中国移动
China Mobile

Mid-Point of 5G Journey

Dr. Chih-Lin I
CMCC Chief Scientist, Wireless Technologies
CMRI, China Mobile

Keynote, European Conference on Networks & Comm. (EUCNC),
June 29, 2016, Athens, Greece

www.10086.cn

From 2011 to 2020 (Rethink Fundamentals)

中国移动
China Mobile

GCRC 绿色通信研究中心
Green Communication Research Center

Green Communication Research Center established in Oct. 2011, initiated 5G Key Tech R&D.

Green

Rethink Shannon
To start a green journey of wireless systems

Rethink Ring & Young
For no more "cells" via C-RAN

Rethink Signaling & Control
To make network application/load aware

Soft

Rethink Antenna
To make BS "invisible" via SmarTile

Rethink Spectrum & Air Interface
To enable wireless signal to "dress for the occasion" via SDAI

Rethink Fronthaul
To enable Soft RAN via NGFI

Super Fast

Rethink Protocol Stack
To enable User Centric Cell and real-time flexible air interface via MCD
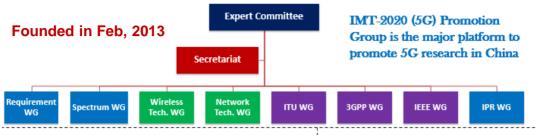
"Towards Green & Soft: A 5G Perspective" IEEE Comm. Magazine, Vol.52, Feb.2014
"5G: rethink wireless communication for 2020+", Philosophical Trans. A. 374(2062), 2015
"New paradigm of 5G wireless internet", IEEE JSAC, vol.34, no.3, March 2016

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IMT-2020 (5G) PG

中国移动 China Mobile

Founded in Feb, 2013

Expert Committee

Secretariat

IMT-2020 (5G) Promotion Group is the major platform to promote 5G research in China

| Requirement WG | Spectrum WG | Wireless Tech. WG | Network Tech. WG | ITU WG | 3GPP WG | IEEE WG | IPR WG |

- The Group has 56 members including the main operators, vendors, universities, and research institutes in China.

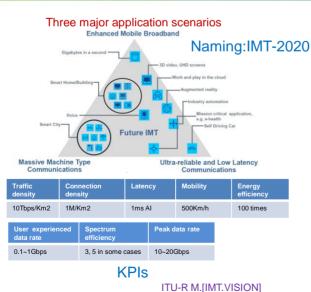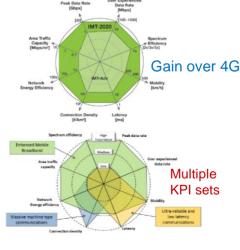工业和信息化部电信研究院 China Academy of Telecommunication Research of MIIT
中国移动 China Mobile
中国电信 CHINA TELECOM
China unicom中国联通

HUAWEI
ZTE
大唐電信 DATANG TELECOM TECHNOLOGY & INDUSTRY GROUP

• • • •

- Official website: www.IMT-2020.cn

IMT-2020 (5G) Promotion Group

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5G KPIs (ITU-R WP5D, Jun 2015)

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Three major application scenarios

Enhanced Mobile Broadband

Naming:IMT-2020

Gigabytes in a second
3D video, UHD screens
Work and play in the cloud
Smart Home/Building
Augmented reality
Industry automation
Voice
Mission critical application, e.g. e-health
Smart City
Self Driving Car
Future IMT

Massive Machine Type Communications

Ultra-reliable and Low Latency Communications

Gain over 4G

Traffic density	Connection density	Latency	Mobility	Energy efficiency
10Tbps/Km2	1M/Km2	1ms AI	500Km/h	100 times

User experienced data rate	Spectrum efficiency	Peak data rate
0.1~1Gbps	3, 5 in some cases	10~20Gbps

KPIs

ITU-R M.[IMT.VISION]

Multiple KPI sets

Feature Diagrams

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Rushing towards 5G?

