GTI

Lessons from the 5G trials in China

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Introduction of GTI 1.0

Kicked off GTI in 2011

01

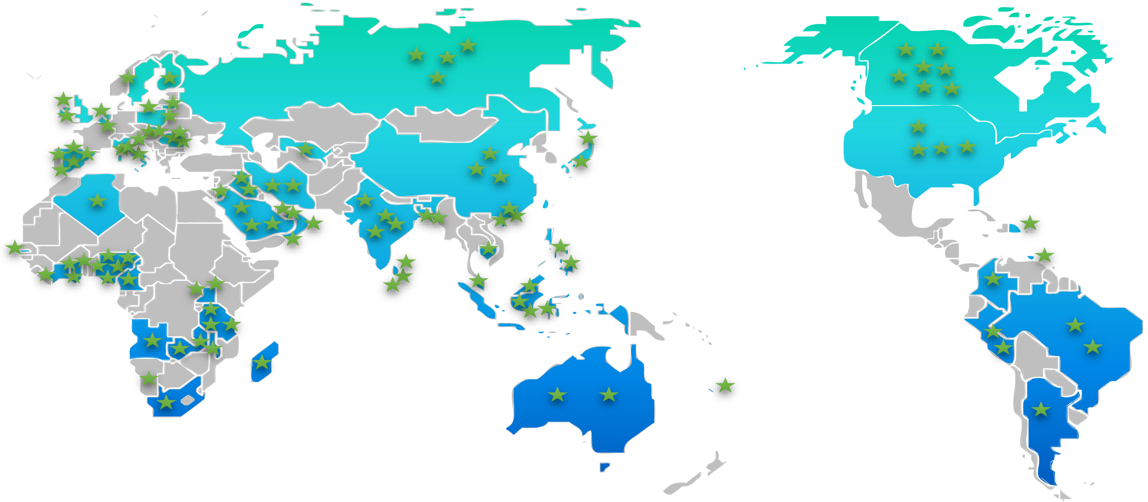
Successfully built global end-to-end
TD-LTE ecosystem

02

Successful global commercialization of TD-LTE

03

Successful convergence of TDD/FDD and initiation of joint operation



- ***122*** TD-LTE commercial networks in ***61***countries, and ***152*** TD-LTE commercial networks in ***77*** countries in progress
- ***2.96 million*** TD-LTE base stations (Q4, 2017)
- ***1.4 billion*** TD-LTE subscribers
- ***8014 TD-LTE*** terminals, ***66.8%*** supporting TDD/FDD

Source: GTI, TDIA and GSA
As of Q1, 2018

Opportunities from 5G

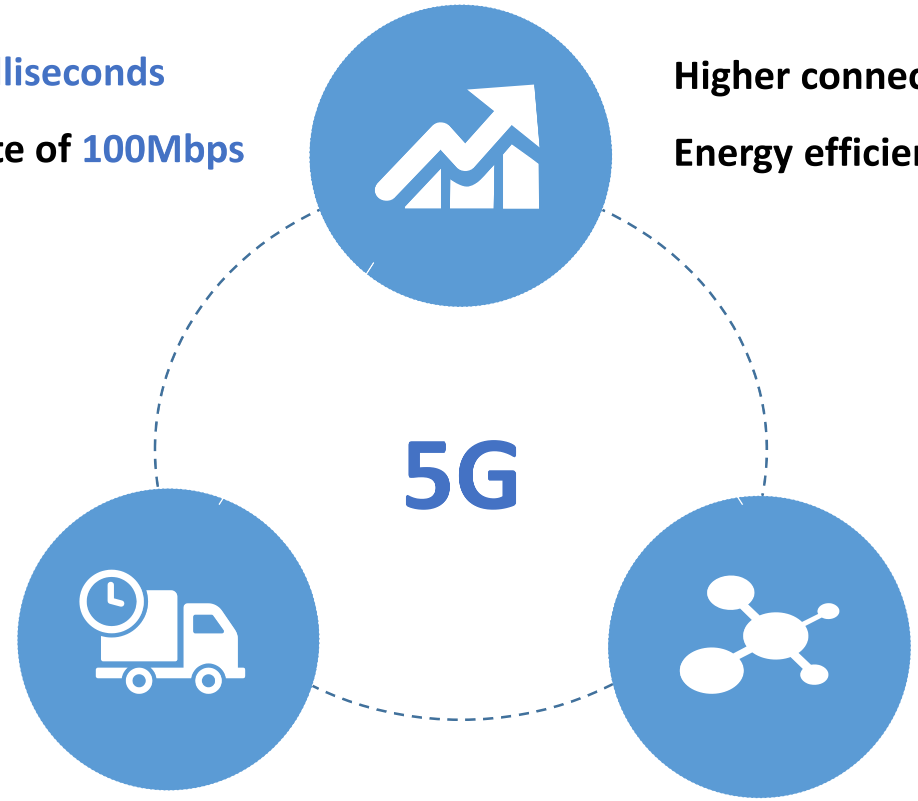
Higher Performance

Access latency in milliseconds

Experienced data rate of 100Mbps

Higher connection density 1 million connections/km^2

Energy efficiency as mush as 100+



More Scenarios

Enhanced Mobile Broadband (eMBB)

massive Machine Type Communications (mMTC)

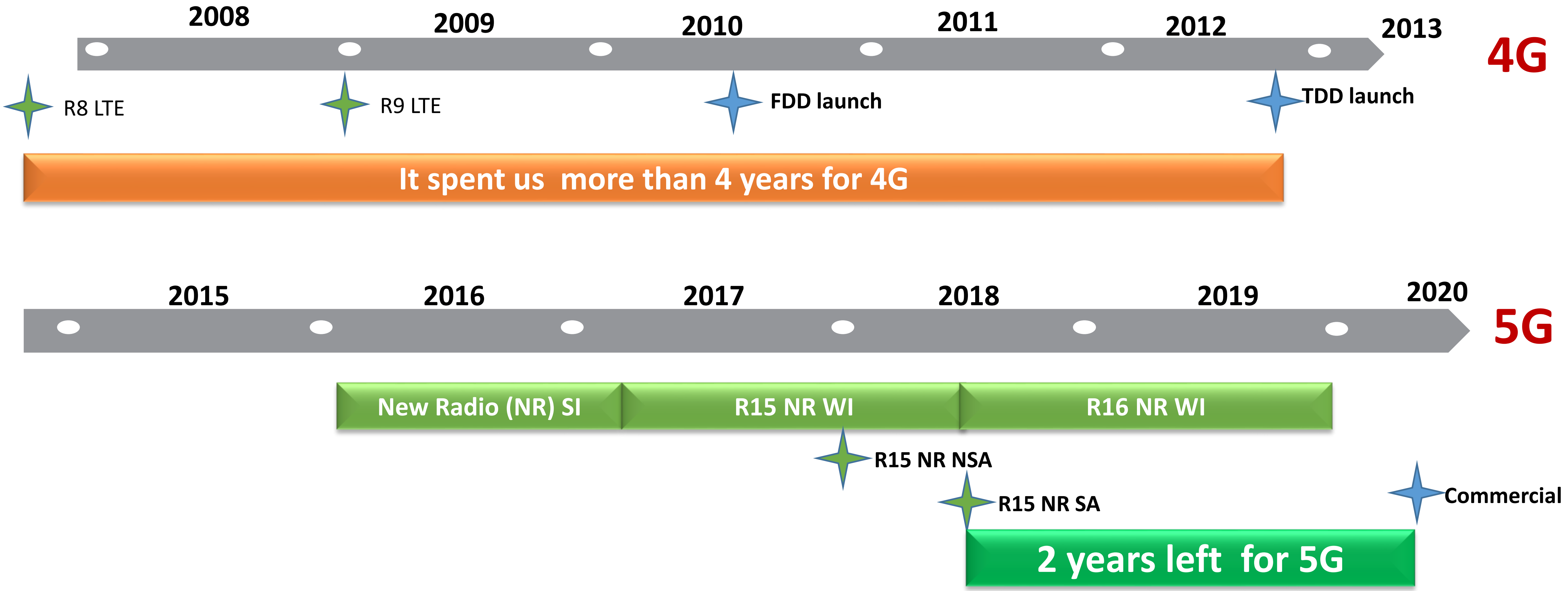
Ultra-Reliable and Low latency Communications (URLLC)

