中国移动
China Mobile

EU-China Cooperative Project Review

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Content

中国移动 China Mobile

Introduction of 5G large-scale trial

Cooperation result review

Latest status of 5G commercial

Project with the MIIT

中国移动 China Mobile

Basic Info

Project Name：5G Large-scale Trial

Vest in：National Major Project 2018ZX03001022

Leading Unit： China Mobile

Participants： Huawei, Datang, Ericsson, RIHMT, TMRI, Shanghai Automobile City, BUPT

Duration：2018.06~2020.12

Responsible Person：Zhang Tongxu

Trial Scale

Application Requirement

Cities： ≥3

Sites：≥50, per city

Fund：500 million

Terminal： ≥100, per city

Implementation Goals

Cites： Shanghai, Guangzhou, Hangzhou, Suzhou, Wuhan

Sites： ≥100, per city

Fund：485.4137 million

Terminal：≥100, per city

Participants

All participants are major companies or ministries in 5G and V2X, including domestic and overseas

Industry

Huawei	Ericsson	Datang
• The world's largest communication equipments suppliers • Leading 5G tech innovation • Completing Phase 1 and 2 test of MIIT	• Famous mobile network providers • Outstanding in 5G Standardization work • Completing Phase 1 and 2 test of MIIT	• Proposer and core developer of TD-S • Completing Phase 1 and 2 test of MIIT

Industry

- C-V2X network equipment provider
- Provider of intelligent vehicle pilot demonstration area

Huawei

Shanghai Automobile City

Research

- Research institute of traffic management technology, and policies and regulations
- Research institute of highway transportation, and traffic management policies and regulations

TMRI

RIHMT

Operation

China Mobile

- The world's largest mobile telecom carrier
- Experienced in TD-LTE key tech researches and applications, 5G standards and industrializations, and C-V2X researches.
- Having national key labs and 5G Joint innovation labs, which can boosting the end-to-end industrial chain competition, and applications in the vertical industry

University

BUPT

- Having national key labs and a professional team
- Experienced in 5G and C-V2X

eMBB

C-V2X

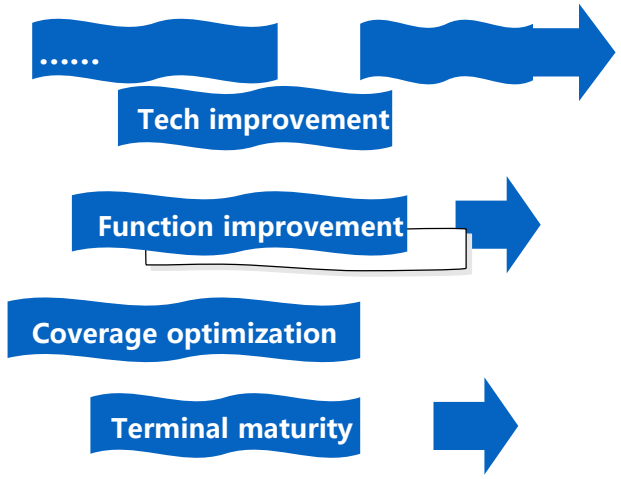
Overall Goals

- Build the trial environment with no less than three typical 5G application scenarios
- Verify and improve 5G E2E capability in typical scenarios; explore the plan, optimization, operation and maintenance of a large-scale network; form a robust tech scheme and system
  - ✓ 5G eMBB: verify key techs, such as 3D-MIMO, networking capability of different frequency bands , slicing, MEC, SDN, etc.
  - ✓ C-V2X: verify networking capability and performance of V2N、 V2I、V2V

Phase One (2018Q3-2019Q2)

Goal：build the trial environment and conduct the basic test; form a pre plan of E2E networking ; E2E industry promotion

- Verify key techs
- Explore the plan and optimization of networking; form the networking scheme
- Find and fix problems in typical network scenarios
- Boost the maturity of network and terminal equipments



Phase Two (2019Q2-2020Q2)

Goal：optimize the trial network and conduct showcases; boost the maturity of eMBB and C-V2X product, to achieve the commercial standard

- Optimize the network to achieve the commercial standard
- Guarantee applications in special scenarios
- Verify VoNR and interoperability
- Verify key techs and performance of C-V2X; boost the product maturity
- Boosting the maturity of 5G UE

Research Content

The project framework consist of 8 research tasks，including several aspects in 5G eMBB and C-V2X, it is an end-to-end system engineering

5G eMBB Verification

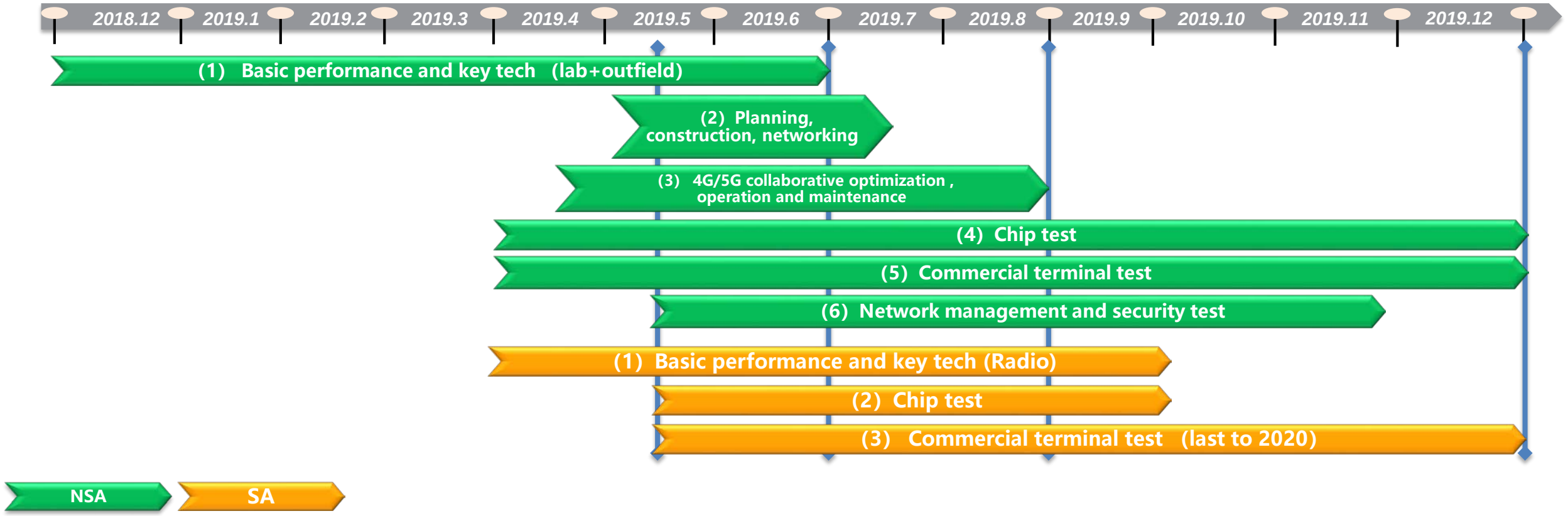
1	Radio Network	Basic function and performance; networking scheme; key tech research and test; 5G eMBB simulation platform construction and evaluation
2	Core Network	Basic function and performance; networking scheme; key tech test in new network
3	Transport Network	Basic function and performance; key networking techs based on SDN
4	Terminal	Basic function and performance; Interoperability Test
5	VoNR, Data, interoperability	VoNR and SMS; 5G data and interoperability
6	Service	techs of 5G message services