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2016	2018	2020
AT&T (USA) **Verizon (USA)**	**KT/SKT (Korea)** **TeliaSonera (Sweden)**	**Docomo (Japan)**
5G Field Trial	5G Pre-Commercialization	5G Commercialization

PyeongChang 2018

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World's Largest 4G Network

中国移动 China Mobile

End of May, 2016

BS

~1.28M 4G BSs

~1.4M @2016

Subscriber

~409M Subscribers (@~835M)

~500M@2016

Terminal

Sales volume 300M+ Types 2000+, Price <50$

Coverage
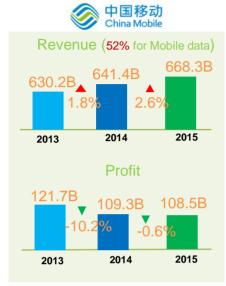
~1.2B pop (~86%), Reach Villages

GTI
120+ Operators 100+ Vendors

- **77** TD-LTE commercial networks in **43** countries
- **1.4 million +** TD-LTE base stations

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Sustainability needed for Operators

中国移动 China Mobile

中国移动 China Mobile

Revenue (52% for Mobile data)

630.2B ▲ 1.8% 641.4B ▲ 2.6% 668.3B

2013 2014 2015

Profit

121.7B ▼ -10.2% 109.3B ▼ -0.6% 108.5B

2013 2014 2015

Operators' Annual Revenue and Profit

Company	Revenue			Profit		
	2013	2014	2015	2013	2014	2015
China Tele (RMB)	321.6B	324.4B (0.90%)	331. 2B (2.1%)	17.6 B	17.7B (0.80%)	20.1B (19.2%)
China Uni. (RMB)	295.0B	284.7B (-3.50%)	277.0B (-2.7%)	10.4 B	12.06B (15.8%)	10.6B (-12%)
DOCOMO (Yen)	4461.2B	4383.4B (-1.7%)	4527.1B (3.3%)	464.7 B	410.1B (-11.8%)	548.5B (33.7%)
SKT (WON)	16602B	17164B (3.4%)	17136.7B(-0.2%)	1610 B	1799B (11.80%)	1515.9B(-15.7%)
AT&T (USD)	128.7B	132.4B (2.87%)	146.8B (10.84%)	18.6 B	6.5B (-64.90%)	13.3 B (104.7%)
Verizon (USD)	120.6B	127.1B (5.41%)	131.6B (3.57%)	11.5B	9.6B (-16.30%)	17.9 B(85.76%)
DEUTSCHE TELEKOM (EURO)	60.1B	62.7B (4.3%)	69.2B (10.37%)	2.8 B	2.4 B (-14.30%)	4.1B (70.83%)
Telefónica (EURO)	45.1B	50.4B (11.70%)	47.2 B (-6.27%)	2.23 B	3.0 B (34.70%)	2.7 B (-8.53%)

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China Mobile 4G+ Network Development

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VoLTE
Has been widely deployed in Commercial Network (2016)

Small Cell
~ 100,000 Small BSs to be deployed in 2016

CA
UL: 2 CC CA, DL: 3CC CA Field test
DL 2CC CA has been deployed in some provinces

IOT
Pre-commercialization at end of 2017

3D-MIMO
3D-MIMO BS Test in 4G Commercial Network

High Order Modulation
DL: 256QAM; UL: 64QAM
Most of vendors support, some terminals will support in later of 2016

Wider **Deeper** **Thicker** **Faster** **Newer** **Fusion**

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World's First 128 Ant BS Deployment in 4G Network 中国移动 China Mobile

Massive MIMO (128 ant.) Pre-com. Product.

CMCC & Huawei mMIMO field test in Shanghai

China Mobile, Shanghai，Sep.18,2015

Targets: 3D coverage, deep coverage, thp improve

Location: urban district with high buildings
(ChangShou Road, Shanghai)

Scheme (high-rise):

BS (25m), aims to cover a 75m building
& neighbouring roads

Tech: 3D beamforming & multi-sector networking

Freq& BW 2.6G&20M
4G commercial. terminals

Thp 630 Mbps

SE Up to 43bit/Hz
5~6x improve

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Rethink Fundamentals 中国移动 China Mobile

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5G: UCN + SDAI

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5G **UCN (NMC)** + **SDAI**

4G OFDM + MIMO

G³ (3G) CDMA

2G TDMA

SDAI: Software defined Air Interface
UCN: User Centric Network
NMC: No More "Cells"

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Green and Soft E2E Architecture with "Three Clouds"

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Green and Soft
- **Flexible** Access Cloud
- **Smart & Open** Control Cloud
- **High efficiency** Forward Cloud

Access Cloud

Unified RAN architecture + Common high layer protocol
(**UCN**, enabled by **C-RAN/NGFI**)
(**SDAI**, enabled by **MCD**)

