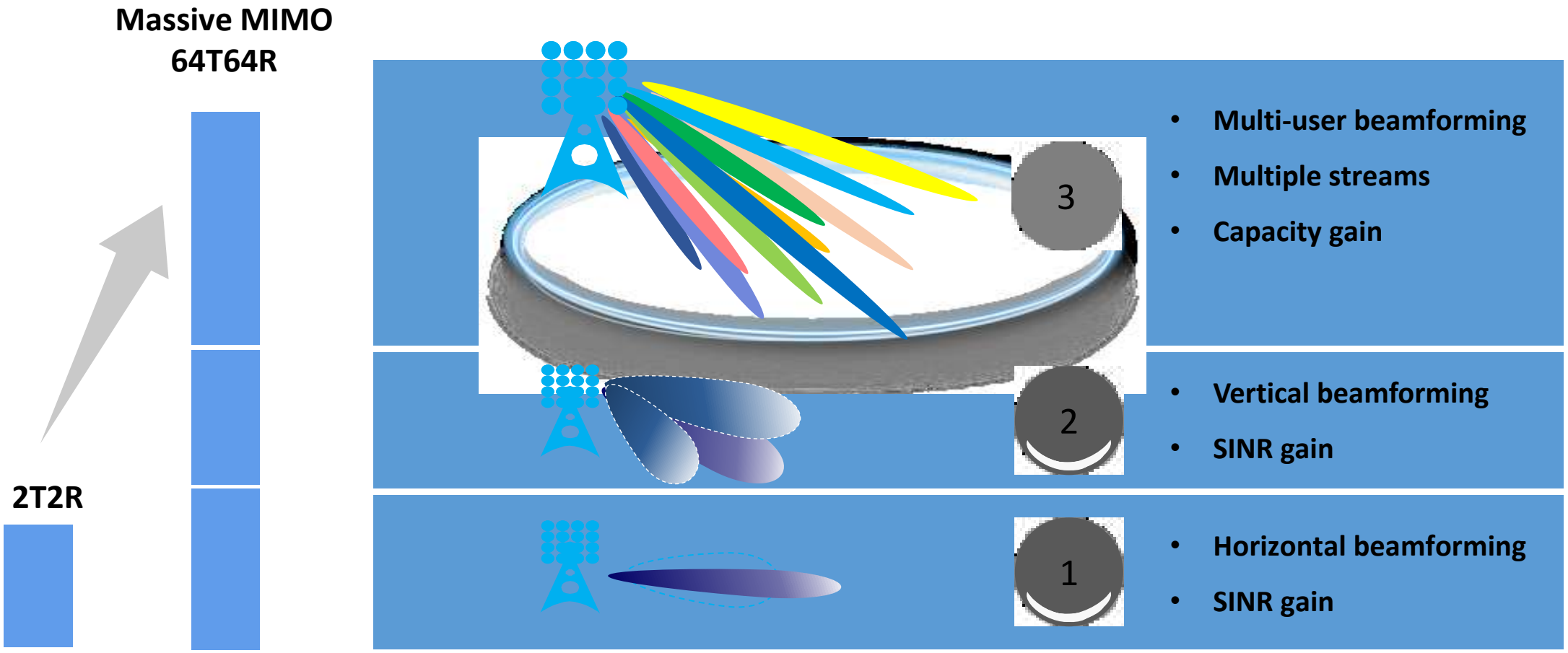


8 dipoles separated by λ / 2
-41° phase shift

8 dipoles separated by λ / 2
0° phase shift