Brand-New Ecosystem

a cross-industry and shared ecosystem

Challenges for 5G Development (1)

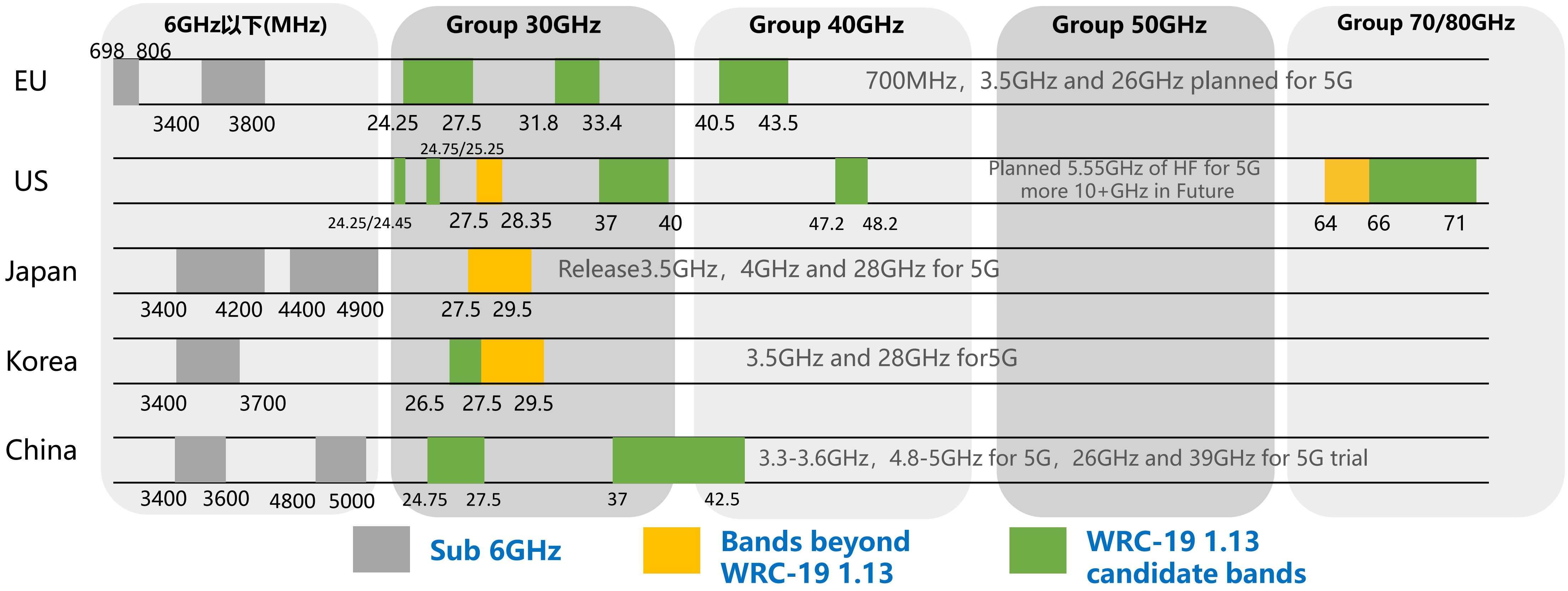
TIGHT SCHEDULE FOR INDUSTRIALIZATION



Challenges for 5G Development （2）

DIVERSE SPECTRUM: SUB 6GHZ VS. MM-WAVE

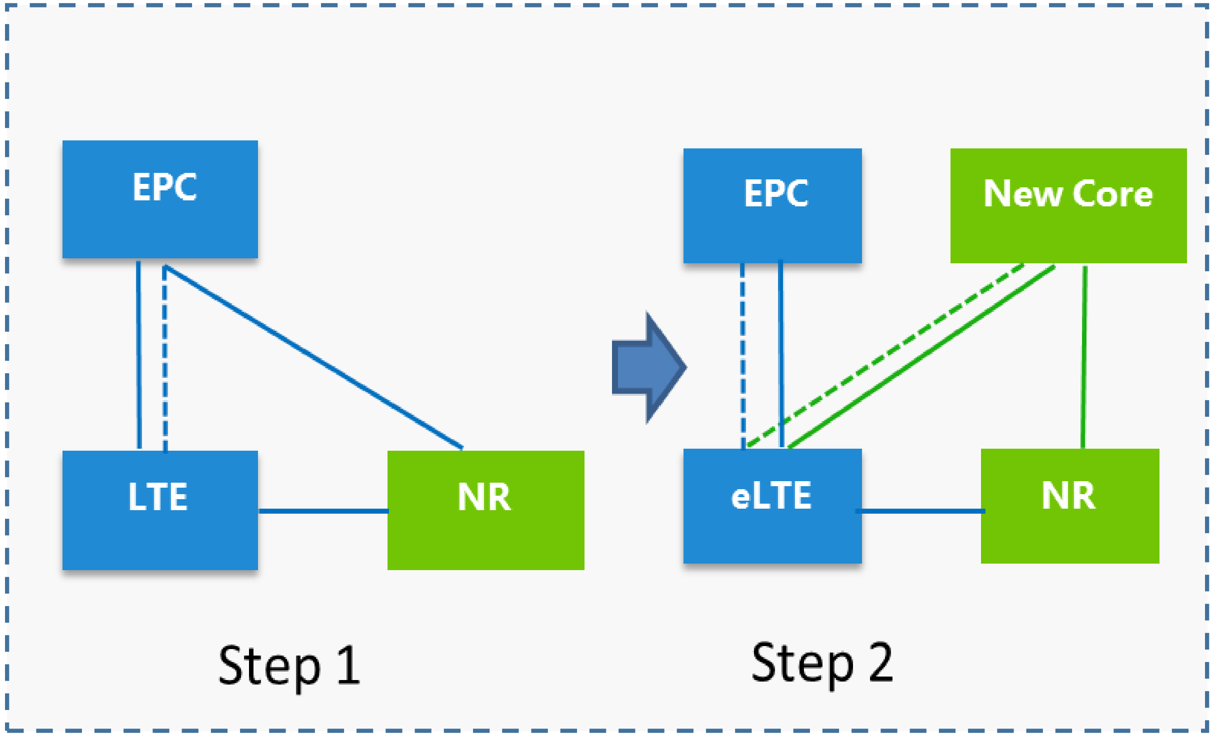
- **3.5GHz seems a global band with better coverage， above 6GHz (focus in 26GHz&40GHz) provides larger bandwidth**
- **US/Korea/Japan are interested in 28GHz, while other operators focus on C band first, e.g. 3.5GHz**