RAN

Low Freq. New RIT | High Freq. RIT | Massive-MTC RIT | Mission-Critical RIT

LTE evolution Low freq. eMBB | NB-IoT | Latency redu. V2X

Seamless wide-area coverage | Hotspot & high data rate | Low-power & massive-connections | Low-latency & high-reliability

Service exposure

OTT | MVNO | Enterprise

API

Infrastructure | Pipeline | Value-added services | Context

Control Cloud

Control modular | Radio | MM | Policy | O&M | Orches tration | Resource management

Network controller

SDN/NFV

Edge caching | Service steering

Distributed GW | Centric DC

Forward Cloud

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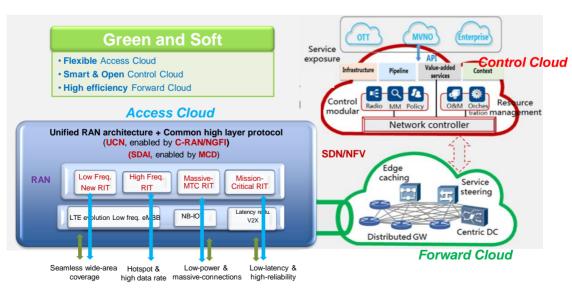
User Centric RAN (UCN) of 5G …

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Mobile Internet

mMTC

uMTC

Big Data based **SON**: high efficient O&M

Smart Operation

HSS/AAA/PCC
CN Entity

Internet/App

Local data processing
Ultra low latency

Cloud-RAN:
More powerful Platform

Centralized Radio Network Controller

Radio Data Center

RAN Entity

Including C-RAN (Centralized and Cloud)

Intelligent awareness
satisfactory service requirements

Signaling

Data

Seamless mobility:
reduced handover delay and interruption time

Next Generation Fronthaul Interface (NGFI)

5G

4G

WiFi

D2D

Flexible functional split:
adaptability to diverse deployment scenarios

Framework of radio access network

CN-RAN Repartition , Turbo Charged Edge , Network Slice as a Service, RAN restructure

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C-RAN: Revolutionary Evolution of RAN

中国移动 China Mobile

C-RAN

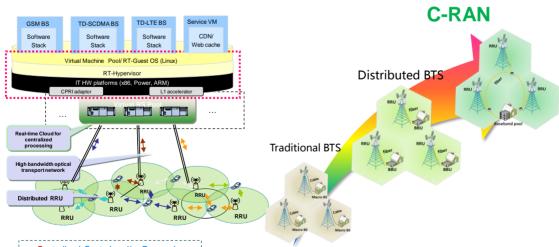| GSM BS	TD-SCDMA BS	TD-LTE BS	Service VM
Software Stack	Software Stack	Software Stack	CDN/ Web cache

Virtual Machine Pool/ RT-Guest OS (Linux)

RT-Hypervisor

IT HW platforms (x86, Power, ARM)

CPRI adaptor

L1 accelerator

Distributed BTS

RRU

RRU

RRU

fiber

Baseband pool

BBU

Real-time Cloud for centralized processing

High bandwidth optical transport network

Distributed RRU

RRU

RRU

RRU

RRU

RRU

RRU

RRU

fiber

RRU

fiber

BBU

RRU

fiber

BBU

Traditional BTS

Macro BS

cable

Macro BS

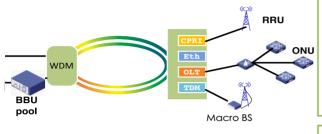cable

Macro BS

cable

- **C**entralized Control and/or Processing
- **C**ollaborative Radio
- Real-Time **C**loud
- **C**lean System Target

WP "C-RAN: The road towards green RAN".[Online]. Available: labs.chinamobile.com/cran
"Recent progress on C-RAN centralization & cloudification" in IEEE Access, 2014
"Cloud Radio Access Networks: Principles, Challenges, and Technologies " in ICC, 2015
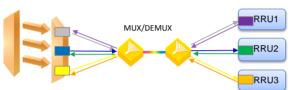
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Overcome the 4G FH Barrier

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CPRI 2:1 compression with SFBD: already mature enough to save the fiber usage by four-folds

- Active WDM/OTN :
  - ✓ Gradually mature since 2015
  - ✓ Diverse functionalities: large capacity, multiplexing, protection, flexible networking
  - ✓Two major concern: cost (especially OTN solutions); demarcation
  - ✓Applicable scenarios: C-RAN with high centralization scale

- Passive WDM:
  - ✓ Maturate fast since 2013
  - ✓ Low cost, easy installation, free of maintenance
  - ✓ Little change on the transport. Infra.
  - ✓ Applicable scenarios: small/medium centralization scale

CMCC currentl C-RAN deployment maily adopts passive WDM.