8 dipoles separated by λ / 2
60° phase shift

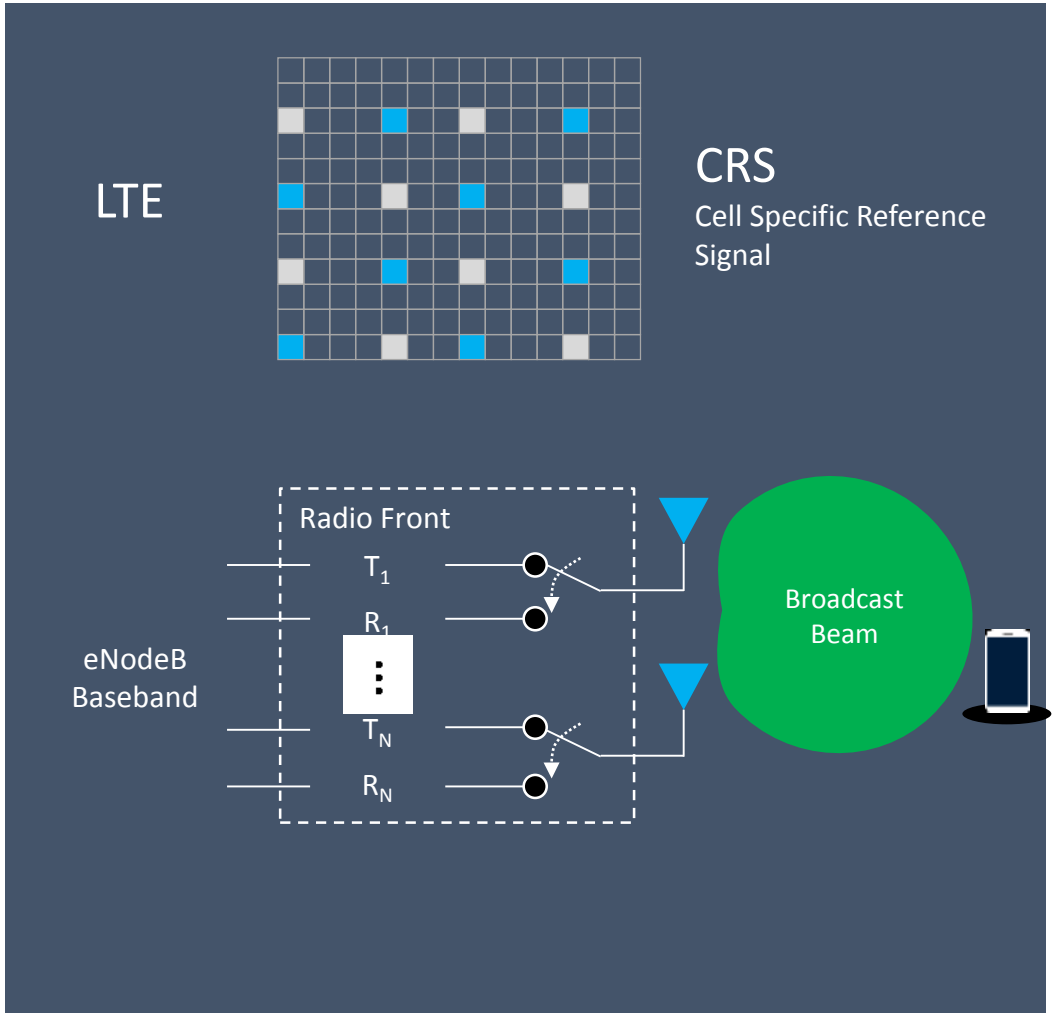
Massive MIMO Increase Spectrum Efficiency In Several Ways