C-V2X Verification

7	C-V2X key tech verification	Network applicability facing transport industry ; network architecture and communication protocol; key techs of road traffic control equipment; system emc test; terminal prototype R&D; network equipment R&D
8	C-V2X networking verification	Service test; networking capability test; terminal test

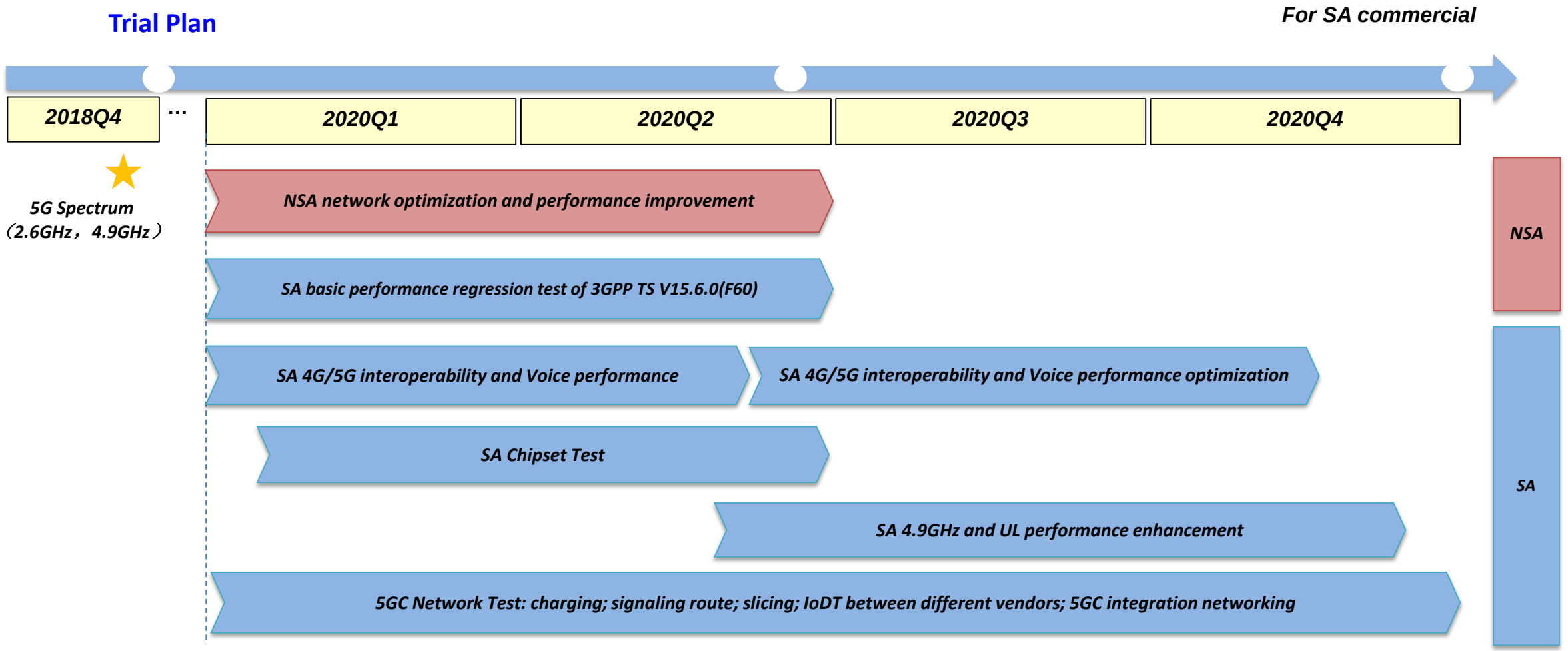
5G trial review in 2019

- For NSA pre-commercial: June: complete basic performance and key tech test, chip+terminal test. August：complete planning, construction, networking and optimization test. December：complete chip + phone test and network management and security test. Continue to optimize the performance.
- For SA pre-commercial: July: complete planning, construction and networking test(radio network). September : complete basic performance and key tech test, chip + terminal test.



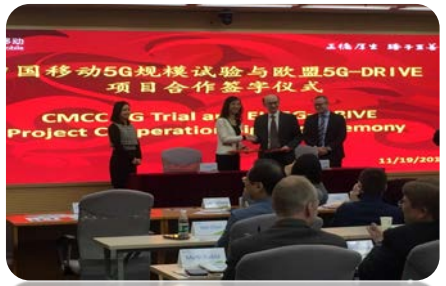
5G trial review in 2020

- NSA and SA basic performance has been verified in 2019
- 5G SA new features, including voice, 5GC, 4G/5G interoperability was tested in 2020 to support SA commercial



Cooperation between CMCC and 5G-DRIVE review

- Cooperation agreement signed on Nov.19, 2018
- Jointly conducted 5G workshops and 5G key technics verification in each other 5G trial networks
- Joint trial methods and results were published on IEEE ICC 2019, ICC 2020 and ETSI, Research results on Massive MIMO was accepted by IEEE OJVT 2020



Agreement signed(2018.11)


1st workshop(2018.11)


Trial network visit (2018.11)


2nd workshop (2019.5)


Joint trial (2019.5~7)


3rd workshop(2019.12)

Joint trial(2019.12)


5G showcase(2019.12)

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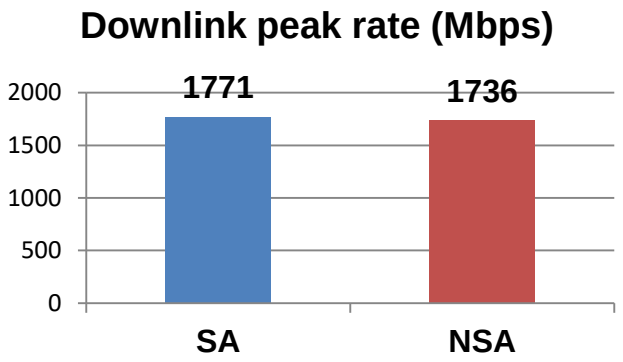
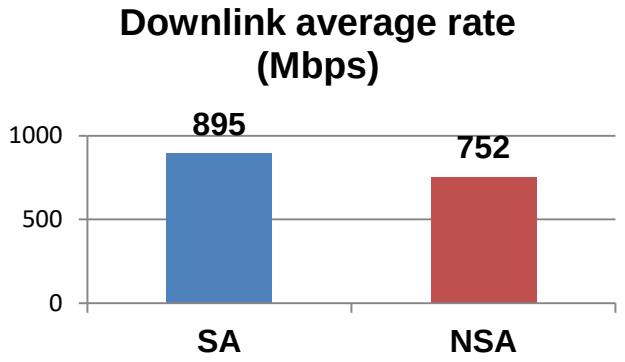
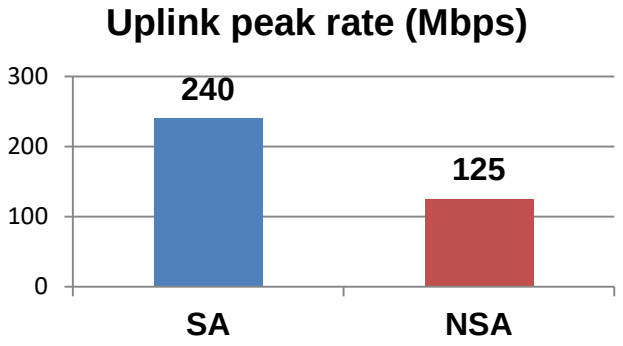
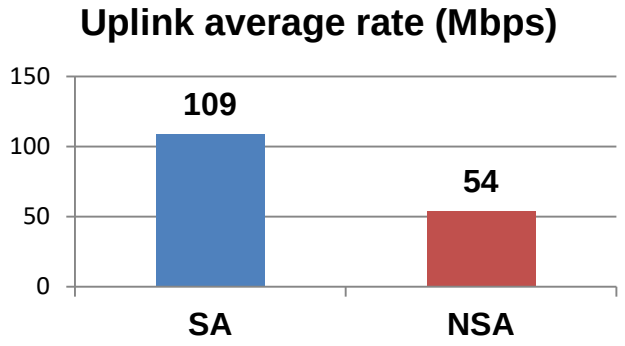
SA 2.6GHz Throughput: SA taking advantage over NSA