C-RAN Deployment Progress (Since 2009)

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C-RAN centralization as a preferred deployment solution
in CMCC's "**Network Deployment Guidance**" (2016)

- 2016 deployment plan: extension to 7 provinces
- One province of the scale of around 2000 sites
- Various FH solutions verified
- Demonstration on TCO saving and performance improvement
  - Energy saving: 60%, CA gain: 83%~ 95%, UL CoMP gain: 50% ~ 300%

4G C-RAN trials & deployment

CA Test

UL CoMP Test

RAN Virtualization: the Latency Frontier

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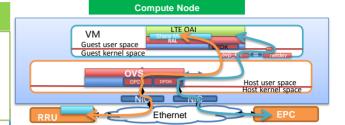
Founding NOC member of ETSI NFV ISG, the one to propose RAN virtualization in **NFV WP (2012)**

• **NFV-compliant C-RAN implementation**
  • VM realization of LTE
  • Key technologies adopted
    - RT enahncement: RT-Linux, DPDK, OVS
    - Effeciency improvement: RT-KVM
    - Management: Openstack

• **Commitment since 2013**
  • Optimization on interrupt latency: Average 4us v.s. ~100us for traditional system
  • Optimization on platform processing latency: 25~30us v.s. 300~500us in traditional Linux system
  • Optimization on VM communication latency: ~10us v.s. ~100us in traditional Linux system

Compute Node

Field Trial in 2015

C-RAN Virtualization field testbed @ Tsinghua University

Testbed:
• 1 TD-LTE macro outdoor BS
• 18 TD-LTE indoor BSs
• 1 GSM outdoor BS
• Area : 0.8km^2,
• General Server/Switch based BBU pool (with PHY1 accelerators)

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Persistence: Making C-RAN a Global Consensus

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•	C-RAN project & RAN EVOLUTION project lead in NGMN, leading the key tech study of C-RAN (2011~2014)
•	Founding NOC member of ETSI NFV ISG, the one to propose RAN virtualization in NFV WP (2012)
•	Platinum and board member of OPNFV (2014)
•	Founding member of IEEE 1904.3 TF & leading the project of NGFI in CCSA (2015)
•	C-RAN as a key component in NGMN 5G WP, FuTURE Forum 5G SIG WP, IMT-2020 WP (2015)
•	C-RAN open source contribution in EURECOM (2015~)
•	MWC showcase since 2014 & various events (2014~)

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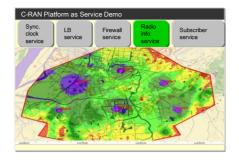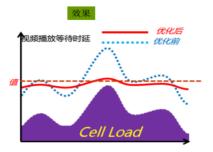
C-RAN based "Service on Edge" since 2012

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C-RAN inherently support MEC

C-RAN Platform as Service Demo

| Sync. clock service | LB service | Firewall service | Radio info. service | Subscriber service |

效果

视频播放等待时延

优化后
优化前

值

Cell Load

Open API provide the ability to capture the network status

Video optimization

Enable Low latency service

Demos as early as in MWC 2014

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UCN Turbo Charged Edge: MEC

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Field and Lab trial on Cache

Cache hit

- Scenarios: area without core network cache
- Solutions: Single-level cache and Two-level cache
- Advantages: latency reduction & transmission saving
- Key concerns: Charging, Mobility management

eNB
PTN N/W
Cache missed
LIG EPC
MME
S-GW P-GW
Internet
Charging info.
Charge node
BOSS

•Lab trial: 50% saving on latency & 50% increase on DL
•Field trial: 17% hit rate at peak traffic time & 16% saving on transport BW

Demo on video optimization for VIP users of iQIYI

RAN as black box

Non-VIP users
UE
VIP users
RAN MEC EPC Video server
Service sensing + optimized scheduling
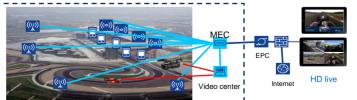
• Packet analysis by MEC to distinguish the service and VIP users, then BS informed
• Differentiated wireless BW and latency guarantee provided by BS