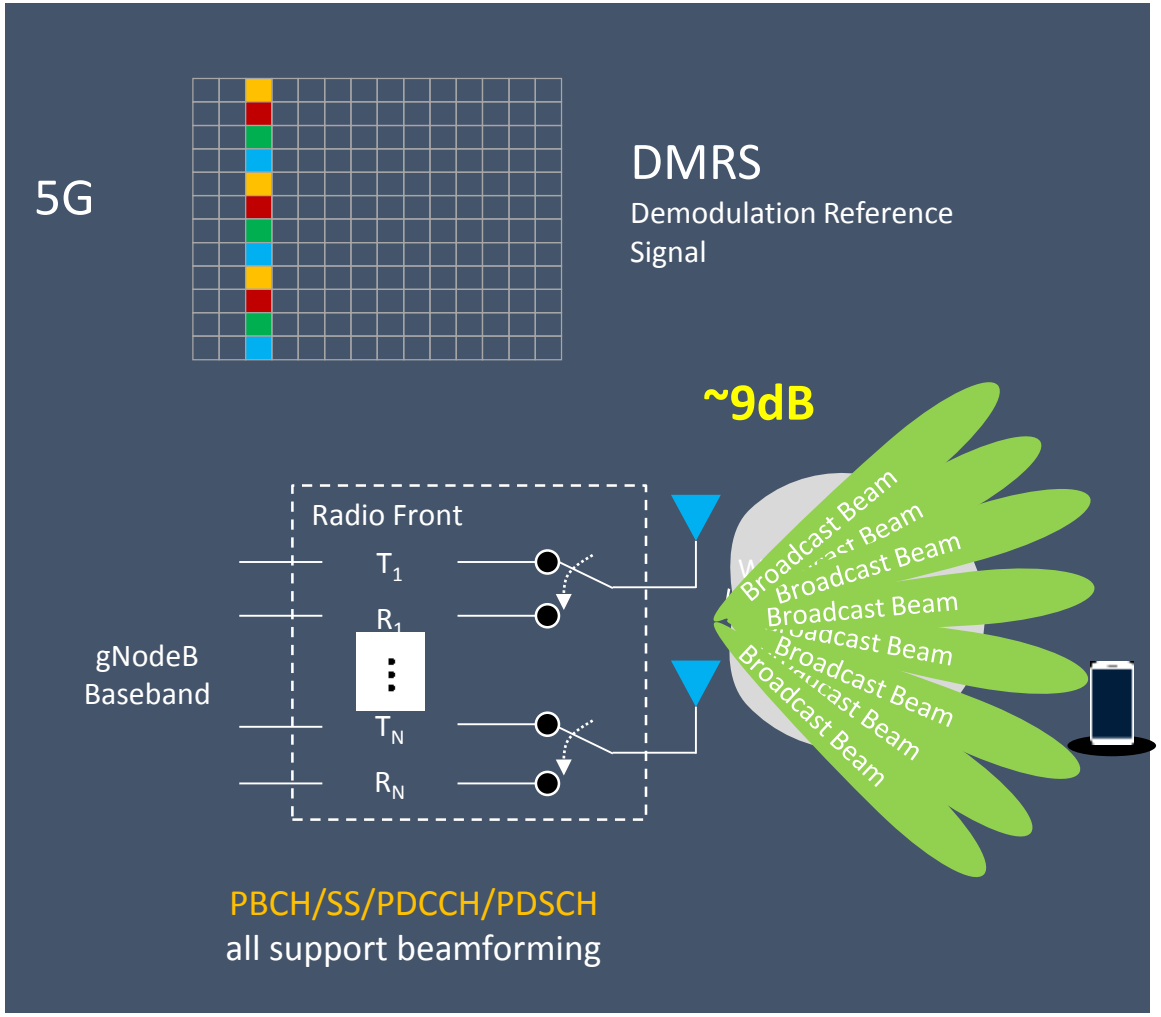


5G Massive MIMO Enhancement: Control Channels Support BF

LTE Broadcast beam is wide beam

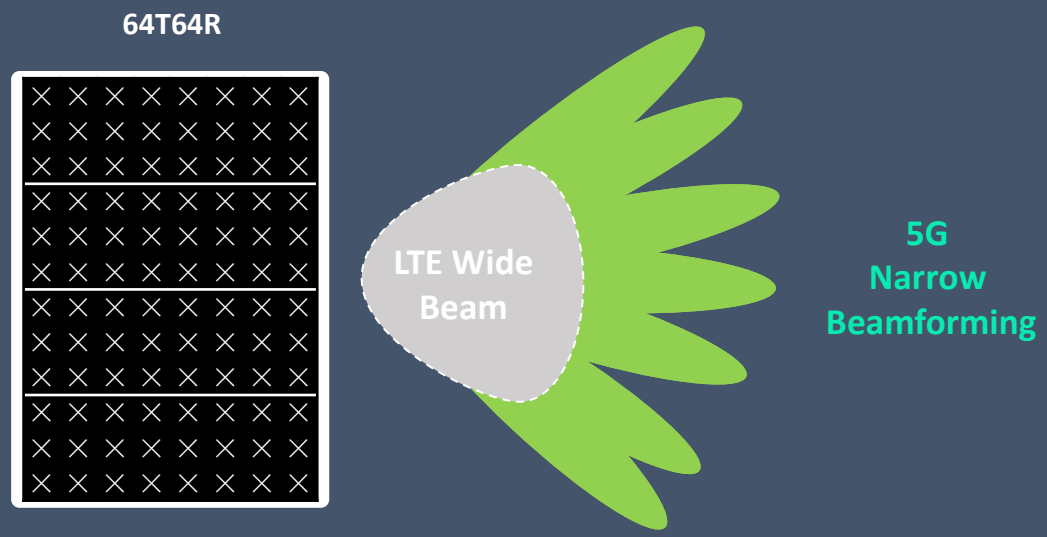