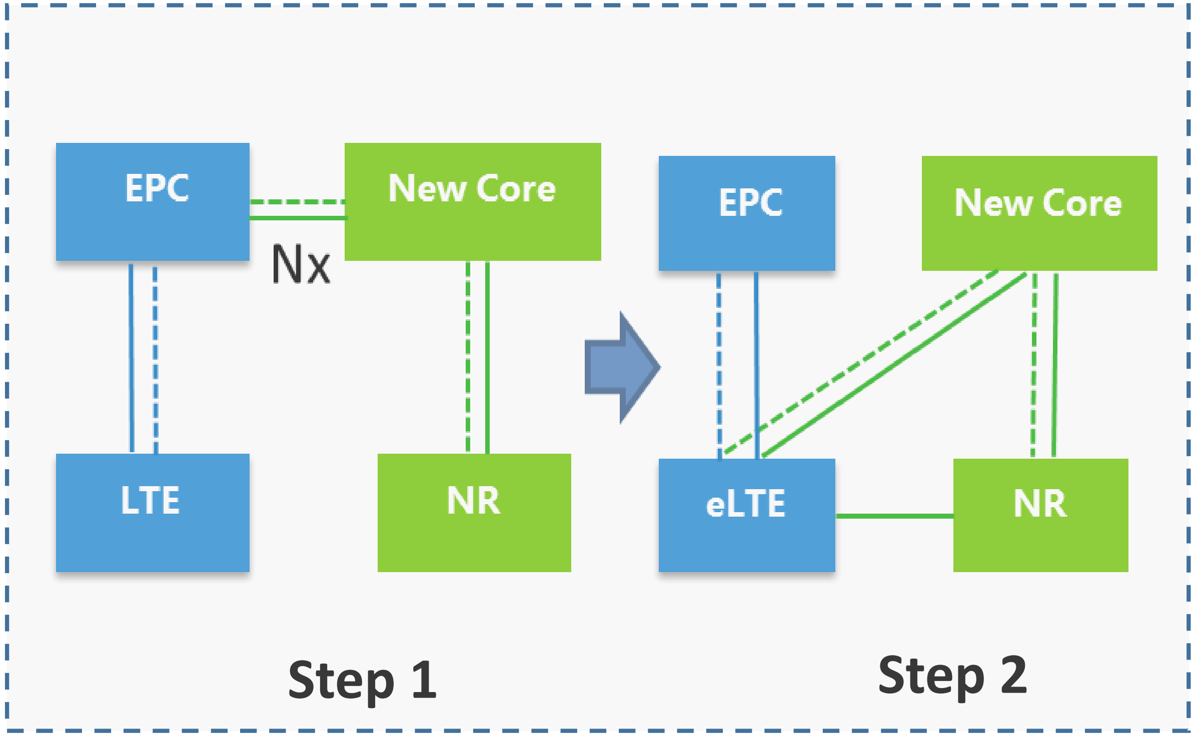
Challenges for 5G Development （3）

DIVERSE PATHS FOR EARLY 5G DEPLOYMENT

NSA system architecture

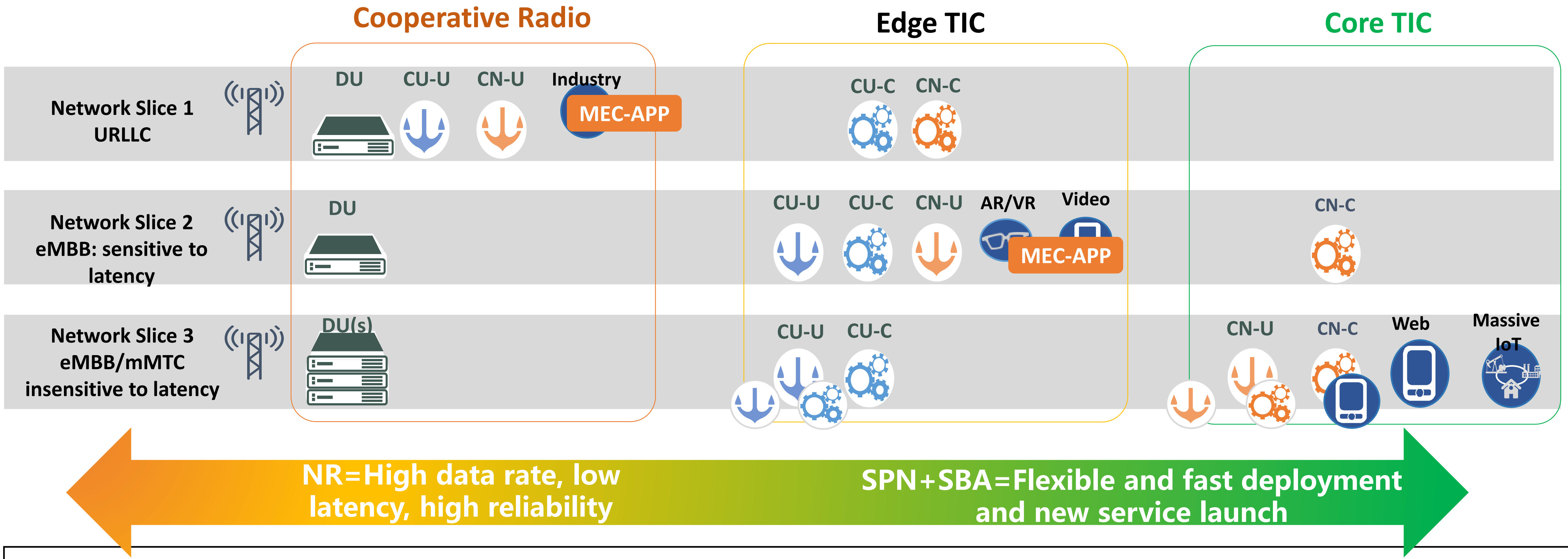


SA system architecture



Challenges for 5G Development (4)

NETWORK SLICING EMPOWERS THE ENTERPRISE AND VERTICAL



With SA, network slicing enables MEC to be supported and provides customized superior user experience for enterprise and vertical industries

GTI 2.0 kicked off in 2016: sub 6GHz 5G industrialization

GTI 1.0
2011 ~ 2015

GTI 2.0
2016 ~

Program	Objective	Projects
5G eMBB	Defining 5G eMBB requirements/use case, validating system solution, defining product requirement and promoting commercial deployment among GTI partners and with wider industry partners	Sub 6GHz New Device Architecture Test Equipment …

Work Scope	2017				2018				2019				2020	
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	H1	H2
Prototype Lab & Field Trials 1. 5G technologies Test 2. Performance Test 3. Deliver Test Reports		• Prototype Test • Technologies Test • Performance Test			• Test Reports									
Proof of Concept 1. Define Proof Points 2. Define Use Case & Requirments 3. Hardware Spec/ Device Promotion 4. PoC Test Results			• Proof Points Defined • Use Case & Requirements • Hardware Spec /Device			• PoC Completed • 5G RAN WP								
Pre-Commercial Trials 1. Trial Planning & Test Environment 2. Set-up trial network Deployment 3. Large Scale Trials Test Results				• Trial Planning • Scnario & requiment			• Deployment & Trial • Industry Promotion		• Trial Result • Pre-commercial WP					