Conclusions:

- DL advantage: It is difficult to get 4 streams for NSA terminals but not for SA, because SA terminals can do 4T SRS antenna switching, thus getting a higher downlink rank
- UL advantage: SA terminals have 2 transmitters thus double the peak uplink rate

Note:

• The average test result is from a showcase network, the general network's result may be reduced by 20~30%.

• NSA without Split Bearer

SA 2.6GHz MU-MIMO Cell Throughput

Test method:

- Peak Cell Throughput: 10 terminals placed at different excellent points
- Average Cell Throughput: 10 terminals, the proportion of locations is “Excellent: Good: Medium: Poor = 1: 2: 4: 3”

10UE excellent point distribution map

Peak Cell Throughput

- **SA: DL: 4.6~5.1Gbps**
  UL: 600~610Mbps
- **NSA: DL: 5~5.1Gbps**
  UL: 600~610Mbps

Average Cell Throughput

- **SA: DL: 3.8~3.9Gbps**
  UL: 510~520Mbps
- **NSA: DL: 3.5~3.7Gbps**
  UL: 510~520Mbps

Signal strength and isolation are worse than peaks

Since NSA and SA test’s locations, environment and date are different, the NSA and SA’s results above do not have comparable conditions

Conclusions:

- When there is sufficient space or beam isolation between users, and radio link quality is good, the cell peak can be reached
- Cell throughput will be reduced by 10% to 20% when neighbors have 50% load
- Peak Cell Throughput test results are based on 2 layers per UE for DL and 1 layer per UE for UL

SA 2.6GHz Latency: In line with the theory

Control plane latency

- NSA：330~500ms
- SA： Idle State: 70~100ms

  Inactive state: 30~50ms
- NSA vs. SA：
  - NSA control plane latency includes 4G random access, 4G bearer setup, 5G measurement, and SCG addition.
  - NSA latency is 260~400ms longer than SA

Definition: Message 1 → RRC Connection Reconfiguration Complete

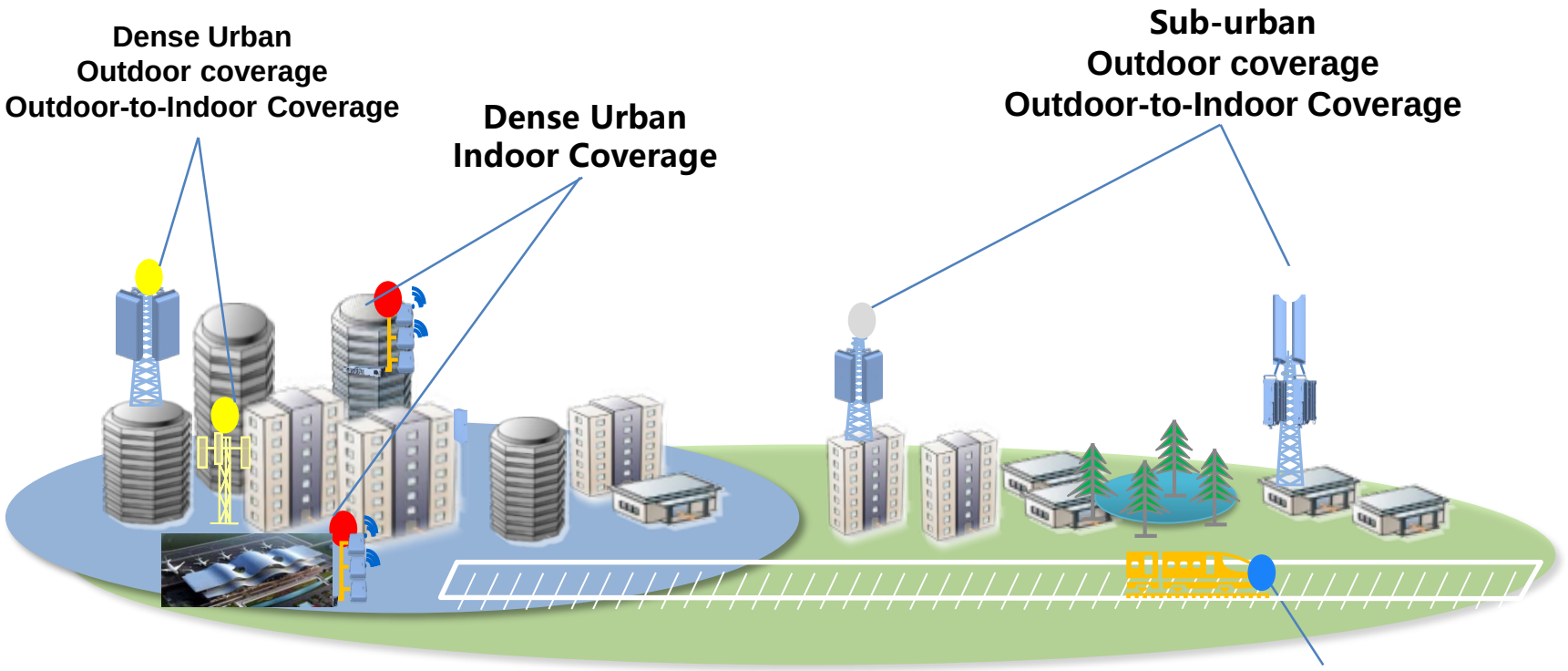
User Plane latency

- NSA： 11-19ms (Air interface)
- SA： 7~8ms (Air interface)
- NSA vs. SA： similar in theory, however the test configuration is different
  - NSA: 2000 Byte, without pre-scheduling
  - SA: 32 Byte, with pre-scheduling

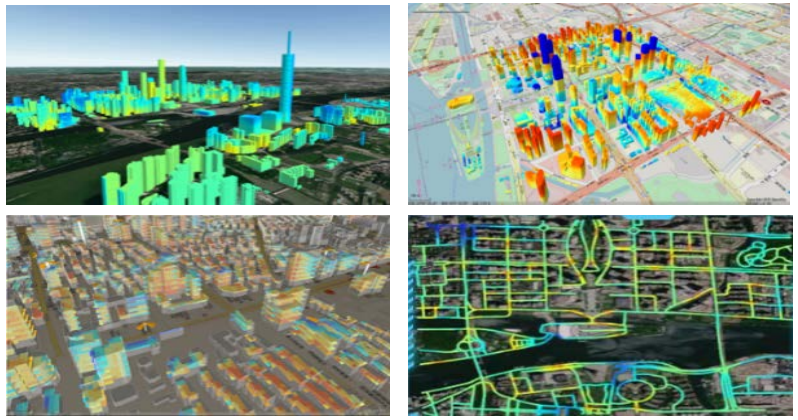
Conclusions:

- Pre-scheduling can significantly reduce user plane latency
- Packet size for Ping Service will also have a certain impact on user plane delay

Typical Scenarios for Site Planning

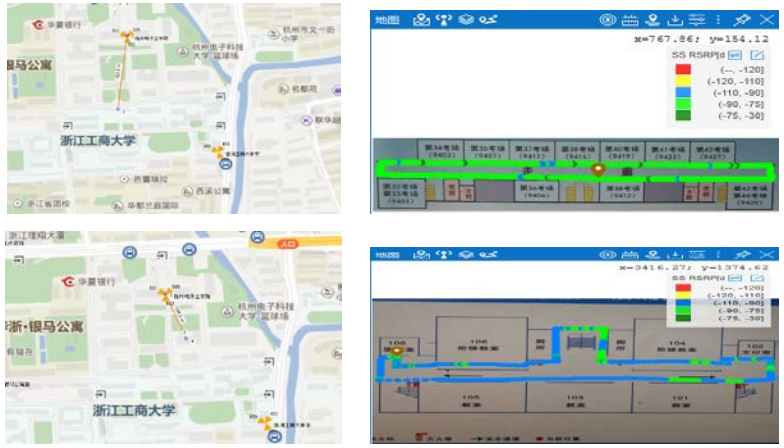


Site Planning Test: Outdoor and Outdoor-to-Indoor Coverage



Site Planning Modeling and Simulation

Outdoor coverage test



Outdoor-to-Indoor coverage test

- **Typical dense urban，cell edge rate：DL 100Mbps（17 times of 4G），UL 1Mbps（12 times of 4G）**
- **Scenarios such as university classroom buildings, the depth of 30-40 meters without obstruction indoors, RSRP can reach -110dBm;**
- **For indoor scenarios, through two walls penetration, RSRP can maintain -119~-124dBm**

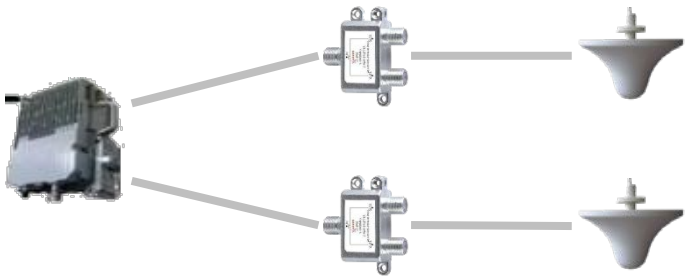
Index requirements		Outdoor road traversal coverage index				Shallow coverage index		Station spacing (m)
		SS-RSRP (dBm)	SS-SINR (dB)	User edge rate (Mbps)		User edge rate (Mbps)		
		edge	edge	DL	UL	DL	UL	
Dense urban	NSA	-87	4	206	7	130	1	330
	SA	-86	2	203	13	142	2	330
Urban	NSA	-91	2	133	5	119	2	450
	SA	-90	3	203	9	123	1	450

Test Results

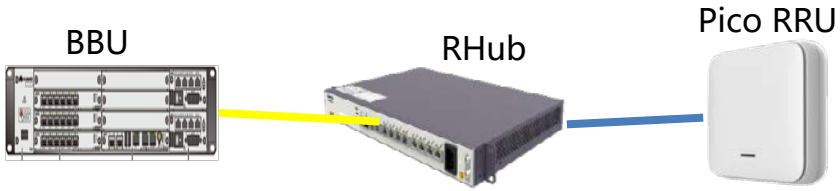
Equipment form	Type	Area	Coverage index (95% probability)		Edge user rate index		Suggested Station spacing (m)
			SS-RSRP Threshold (dBm)	SS-SINR Threshold (dB)	DL (Mbps)	UL (Mbps)	
64TRx	Dense urban	Core	-88	-3	93	1	300-350
		Other	-91	-3	93	1	400-450
	urban		-91	-3	93	1	450-500
	Sub urban		-93	-3	93	1	550-600

Network Construction Requirements

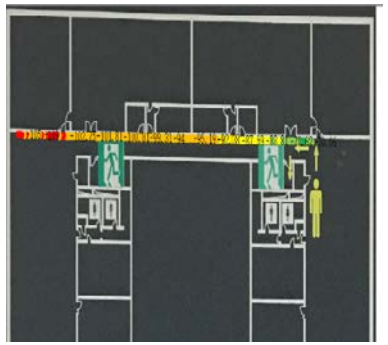
Site Planning Test: Indoor Coverage



Indoor Coverage Option 1: DAS



Indoor Coverage Option 2: Pico RRU



Single Point Test

Continuous Coverage Test

- **5G and 4G are deployed at the same point, and the SINR index of 5G is lower than 4G; The average downlink rate and peak rate are about 5-10 times that of 4G;**
- **Deploy 4T4R distributed pico in high-capacity, high-value and other business demand scenarios.**

Coverage area	SA/NSACoverage index (95% probability)	
	SSB-RSRP (dBm)	SSB-SINR (dB)
General requirements	≥-105	≥0
Important scenarios or areas, high-value and high-business demand scenarios or areas (Such as airports, large supermarkets, etc.)	≥-95	≥3

	Indoor coverage base station type	Frequency (GHz)	Band (MHz)	Service edge rate (Mbps)	
				UL	DL
CMCC	Distributed pico 4T4R	2.6	100	11	110
	SingleDAS			1.5	35
	DualDAS			2.2	70
CTCC/CUCC	Distributed pico	3.5	100	7	85

4G/5G interference test and solution

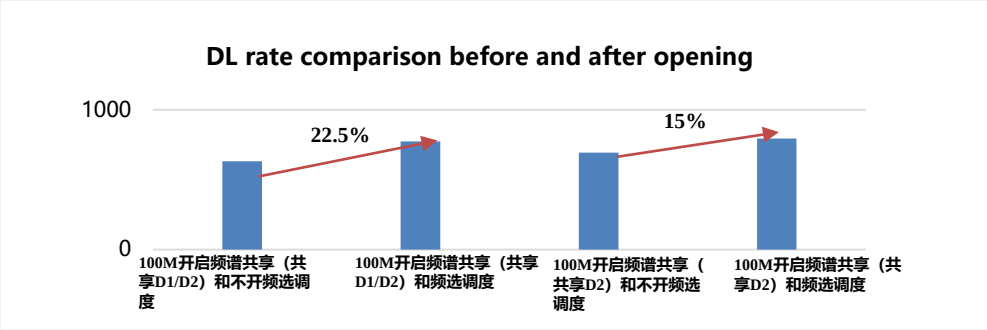
4/5G interference avoidance scheme can improve downlink throughput by about 20%

Frequency selective scheduling

■ **Plan**

- **In order to avoid 4G to 5G interference, enable frequency selective scheduling function**
  - ✓ **Independent channel measurement for different frequency band configurations**
  - ✓ **Judge the interference level of the shared frequency band through CQI comparison, and adaptively adjust the available bandwidth of the UE.**