NR Broadcast beam is narrow beam (sweeping)





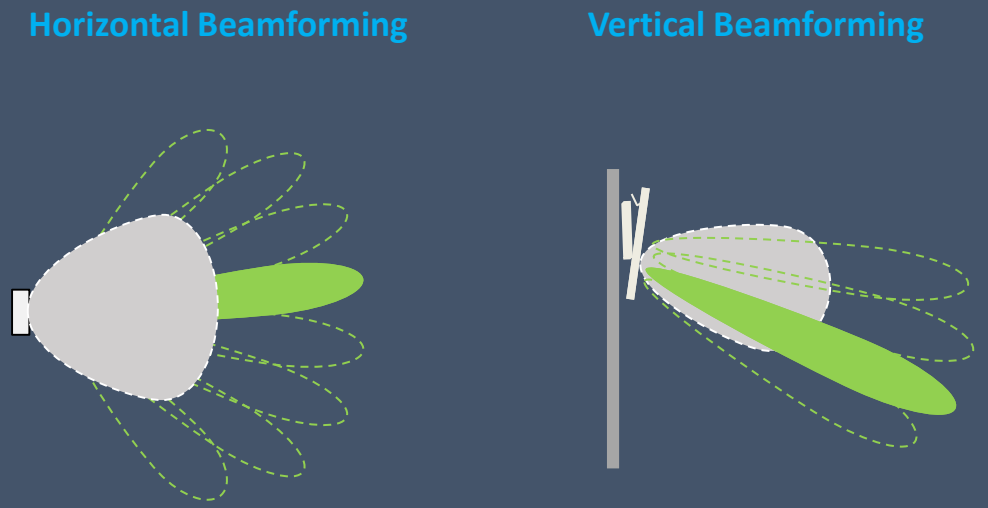
5G Massive MIMO Narrow Beam Design Enables 3D-Shaping