Local breakout: trial of Multi-visual-angle live program of competitive sports
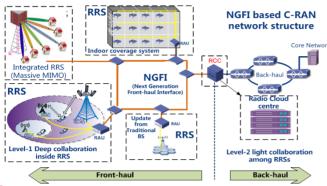
- Scenarios: smart gateway, local content forwarding etc.
- Solutions:
  ✓ Service delivery by eNB
  ✓ Service delivery by MEC
- Major advantage: latency reduction
- Key concerns: Security

- More than 90 small cells
- Maximum 100 users in service
- 0.5s latency compared to live broadcast

MEC
EPC
Internet
Video center
HD live

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NGFI (xHaul) since 2014 (Function Partition since 2012)

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NGFI

NGFI considerations

The objectives of NGFI
- Enable **statistical multiplexing** for FH
- Decoupling **cell proc. & UE proc**, and **UL&DL**
- Support 5G key tech., Massive MIMO etc.

The key is function re-split between BBU and RRU, & re-design of underlined transport networks

Ethernet as promising (Low-cost & Flexible)
- NGFI encapsulation: IEEE 1904.3 WG
  (2-3 Jun 2015 in Beijing hosted by CMCC)
- Latency enhancement: TSN
- Synchronization: IEEE 1588WG & ITU-T

Features:
- Separation of ant-related processing and non-ant-related processing
- Separation of baseband upper and lower layer processing
- Layered coordination to address interference for area of different scale
- Support 5G new technologies e.g. UDN, massive MIMO

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NGFI WP and Related work in IEEE 1914

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WP on NGFI released in June 2015

下一代前传网络接口
白 皮 书

White Paper of
Next Generation Fronthaul Interface

Version 1.0
June 4th, 2015

China Mobile Research Institute
Alcatel-Lucent
Nokia Networks
ZTE Corporation
Broadcom Corporation
Intel China Research Center

- IEEE 1914 (NGFI) WG officially approved in Feb. 2016, led by CMCC
- 1st NGFI WS held & NGFI WP released in June, 2015
  - MoU signing with Broadcom, Intel, Alcatel-Lucent, HuaWei, ZTE, Nokia, Xilinx & Altera

IEEE 1914 WG (7 Founding members)
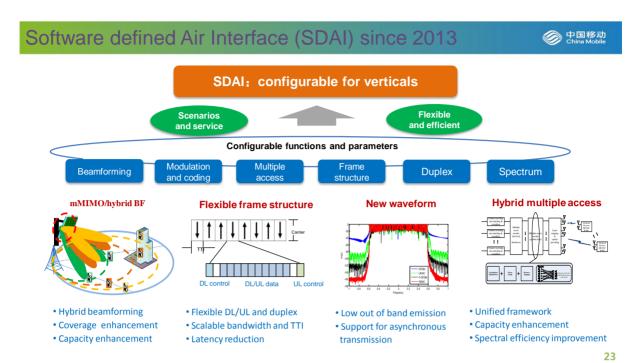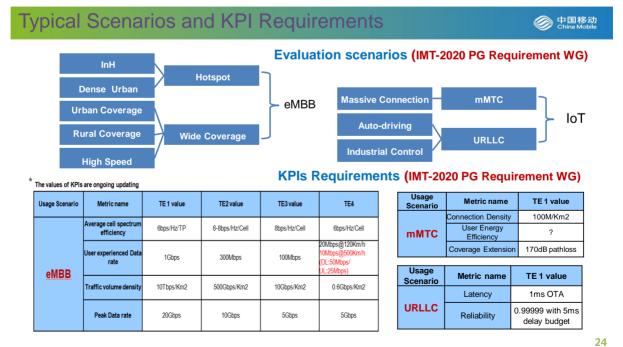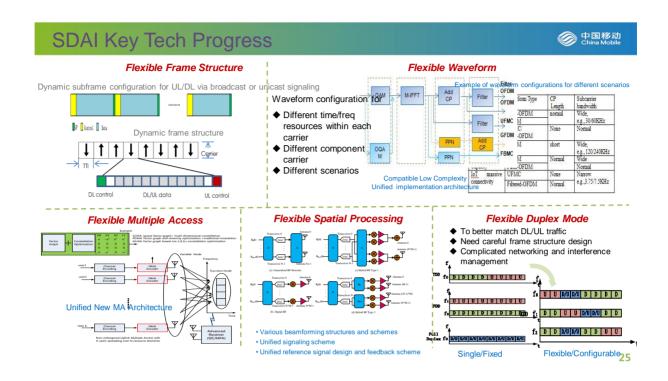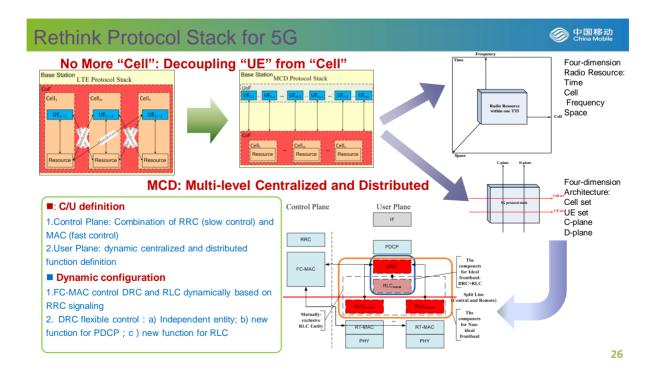
- Officially approved: Feb. 2016
- Sponsor: IEEE COM/SDB
- 7 founding companies with more than 100 subscribers so far from ~40 companies
- Target: efficient & scalable FH for 5G
- Scope of 1914.1 project:
  - NGFI transport network architecture
  - Requirements
  - Function split analysis for LTE
- http://grouper.ieee.org/groups/1914/
- The first NGFI WG meeting held on 25 – 28 April, San Jose
- Possible transfer of 1904.3 RoE project to under 1914 WG;
- Potential collaboration with 802.1 CM