5G eMBB Progress: White Paper and Technical Reports

GTI Released Groups of 5G White Papers and Technical Reports to drive the 5G industrial maturity

13 White Papers and Technical Reports

RAN
- Sub-6GHz 5G Spectrum Whitepaper
- Sub-6GHz 5G Deployment Whitepaper
- Proof of Concept of 5G System Whitepaper
- Sub-6GHz 5G Radio Access Network Whitepaper

Core Network
- Sub-6GHz 5G Core Network Whitepaper
- 5G Network Architecture Whitepaper
- 5G Network Slicing Whitepaper

Device
- Sub-6GHz 5G Device Whitepaper
- 5G New Device Type Research Report
- 5G Device RF Component Research Report

5G eMBB Progress: Products and Prototypes

7

Products and Prototypes

5G System Prototype

Sub-6GHz 5G FPGA Prototype Device

5G RF Components

Base Station :192 antenna elements

- Baseline: 64Tx/Rx for coverage and capacity
- Alternative: 16Tx/Rx base stations

Base Station KPIs

- **Current Prototype**

200 W | 77.5 dBm | –114 dBm | 0.32m^2 | 45Kg | 15%

- **Pre-commercial product**

200 W | 78.5 dBm | –115.5 dBm | 0.5 m^2 | 45Kg | 20%

5G eMBB Progress: 5G PoC Trial

Lab Test

Hardware/OTA Test, functions and performance

5G BS prototype

test UE/CPE/instruments

Frequency	3.4-3.6GHz
BW	100MHz
Power	200 w
antenna elements	192/128
Path	64TR

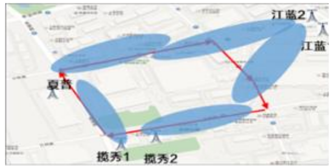
antennas	4T8R/2T4R*
Power	23 dBm@1Tx /26dBm@2Tx

* in different scenarios

Field Test

- *key performance of 5G:*
  - *4G/5G coverage, latency, data rate, capacity…*
- *in Beijing, Shanghai, Guangzhou, Ningbo, Suzhou*

Beijing , 5 sites/vendor



Shanghai, 7 sites

Guangzhou, 7 sites

Suzhou

Ningbo

- ***Achievements:***
  - Basic coverage and system performance has been verified
  - Hardware architecture has achieved pre-commercial capabilities
  - Valuable experiences has been accumulated for 5G pre-commercial trial

Findings from 5G PoC trial : Coupling loss of different bands

Questions to be answered for PoC coverage trials

- **Propagation discrepancies** between **3.5/4.8GHz** and **1.9 GHz/2.6 GHz (current TD-LTE bands)**?
- With **5G coverage enhancement schemes**, whether NR can **achieve similar coverage with current TD-LTE network**?

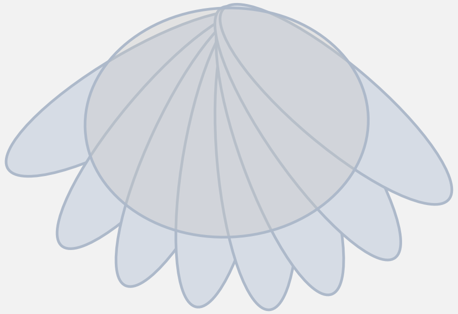
Coupling Loss of Each System/Band **Compared to 1.9 GHz TD-LTE** (dB)[1]

Scenario			1.9 GHz TD-LTE	2.6 GHz TD-LTE	3.5 GHz NR	4.8GHz NR
Outdoor		Theoretical	0	-4.3	-6.38	-10.71
		Test	0	-4.3	-7.3	-9.76
O2I	Low Penetration	Theoretical	0	-6.3	-10.38	-16.71
		Test	0	-6.5	-10 ~ -10.5	-17.7~-18.2
	High Penetration	Theoretical	0	-	-	-
		Test	0	-9	-13.5~-15.5	-24.2~-27.2 (*can reach -34.1 in some scenarios)

Note1 : The discrepancies above is composed of the differences of antenna gain, propagation and penetration loss of each system/band
Note2: No 5G NR coverage enhancement scheme is considered above

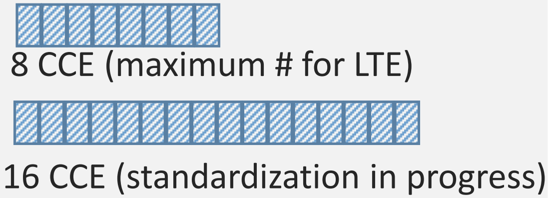
Findings from 5G PoC trial : Coverage enhancement in 5G

DL Control



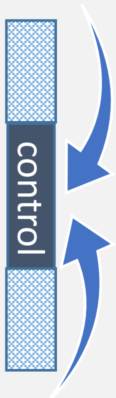
Beam Sweeping(Up to 8 beams for DL Broadcast/Control)

Theoretical/predicted gain: 9/5dB



8 CCE ->16 CCE

Theoretical/predicted gain: 3/2.5dB



Power Boost

Theoretical/predicted gain: 3/3dB

2T4R UE

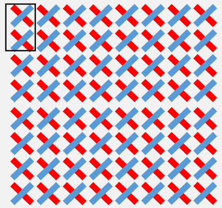
2R->4R

Theoretical/predicted gain : 3/2dB

PRACH

HPUE
(23 dBm +23 dBm)