All Channels Beamforming in 5G NR



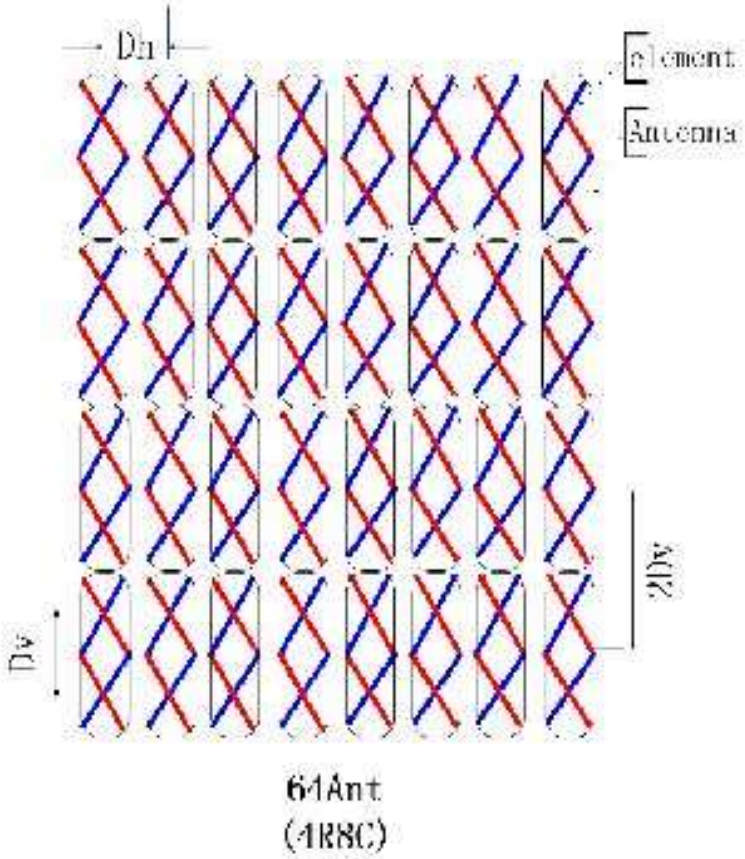
- Narrow beam by massive dipoles (64T/32T)
- Beamforming for BCH, SCH, CSI-RS to improve common channel coverage

3D Shaping Improves H+V Coverage

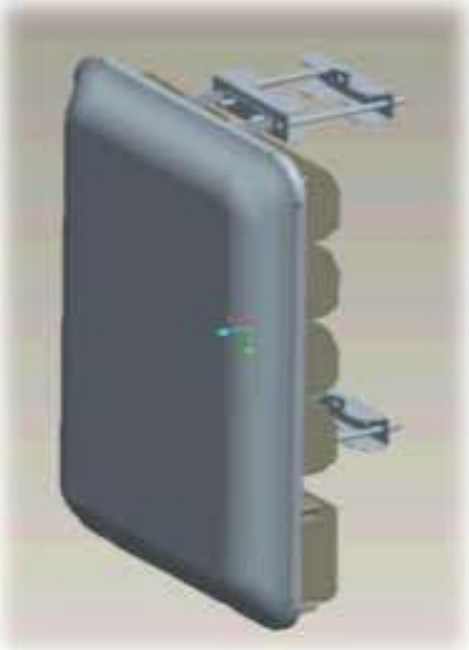


- More precise beam & scanned area, more coverage gain
- Higher user SINR and Better interference control

Massive MIMO Product Overview



4Row × 8Column
×2Polarization



- Band:2.6GHz
- Bandwidth: 20MHz
- Transmission Power： 40W/Carrier
- Weight: 40Kg

Windward Area is Less than 8 Antenna which was used in CMCC network.

Difference Between AAS and Massive MIMO

	AAS	Massive MIMO
Quantity of Antennas	16-32	128-256
Independent Channels	8-16	64-128
Beam Control	RF Part	Baseband
Beam Pattern	Simple Vertical Beam Splitting at Cell- level	3D Sharp Beam-forming at User-Level
Spectrum Efficiency	1.3X - 1.5X	8X - 10X
Coverage and Reliability	Good	Better
Key Technologies	Highly Integrated RF array	Highly Integrated RF array, Compressive Sensing, MU-MIMO, Adaptive Beam-forming etc.

(Trainer information)

Trainer: Wu Xiang

E-mail: wuxiang@caict.ac.cn

Department: Institute 0f Technology and Standard Research

Address: No.52 Huayuan Bei Road, Haidian District, Beijing

Photo：