■ **Outfield test results**



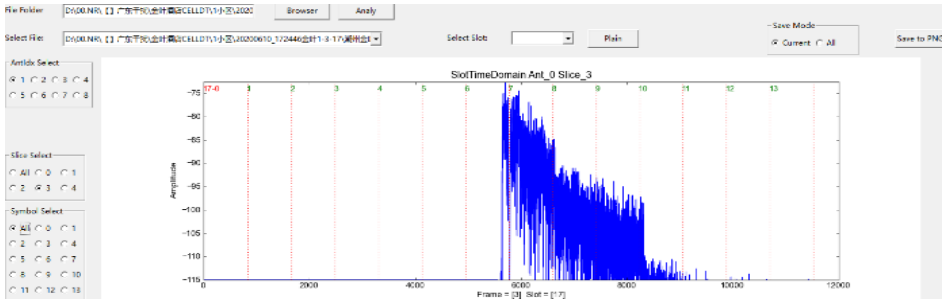
■ **Application scenario recommendations**

- **There are 4G base stations with the same frequency around 5G.**
- **5G contiguous networking scene, 5G periphery and 4G adjacent area.**
- **The area where 4G and 5G spectrum are shared.**

Far-end interference affects channel correction

■ **Live network problem**

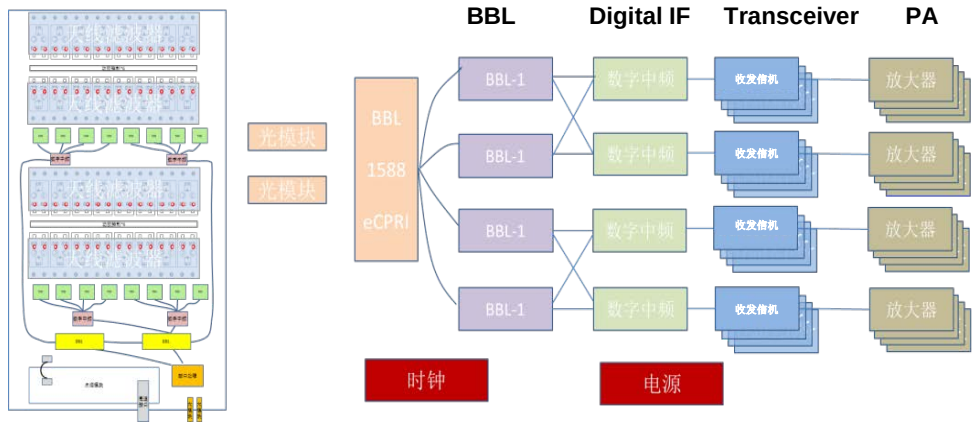
- **4G remote interference causes 5G cell channel correction failure**
  - ✓ **Analyze the time-domain characteristics of the signal, and the interference signal shows a decreasing trend on different symbols.**
  - ✓ **interference symbols: 6-10, the interference is about 4.5 symbols;**
    7, interference>30dB; 8, interference about 20dB; 9, interference about 10-15dB.



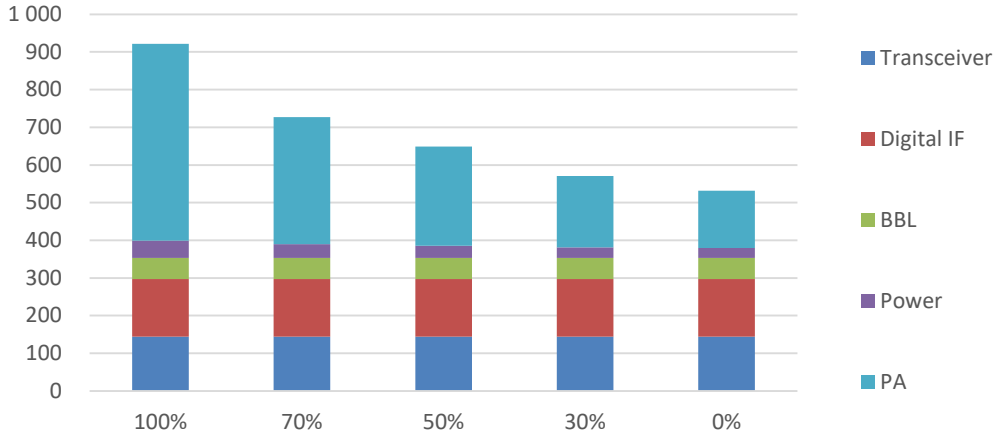
■ **Solution**

- **One (preferred)：Adaptively change the channel correction symbol position without changing the special time slot ratio**
- **Two：Downward mechanical inclination**
- **Three：Clear frequency D1, D2; can effectively reduce interference**

Research and test on 5G energy consumption



AAU Architecture

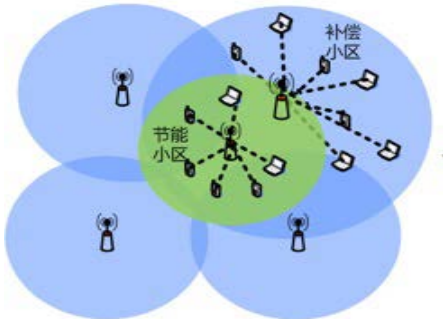


Power Consumption of different modules

Performance Verification of Energy Saving Features

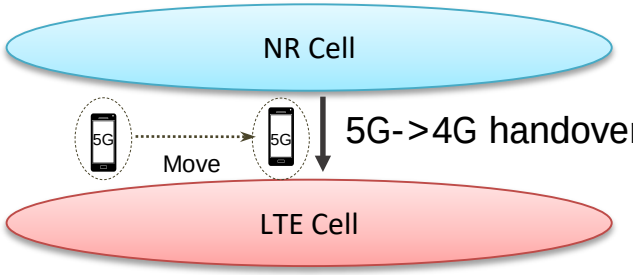
Function	Requirements	Performance
Sub-frame silence	Hibernate some devices (at least power amplifier) for Time Slot level	8%~30%
Channel silence	Make part of the RF channel related devices dormancy	15%~35%
Dormancy	Shallow: PA and Transceiver	20%~50%
	Deep: Only necessary function module work	40%~80%
Energy consumption data statistics	Provide energy consumption data including with BBU and RRU respectively	<5%

To further improve the network energy efficiency, i-Green system will analyze user data and cell traffic data of 5G network, and propose an intelligent energy- saving scheme by using wireless big data and AI



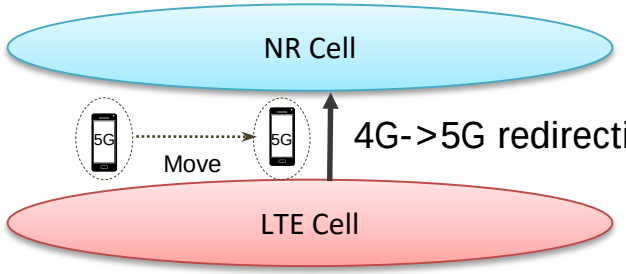
SA Pre-commercial Trial Progress：4G/5G interoperability

Completed 4G/5G interoperability performance evaluation, all conclusions are meeting expectation



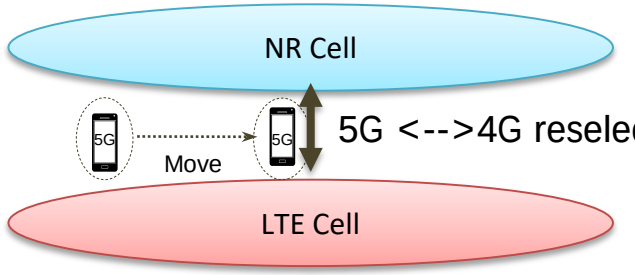
Latency: 60~80ms

Interrupt latency : From UE receive HO CMD, to UE random access complete in target cell



Latency: 800~1000ms

Interrupt latency : From UE receive RRC Release, to UE Registration complete in target cell



Latency: : 800~1000ms

Paging latency : From UE makes the reselection decision, to UE TAU/ Registration complete in target cell

Typical issues

Priority of SA ans NSA	Interference avoiding	Time synchronization	Sub frequency priority
A NSA/SA UE shall accesses to SA network preferentially in NSA/SA dual-mode network.	Interference avoiding in boundary region of NSA/SA dual-mode network and SA network.	In order to measure SSB for 4G/5G interoperability , the time synchronization between the LTE system and NR system is needed.	Frequency priority should be planned . Sub frequency priority can be introduced for the cell reselection from 4G to 5G.