Theoretical/predicted gain: 3/3dB



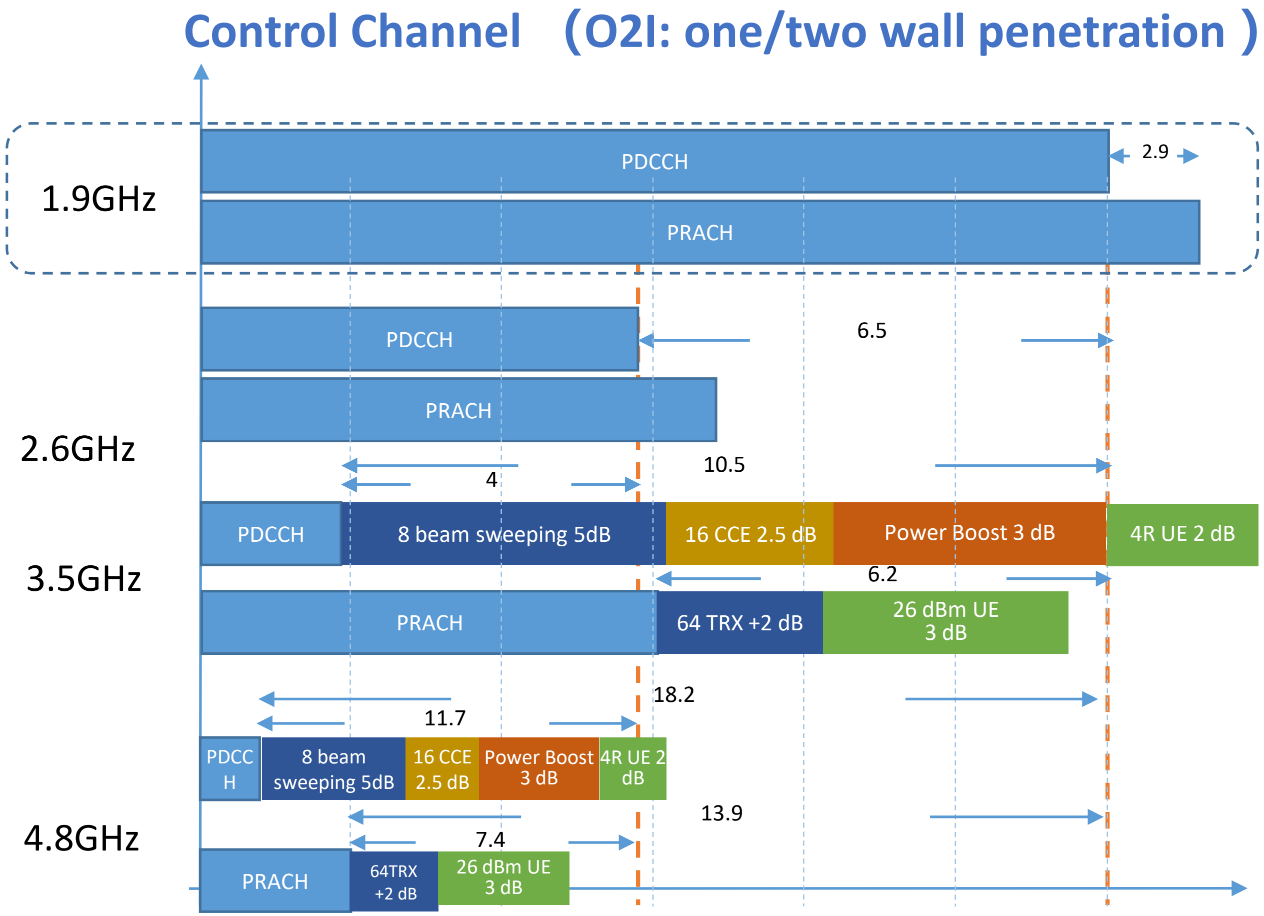
3D-MIMO (128/192 antenna elements)