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Software defined Air Interface (SDAI) since 2013

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SDAI：configurable for verticals

Scenarios and service

Flexible and efficient

Configurable functions and parameters

| Beamforming | Modulation and coding | Multiple access | Frame structure | Duplex | Spectrum |

mMIMO/hybrid BF

Flexible frame structure

Carrier

TTI

DL control DL/UL data UL control

New waveform

Hybrid multiple access

- Hybrid beamforming
- Coverage enhancement
- Capacity enhancement

- Flexible DL/UL and duplex
- Scalable bandwidth and TTI
- Latency reduction

- Low out of band emission
- Support for asynchronous transmission

- Unified framework
- Capacity enhancement
- Spectral efficiency improvement

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Typical Scenarios and KPI Requirements

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Evaluation scenarios (IMT-2020 PG Requirement WG)

InH

Dense Urban

Urban Coverage

Rural Coverage

High Speed

Hotspot

Wide Coverage

eMBB

Massive Connection

Auto-driving

Industrial Control

mMTC

URLLC

IoT

KPIs Requirements (IMT-2020 PG Requirement WG)

* The values of KPIs are ongoing updating

Usage Scenario	Metric name	TE 1 value	TE2 value	TE3 value	TE4
eMBB	Average cell spectrum efficiency	6bps/Hz/TP	6-8bps/Hz/Cell	8bps/Hz/Cell	6bps/Hz/Cell
	User experienced Data rate	1Gbps	300Mbps	100Mbps	20Mbps@120Km/h 10Mbps@500Km/h (DL:50Mbps/ UL:25Mbps)
	Traffic volume density	10Tbps/Km2	500Gbps/Km2	10Gbps/Km2	0.6Gbps/Km2
	Peak Data rate	20Gbps	10Gbps	5Gbps	5Gbps

Usage Scenario	Metric name	TE 1 value
mMTC	Connection Density	100M/Km2
	User Energy Efficiency	?
	Coverage Extension	170dB pathloss

Usage Scenario	Metric name	TE 1 value
URLLC	Latency	1ms OTA
	Reliability	0.99999 with 5ms delay budget

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SDAI Key Tech Progress

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Flexible Frame Structure

Dynamic subframe configuration for UL/DL via broadcast or unicast signaling

IP Control Data

Dynamic frame structure

Carrier

TTI

DL control   DL/UL data   UL control

Flexible Multiple Access

Factor Graph + Constellation Optimization

Example
SCMA: sparse factor graph+ multi-dimensional constellation
PDMA: factor graph with diversity optimization +traditional modulation
MUSA: factor graph based on(-1,0,1)+constellation optimization

user1 Channel Encoding NMA Encoder
user2 Channel Encoding NMA Encoder

User K Channel Encoding NMA Encoder

Variable Node   Frequency

Function Node

Time

Advanced Receiver (SIC/MPA)

Unified New MA Architecture

Non-orthogonal Uplink Multiple Access with K users spreading over N resource elements.