SA Pre-commercial Trial Progress：4G/5G interoperability

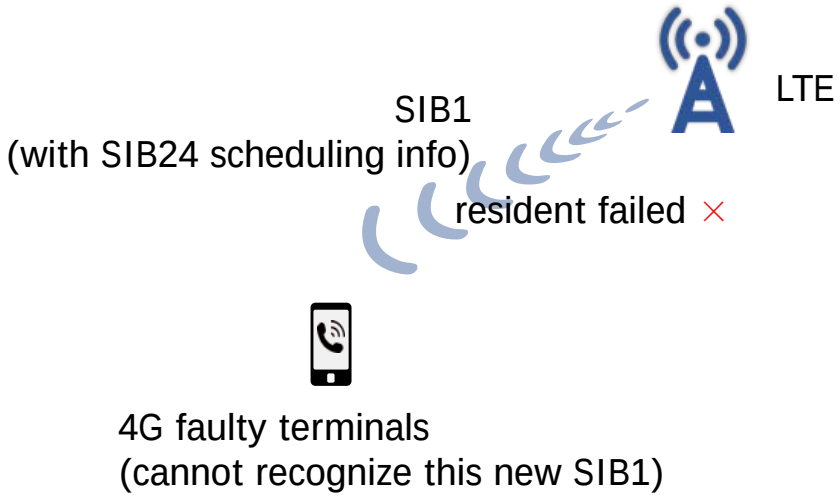
4G/5G interoperability key issue, provide three network solutions

Question

After LTE network upgrading to support 4G/5G interoperability, there are a number of 4G terminals failed to access LTE networks.

Analysis

4G faulty terminals cannot identify SIB with SIB24 scheduling info, thus lead to the resident failed.



These 4G faulty terminals are hard to upgrade. The number is millions.

Network solutions

LTE only broadcast the old SIB1(without SIB24 scheduling info)	Part of LTE cells broadcast the new SIB1(with SIB24 scheduling info)	LTE broadcast the old SIB1 and the new SIB1 alternately

The performance of network solutions need to verify.

SA Pre-commercial Trial Progress：5G Voice

Completed EPS FB and VoNR performance evaluation, all conclusions are meeting expectation 4G/5G interoperability

	Delay	Coverage (Min RSRP of call success rate greater than 90%)	MOS
EPS FB	3.5 ~ 4.5s	-118 ~ -120dBm	3.4 ～3.8
VoNR	2.5 ~ 3.5s	-119～-121dBm	3.4 ～3.9

Industry promotion

EPS FB: Promote one network vendor to support EPS FB based on handover.

VoNR: Promote some network and chip vendors to support and improve the VoNR function.

Typical issues

Using 4G band with better coverage

In EPS FB, if 4G and 5G are deployed at the same frequency and co-site, the RSRP of 5G is about 6dB higher than that of 4G. Therefore, 4G is recommended using the frequency with better coverage on the existing network.

The B1 threshold of EPS FB

The B1 threshold of EPS FB 4G returning to 5G is recommended to be consistent with the SCG addition threshold in NSA

Contribution of 5G scale trial results

The results have been applied to 5G commercial network construction in China Mobile: including outdoor and indoor site planning, parameter configuration, and optimization suggestions

Outdoor planning indicators

✓ Outdoor edge rate downlink 100Mbps, uplink 5Mbps, and achieve "0 new site" network construction

Equipment form	Type	Area	Coverage index (95% probability)		Edge user rate index		Suggested Station spacing (m)
			SS-RSRP Threshold (dBm)	SS-SINR Threshold (dB)	DL (Mbps)	UL (Mbps)	
64TRx	Dense Urban	core	-88	-3	93	1	300-350
	Dense Urban	other	-91	-3	93	1	400-450
	Urban		-91	-3	93	1	450-500
	Sub urban		-93	-3	93	1	550-600

Indoor coverage plan

✓ With the same RSRP, the distributed leather station capacity performance is better, 4T4R distributed pico can be deployed in high capacity and high value scenarios; DAS in other scenarios

Coverage area	Coverage probability 95%		Distributed pico (4T4R)		Distributed pico (2T2R)	
	SS-RSRP(dBm)	SS-SINR(dB)	Single user DL rate (Mbps)	Single user UL rate (Mbps)	Single user DL rate (Mbps)	Single user UL rate (Mbps)
General area	≥-105	≥0	600	70	300	30
High-value and high-business demand scenarios	≥-95	≥3				

In/ourdoor co-frequency networking

✓ Base station level: indoor>outdoor 15dB Rate loss < 20%;

✓ indoor>outdoor 10dB Rate loss about 30%;

✓ indoor>outdoor 5dB Rate loss about 45%;

SSB broadcast beam configuration:

✓ For general ground coverage, horizontal 8-beam is recommended.

✓ Compared with 1 beam, the RSRP gain of horizontal 8 beams is 5~8dB; SINR gain is 3~9dB

Downtilt configuration:

✓ On the basis of inheriting the total inclination of 4G, press down 3~6 degrees

✓ The average download speed on the road 14%↑

4/5G interference:

✓ Initial stage

the average 5G rate :

in isolated points 20% to 40% ↓

✓Middle and late stages

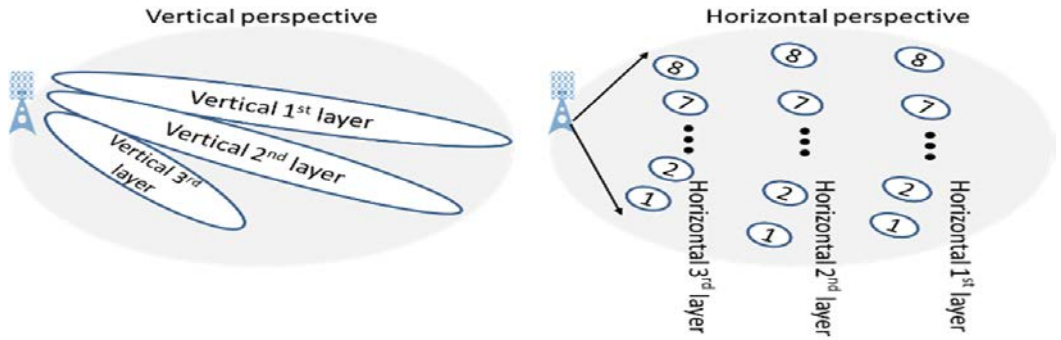
the average 5G rate:

in the contiguous area 10% ↓

in the edge 20%~30% ↓

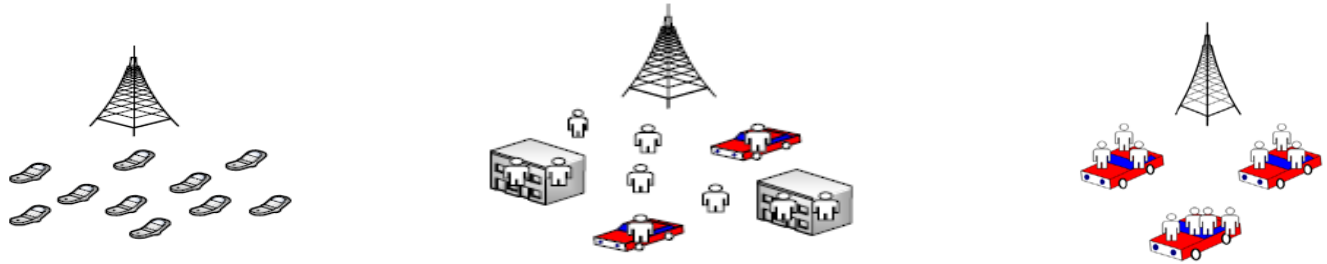
Novel Test Methods for 5G Network Performance Field Trial

- **Beam Scanning Requirements**
  - PDSCH divided into several layers
  - RB occupied by random data generated by OCNG



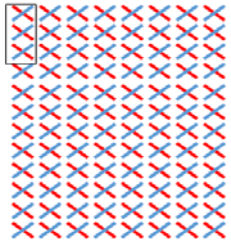
Beam Scanning Requirement

- **Test Scenarios**
  - Static scenario
  - Moving scenario
  - Vehicle scenario

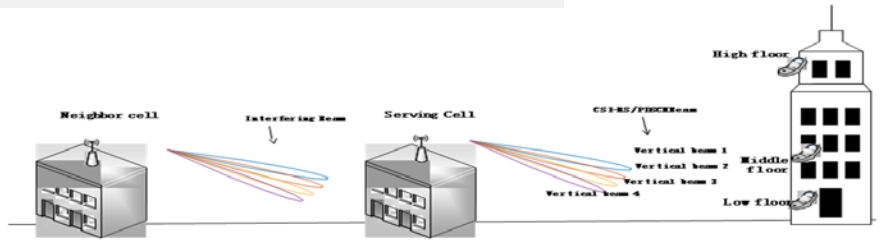


different scenario setup

- **Vertical Dimension Test**
  - Different CSI- RS vertical beams
  - Different distance building



5G 192 dipoles antenna design



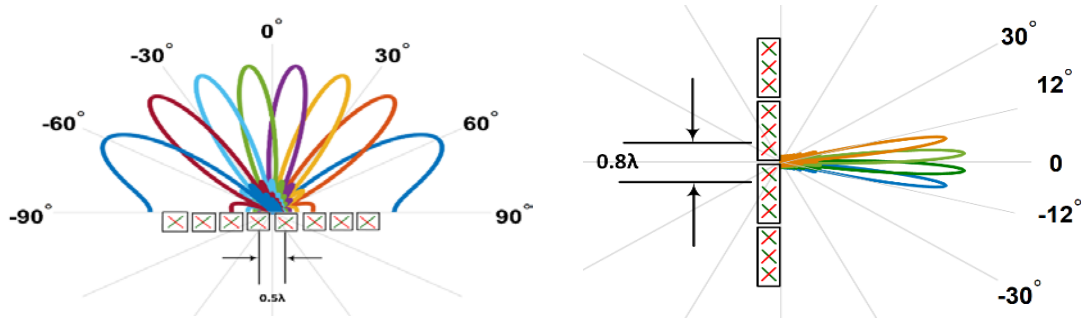
Proposed down-tilt angle method for 5G

Xin Li1, Wei Deng1, Lei Liu1, Yuqi Tian1, Hui Tong1, Jianhua Liu1, Yi Na2, Jiangzhou Wang3, Seppo Horsmanheimo4, Anastasius Gavras5 1China Mobile Research Institute, Beijing, China; 2University of Surrey, Surrey, GU2 7XH, UK; 3University of Kent, Canterbury, CT2 7NZ, UK; 4VTT Technical Research Centre of Finland, Espoo, Finland; 5EURESCOM, Heidelberg, Germany. ICC-2020

3D Beamforming Technologies and Field Trials in 5G Massive MIMO Systems

3D beamforming characteristics

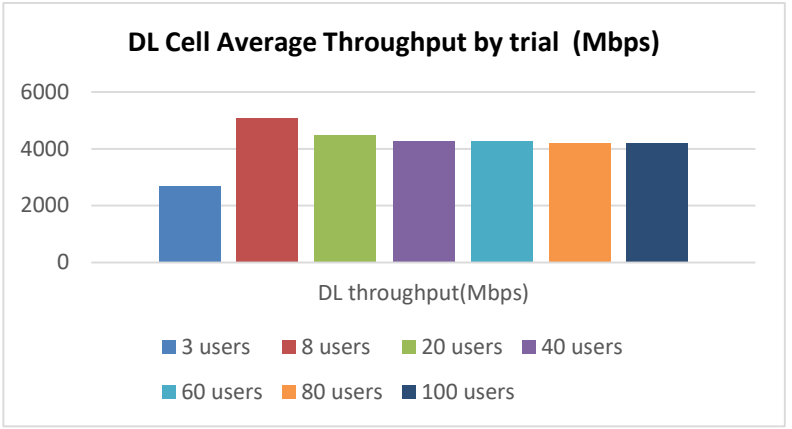
- Horizontal array
  - 8-antenna array
  - angle range can be 120 degrees
- Vertical array
  - 4 antenna units
  - may cover 24-degree angles



Horizontal and vertical array with beamforming

Field trial results

- Cell throughput can be increased 3 to 4 times
- Users with uniform angular distribution achieve larger sum rate than centralized distribution
- The best performance is static-user conditions, with it dropping considerably for mobile conditions, even by more than 50%



Multiuser (larger than 10 users) trial site

jiangzhou Wang, Fellow, IEEE, Wei Deng, Xin Li, Huiling Zhu, Manish Nair, Tao Chen, Na Yi, and Nathan Gomes, IEEE Open Journal of Vehicular Technology 2020