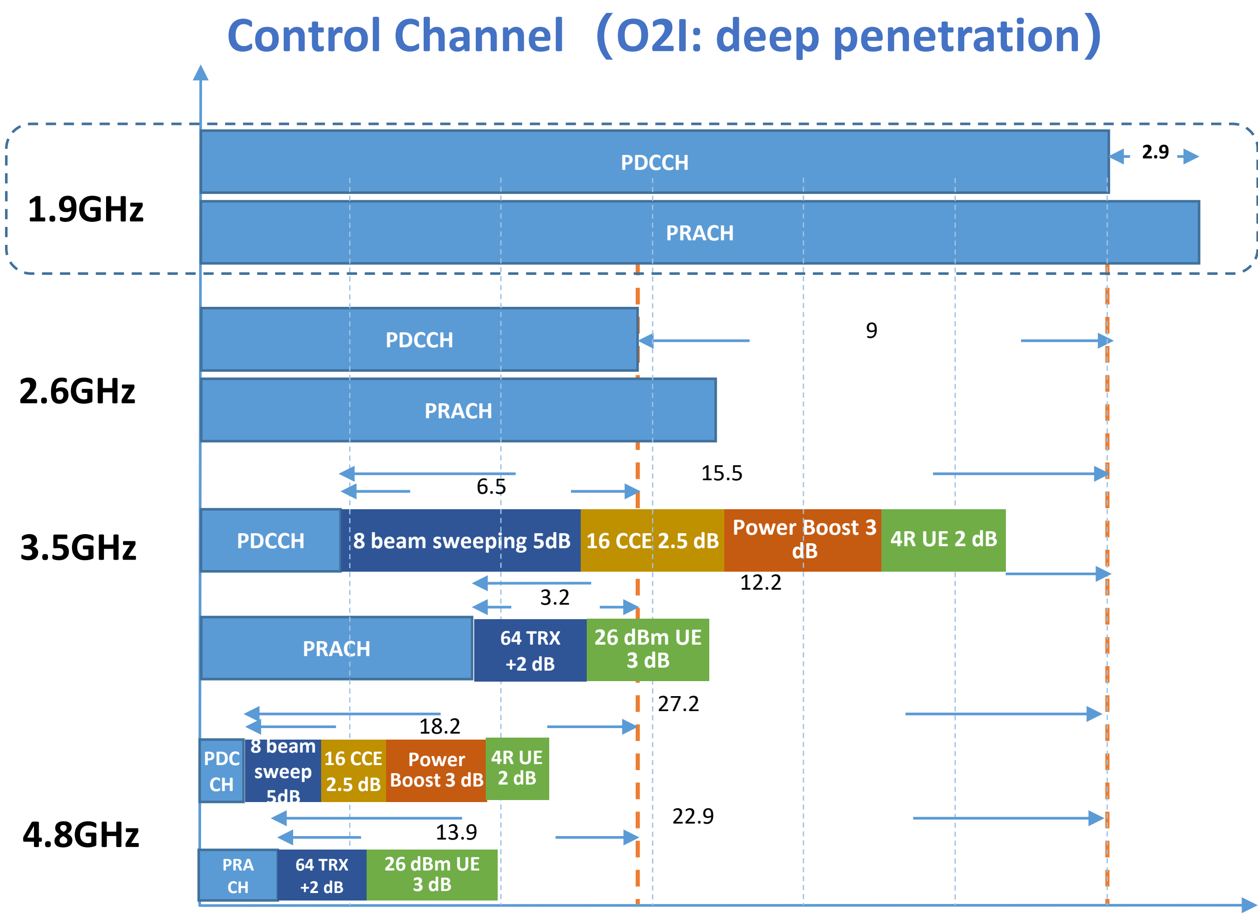
Beamforming gain

Theoretical/predicted gain: 3/2dB

Predicted Gain (dB)	1T2R 23 dBm	2T4R 26 dBm
DL Control	10.5	12.5
PRACH	2	5

Findings from 5G PoC trial：Control coverage in 5G



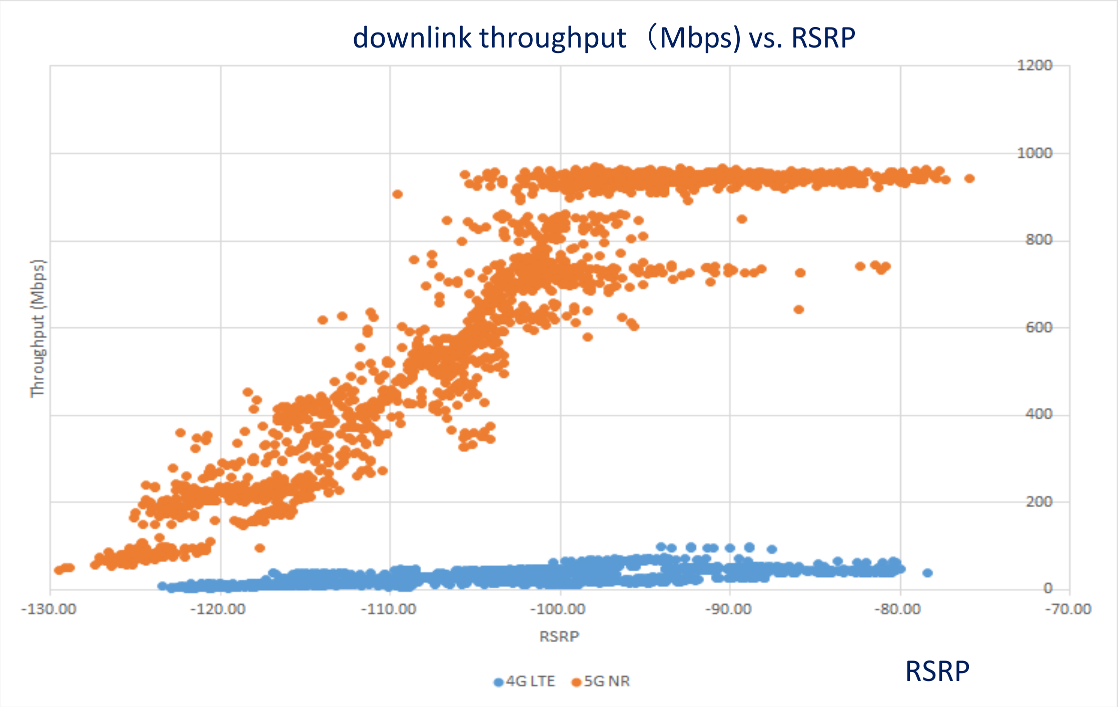


- **Coverage of control channel**：
  - — 3.5GHz is better than 2.6GHz (8TRX) and close to 1.9GHz (8TRX) **at outdoor or O2I with one/two wall penetration**
  - — 3.5GHz can achieve the 2.6GHz (8Tx) **at OI2 with deep penetration**
  - — 4.8GHz is hard to achieve the control channel coverage compared to 1.9GHz/2.6GHz (8TRX)

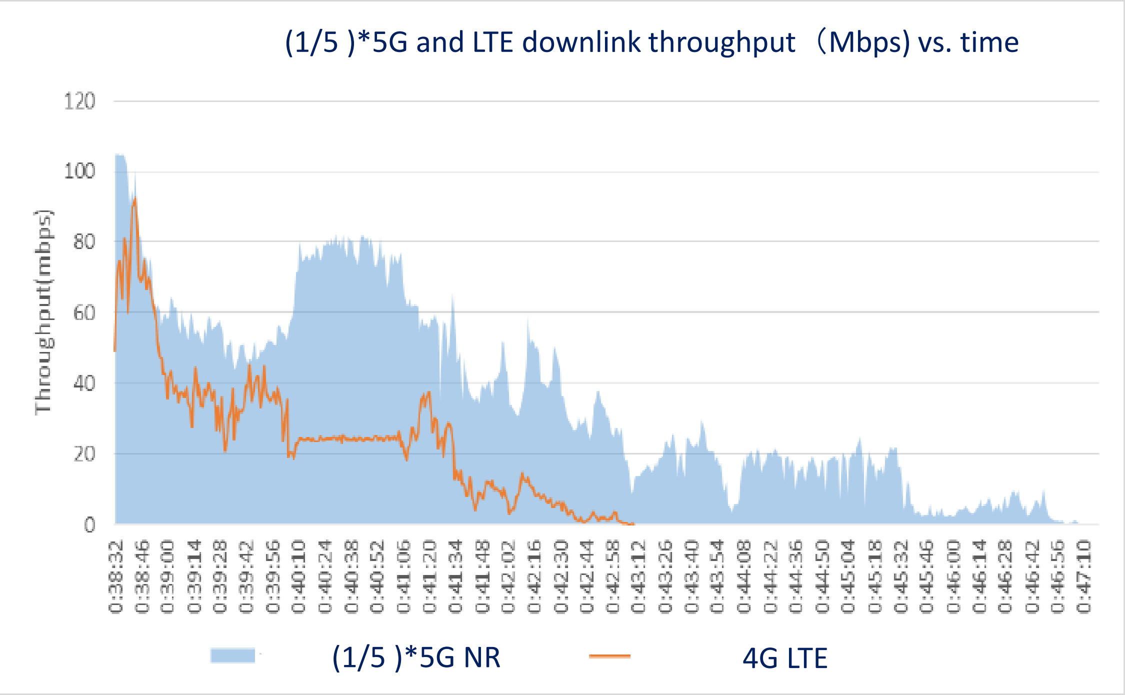
Findings from 5G PoC trial : Downlink coverage in 5G

2.6 GHz (8TRX） and 3.5 GHz 5G NR downlink throughput

2.6 GHz TDD（8TRX,20MHz）Vs. 3.5 GHz 3D-MIMO



2.6 GHz TDD（8TRX, 20MHz）Vs. 3.5 GHz 3D-MIMO

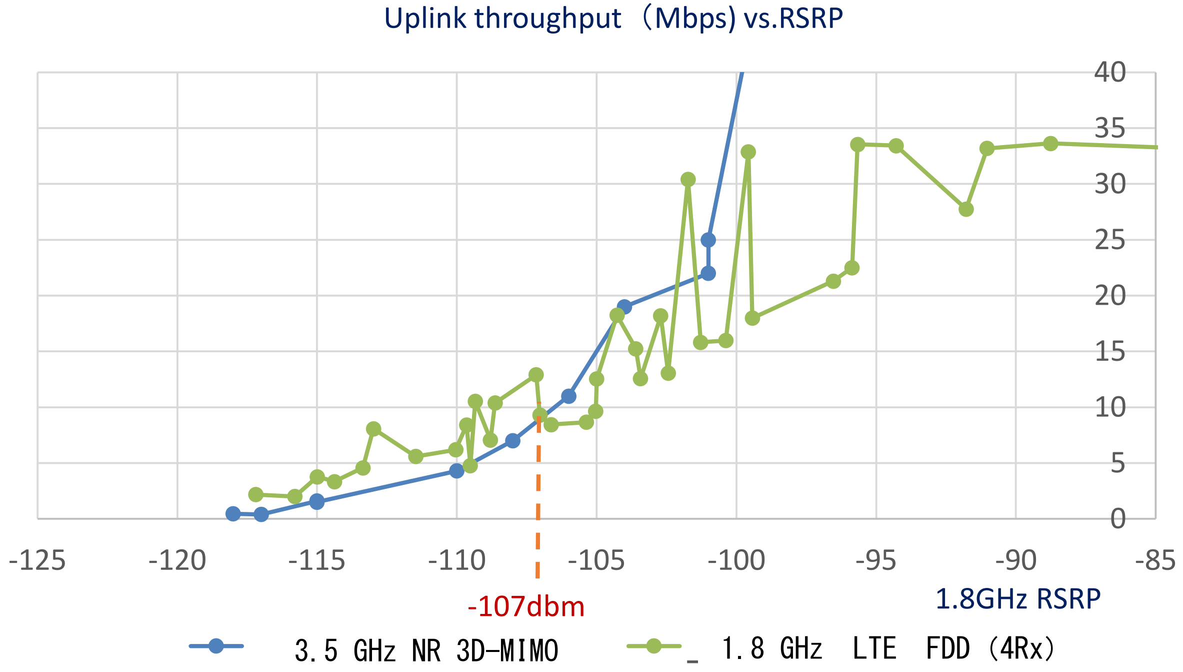


- **Coverage of downlink data channel：**
  - **Due to the large bandwidth and the 3D-MIMO beamforming of 3.5GHz 5G NR,** DL THP for 3.5GHz 5G NR can achieve obvious gain **more than 5X** vs. 2.6GHz TD-LTE (8TX)