Flexible Waveform

Example of waveform configurations for different scenarios

QAM — M-IFFT — Add CP — Filter — OFDM
OQAM — Filter — OFDM, UFMC
PPN — Add CP — GFDM
PPN — FBMC

Waveform configuration for
◆ Different time/freq resources within each carrier
◆ Different component carrier
◆ Different scenarios

Compatible Low Complexity Unified implementation architecture

Scenario	form Type	CP Length	Subcarrier bandwidth
	OFDM	normal	Wide, e.g.,30/60KHz
	M		
	C/ OFDM	None	Normal
	M	short	Wide, e.g.,120/240KHz
	M OFDM	Normal	Wide
	OFDM	Normal	Normal
IoT massive connectivity	UFMC	None	Narrow
	Filtered-OFDM	Normal	e.g.,3.75/7.5KHz

Flexible Spatial Processing

S₀(t) DAC A₀
Sₙ₋₁/R DAC Aₙ₋₁
(a) Generalized RF Structure

S₀(t) DAC
Sₙ₋₁/R DAC
(b) Digital BF

Transceiver 0 Antenna 0
Transceiver N-1 Antenna (N*M-1)
(c) Hybrid RF Type 1

Transceiver 0 Antenna 0
Transceiver N Antenna (N-1*M)
Antenna (N*M-1)
(d) Hybrid RF Type 2

• Various beamforming structures and schemes
• Unified signaling scheme
• Unified reference signal design and feedback scheme

Flexible Duplex Mode

◆ To better match DL/UL traffic
◆ Need careful frame structure design
◆ Complicated networking and interference management

TDD f₀ D D D D D U U U U

FDD f₀ U U U U U U U U
     f₁ D D D D D D D D

Full Duplex f₀ D/U D/U D/U D/U D/U D/U D/U D/U

f₀ U U D/U D/U D D D D
f₁ D D D D D/U D/U D/U D
f₂ D D D/U D/U D D U

Single/Fixed   Flexible/Configurable

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Rethink Protocol Stack for 5G

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No More "Cell": Decoupling "UE" from "Cell"

Base Station
LTE Protocol Stack
CoF
Cell₁   Cellₘ   Cellₙ
UE₁₋ₓ   UE₁₋ₓ   UE₁₋ₓ
Handover
Resource   Resource   Resource

Base Station
MCD Protocol Stack
UoF
UE₁,₁ UE₁,ₓ UEₙ,₁ UEₙ,₂ UEₙ,₁ UEₙ,₂
CoF
Cell₁   Cellₘ   Cellₙ
Resource   Resource   Resource

Time   Frequency
Radio Resource within one TTI
Space   Cell

Four-dimension Radio Resource:
Time
Cell
Frequency
Space

MCD: Multi-level Centralized and Distributed

Control Plane   User Plane

IP

RRC

FC-MAC

PDCP

DRC

RLC_central

RLC_remote   RLC_remote

RT-MAC   RT-MAC

PHY   PHY

Mutually-exclusive RLC Entity

C-plane   D-plane

5G protocol stack   Cell set

UE set

Four-dimension Architecture:
Cell set
UE set
C-plane
D-plane

The components for Ideal fronthaul: DRC+RLC

Split Line (Central and Remote)

The components for Non-ideal fronthaul

■: C/U definition
1.Control Plane: Combination of RRC (slow control) and MAC (fast control)
2.User Plane: dynamic centralized and distributed function definition

■ Dynamic configuration
1.FC-MAC control DRC and RLC dynamically based on RRC signaling
2. DRC flexible control : a) Independent entity; b) new function for PDCP ; c) new function for RLC

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China Mobile 5G Prototype Demo (2014-2015)

中国移动 China Mobile

IMIC 2014

NGMN 2014

PT/EXPO 2014

GSMA 2014

2015.3, C-RAN live carrier migration & SmarTile based Invisible BS

2015.9 Mini C-RAN
2015.9 SDAI first-phase demo

2014.2, Greener and Softer Network

MWC2014   **MWC2015**   **PT/EXPO China 2015**

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China Mobile 5G Prototype Demo (MWC2016)