Content

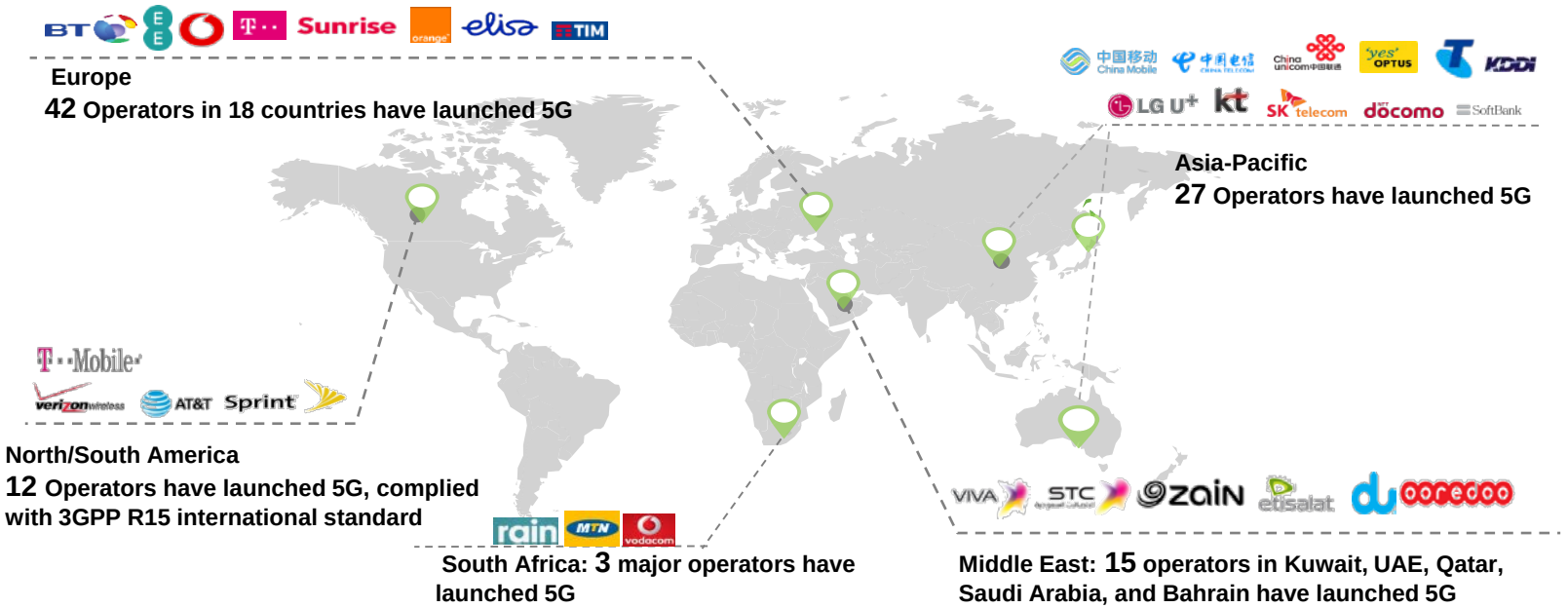
Introduction of 5G large-scale trial

Cooperation result review

Latest status of 5G commercial

Latest Progress of 5G commercial in domestic and foreign countries

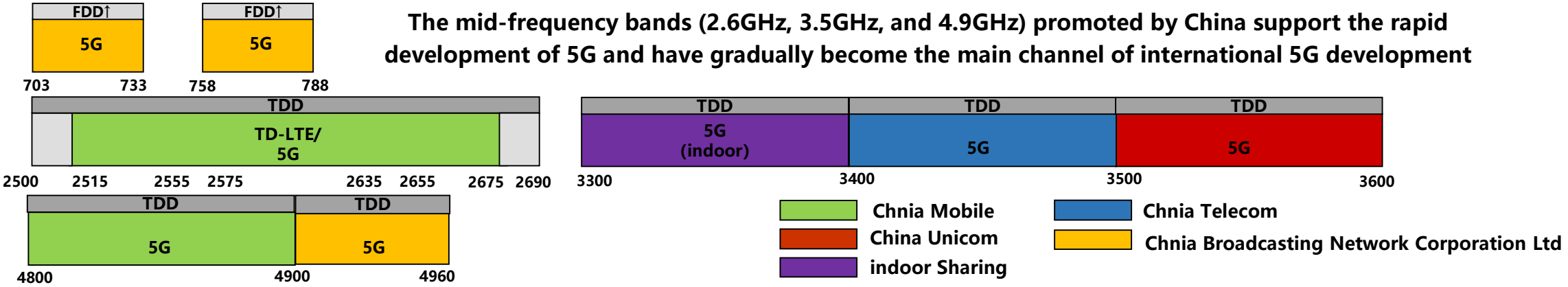
With the support and guidance of the Chinese government, 5G has developed rapidly, especially the planning and allocation of mid-frequency bands, laying a solid resource foundation



China's 5G construction progress

- **5G base stations ≥ 700 thousand**
- **5G terminal connection ≥ 180 million**
- **5G access license terminal 253 models**

As of October 2020

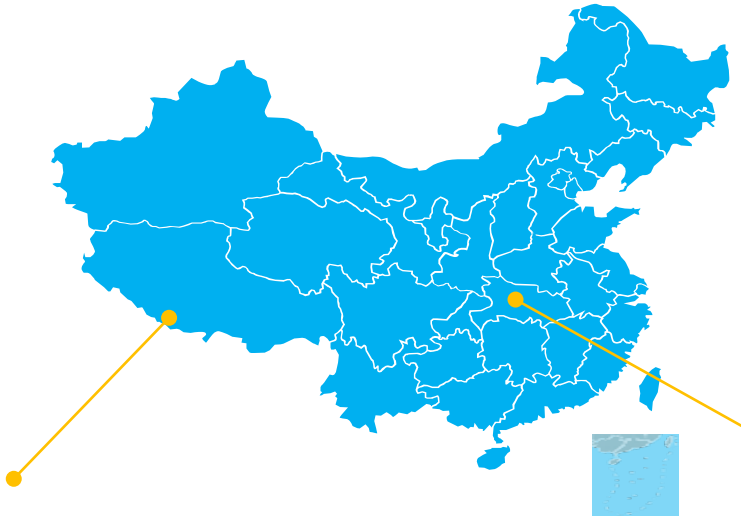


The mid-frequency bands (2.6GHz, 3.5GHz, and 4.9GHz) promoted by China support the rapid development of 5G and have gradually become the main channel of international 5G development

Latest Progress of 5G commercial in China Mobile

Overcome the impact of the COVID-19 epidemic, China Mobile has strived to build a 5G boutique network with extensive coverage, advanced technology and excellent performance, and to promote the development of 2C and 2B services based on large-scale commercial use of SA.

380,000+ SA base stations
5G SA in 337 cities



5G terminal connection ≥ 90 million

100+ gourp-level demo projects
2000+ provincial-level regional projects

World's highest
5G base station at 6500 m

Underground
5G private network at 534 m

Top-Quality Network

Wide Coverage

- 64/32/8/4/2 channels
- Macro, micro, pico, and DAS
- High-speed railway and metro

Advanced Technology

- NSA/SA
- Cloud and virtualization
- Massive MIMO, CA, and SUL

Superior Performance

- 1.7 Gbps DL per user
- 1Gbps UL at 100 MHz
- MEC based, <10 ms UP latency

High Efficiency

- 2.6G/4.9G dual-band
- 700M co-construction and co-sharing
- 5G/4G collaboration

Created benchmark cases to quickly extend 5G+X application

In face of the urgent need for realizing digital and intelligent transformation of 5G, China Mobile promoted high-quality 5G industrial application “benchmark cases”, which has scaled application in 15 industries for 100+ gourp-level demo projects and 2000+ provincial-level regional projects

Benchmark Cases, Industry first

World's first 5G smart logistics product

KSEC, Yunnan, June 2020

China's first 5G full-scenario smart port

Xiamen Ocean Gate Container Terminal, May 2020

World's first 5G hydro-aluminum smart factory

Yunnan Shenhuo Aluminum, May 2020

World's highest 5G HD and VR live broadcast

Mount Qomolangma, April 2020

China's first multinational 5G AR remote assembly

XISC, April 2020

Holographic customer service

Shanghai, April 2020

5G holographic teaching

Beijing, November 2019

China's first 5G cloud game

Guangdong, October 2019

中国移动
China Mobile

Thank you!

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