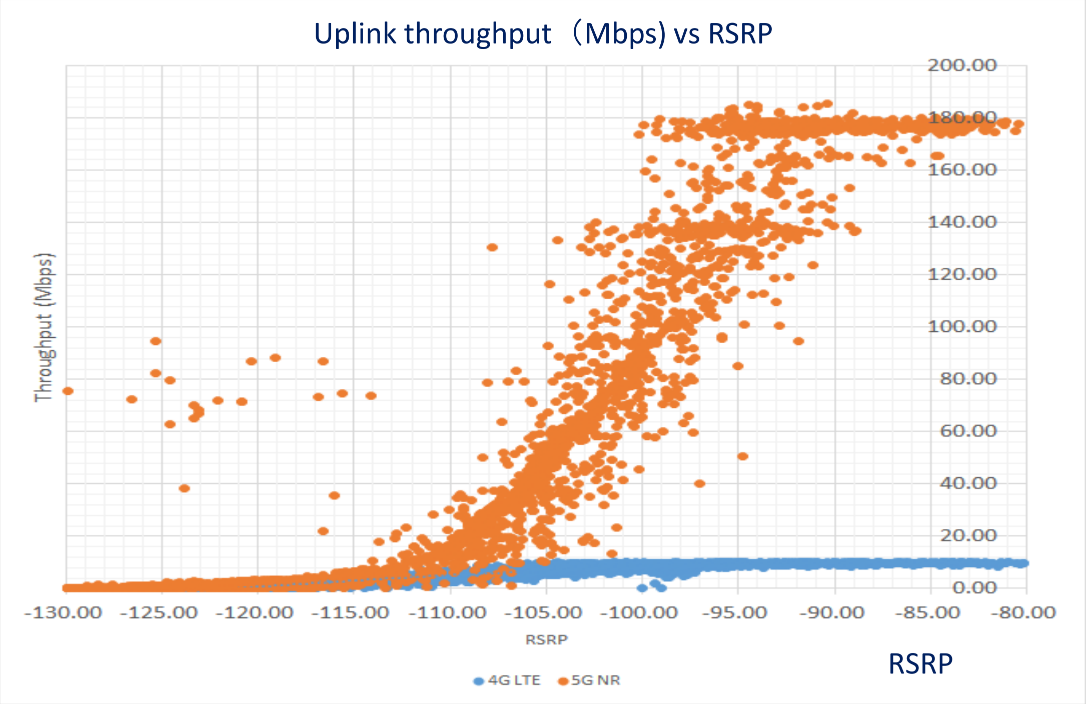
Findings from 5G PoC trial：Uplink coverage in 5G

1.8 GHz (FDD, 4TRx)、2.6 GHz (8TRX） and 3.5 GHz 5G NR Uplink throughput

1.8 GHz FDD（4TRx） Vs.3.5 GHz 3D-MIMO



2.6 GHz TDD（8TRX, 20MHz） Vs. 3.5 GHz 3D-MIMO



- **Observation for coverage of uplink data channel：**
  - **Coverage of 3.5GHz 5G NR is limited at PUSCH** with the 5G NR control channel enhancements.
  - **O2I,** UL THP at cell edge for 3.5GHz is about **2~4X** vs. 2.6GHz TD-LTE **with one/two wall penetration**， and is **close to** 2.6GHz TD-LTE **with deep penetration**
  - **O2I** : UL THP at cell edge for 1.8GHz（4TRx, FDD LTE） is **2~3x** vs. 3.5GHz（64TRx) **at low load case with one/two wall penetration**

Findings from 5G PoC trial : Throughput

Single UE peak thoughput for downlink

Test case	A	B
test data rate	**3.203Gbps**	**2.3Gbps**
theoretical data rate	3.29Gbps	2.33Gbps
layers (8Rx/4Tx)	8	8
Modulation	256QAM	64QAM

Single UE peak thoughput for uplink

Test case	A	B
test data rate	**558Mbps**	**388Mbps**
theoretical data rate	558Mbps	390Mbps
layers (8Rx/4Tx)	4	4
Modulation	256QAM	64QAM

Note1 : TDD DL/UL configuration is assumed as 3:1 or 70% DL
Note 2 : 8Rx/4Tx were configured for 5G UE prototypes

Cell peak thoughput for downlink

Test case	A	B
test data rate	**6.03 Gbps**	**11 Gbps**
theoretical data rate	6.98Gbps	12.41Gbps
total UEs	12	16
total layers	24	32
layers /ue	2	2

Cell peak thoughput for uplink

Test case	A	B
test data rate	**0.79 Gbps**	**1 Gbps**
theoretical data rate	0.8 Gbps	1.16Gbps
total UEs	4	12
total layers	8	12
layers /ue	2	1

- **Observation for throughput：**
  — 3.5GHz 5G NR can achieve peak data rate close to theoretical value, which depends on the configuration and test environments.
  — Though peak data rate is high for 8Rx/4Tx UE prototype, **4Rx/2Tx are the available config.** for pre-commerical TUE (SA)

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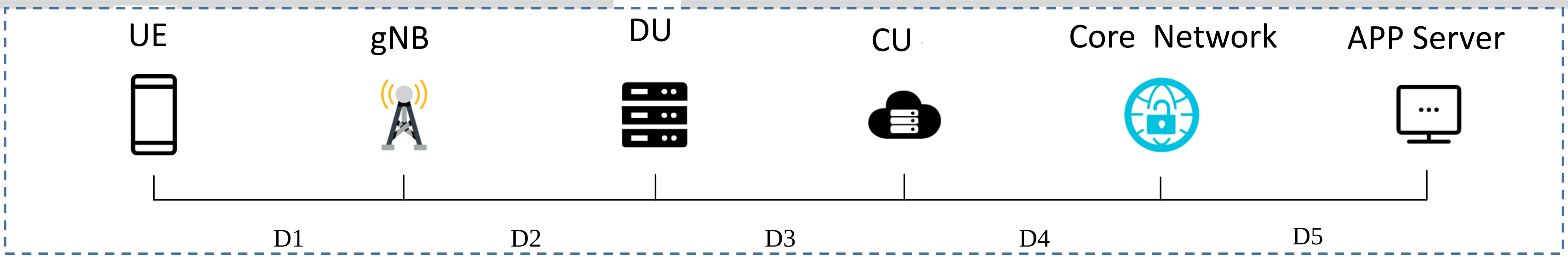
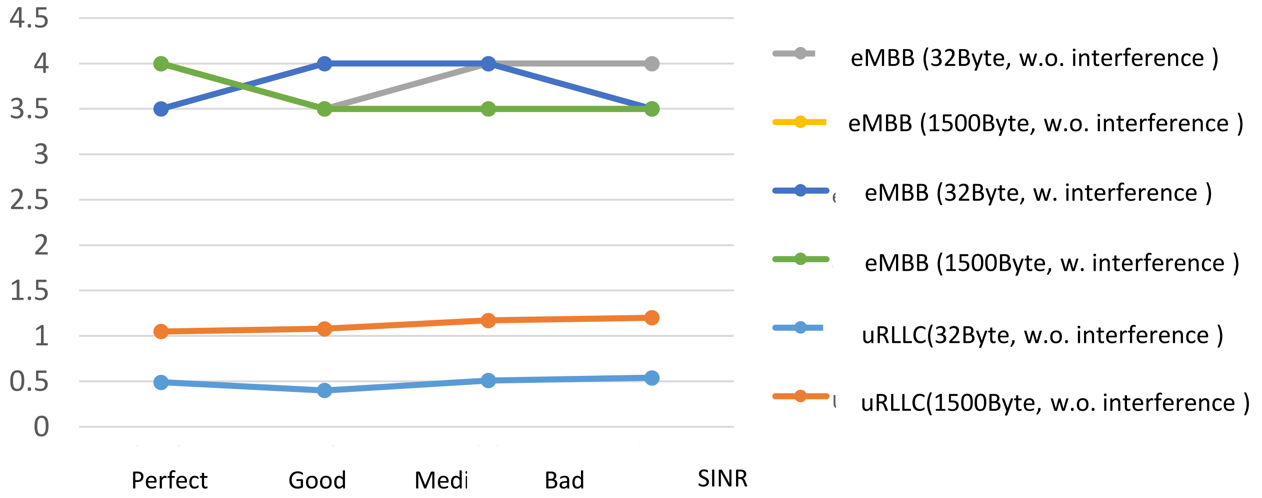
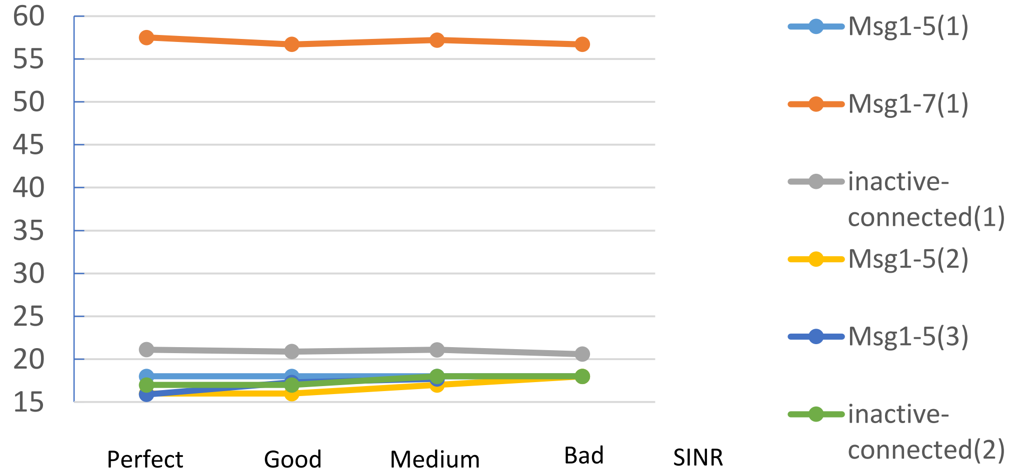
Findings from 5G PoC trial : Latency



U-Plane latency (ms)



C-Plane latency (ms)



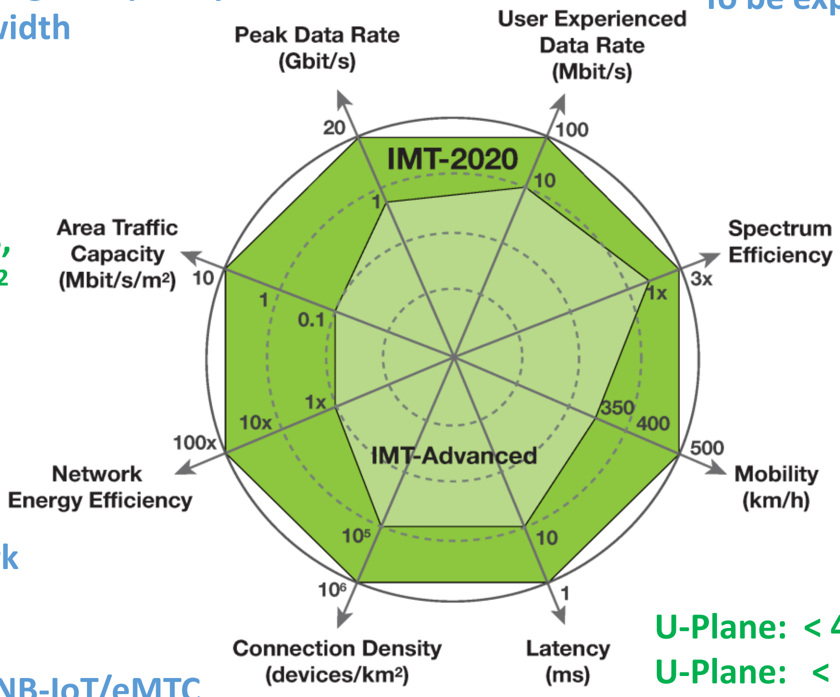
- **Observation for latency：**
  - UP latency： < 4ms(eMBB) , **0.4-0.54ms （uRLLC 32Byte with short TTI and Grant-free transmission）**
  - CP latency： ~20ms from "inactive" state - > "connected" state with 5G NR enhancements
  - **Latency is still to be optimized ，since U-Plane latency is only a minor part of end-to-end latency (~X*10ms)**

Findings from 5G trial : Against the ITU-R requirements

To be expected by high frequency mmWave with a large bandwidth

To be expected by seamless coverage at dense urban

ultra dense deployment of 5G eMBB, 100MHz, 8TRP&8TUEs,11.2Mbps/m^2



Satisfy peak spectrum efficiency requirements (DL 30bps/Hz, UL 15bps/Hz)
Satisfy average spectrum efficiency requirements （DL/UL: 7.8/5.4bps/Hz）

To be expected in high railway scenarios

To be expected by very low power comsumption of commericial network

To be expected by NB-IoT/eMTC

U-Plane: < 4ms for eMBB
U-Plane: < 1ms for uRLLC with small packets
C-Plane: ~ 20ms for “inactive -> connected “state

- **Observation against the ITU-R requirements**:
  — ITU-R requirements can be achieved at multiple scenarios by different numerology configuation.

Next step: Pre-commercial trial

GTI 5G eMBB Objective

Experience on 5G Key Solutions, Networking & Deployment

serves as the output for 5G key solutions and experience

construction

network planning

operation & optimization

Commercial Industrialization

prmoting maturity of 5G networks, terminals, chips and instruments

3.5GHz Commercial Product

5G Chipset and Terminals

>6GHz RF Components

Innovative services and applications

Cultivate the new service, application and new business model for personal, enterprise and vertical industry

Pre-commercial Trial

- **Promote the end-to-end products compliant with 3GPP specs and accelerate 5G pre-commercial phase as soon as possible, targeting the commercial launch of 5G in 2020**
- **Experience Sharing on 5G networking, deployment scenarios and key solutions**
- **Sharing on 5G+vertical industry requirements, use cases and solutions**

Jointly Creating a Bright 5G Future!