中国移动 China Mobile

SDAI/Smartile 2.0: CMCC & Cobham/Keysight/R&S/Sunnad

Mini C-RAN/NGFI: CMCC & Intel/WindRiver

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FuTURE 5G SIG

- **FuTURE 5G SIG launched in Mar. 2014**
- **FuTURE 5G WP 1.0 (Nov 6, 2014):**
- **FuTURE 5G WP 2.0 series**
  - **- FuTURE 5G WP 2.0 (Nov 6, 2015)**
  - **- Topical WP 2.0a to 2.0g (Nov 6, 2015)**
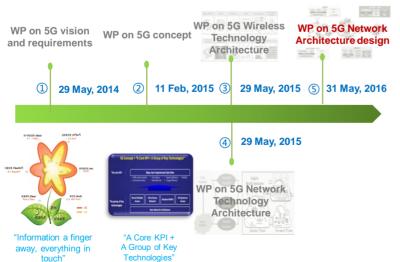 - **- Topical WP 2.0h : 5G High Mobility (Jun, 2016)**

White Paper V2.0, 2015. 11

5G enabler : Massive MIMO Technology

5G enabler : Agile Duplex

5G enabler : High Frequency Communications

5G enabler : Alternative Multiple Access

5G enabler : Ultra-Dense Network

5G enabler : Security Technologies for 5G

5G enabler : Test and Measurement Technologies for 5G

5G enabler : High Mobility

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IMT-2020 (5G) PG Progress

WP on 5G vision and requirements

WP on 5G concept

WP on 5G Wireless Technology Architecture

WP on 5G Network Architecture design

Multilateral Partnerships for 5G

① **29 May, 2014**   ② **11 Feb, 2015**   ③ **29 May, 2015**   ⑤ **31 May, 2016**

④ **29 May, 2015**

WP on 5G Network Technology Architecture

"Information a finger away, everything in touch"

"A Core KPI + A Group of Key Technologies"

October 20, 2015

★ 31 May – 1 Jun, 2016 in Beijing

THE 1st Global 5G Event
BUILDING 5G TECHNOLOGY ECOSYSTEM
May 31-June 1, 2016, Beijing, China

★ Oct. 2016 in Rome (5G PPP)

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National S&T Major Project "NextGen MBB Comm. Network"　◆ 中国移动 China Mobile

- **Project 1 5G R&D**

  1.1 5G standardization overall scheme research & promote (CMCC, in part)
  1.2 5G high performance BS AD/DA converter test sample R&D
  1.3 5G BS high-freq. wide-BW PA test sample R&D
  1.4 5G BS high-freq. wide-BW RF filter test sample R&D
  1.5 5G high-mobility wide-area seamless coverage scheme and test-bed R&D (CMCC, in part)
  1.6 5G low-power massive-connection scheme and test-bed R&D
  1.7 5G high freq. comm. scheme & test-bed R&D (CMCC, in part)
  1.8 5G Ultra dense networking scheme & test-bed R&D
  1.9 5G new multiple access scheme & test-bed R&D
  1.10 5G RAN architecture & system R&D (CMCC, lead)
  1.11 5G network based high-precision indoor location R&D
  1.12 Automatic driving oriented 5G key tech. research & demo (CMCC, in part)

- **Project 2 LTE-A R&D and Industrialization**

  2.11 LTE-V wireless transmission tech. standardization & prototype (CMCC, in part)

- **Project 3 Mobile Network Supports Industrial Internet**

  3.1 Wireless mobile oriented industrial internet (CMCC, in part)

(2016.1-2017.12)

国家科技重大专项
National Science and Technology Major Project

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CMCC 5G Activities　◆ 中国移动 China Mobile

- **ITU：**
  - 8 KPIs proposed by China adopted by ITU-R;
  - Co-lead ITU-T IMT-2020 FG work and contribute to the network softwarization paper and gap analysis.
- **IEEE：**
  - IEEE 1914 NGFI WG led by CMCC officially launched in Feb. 2016;
  - Contribution on White Paper of IEEE SDN Initiative.
- **NGMN：**
  - Lead in 5G requirements study, actively contributed tech & network architecture study, & jointly issued NGMN 5G WP;
  - As NGMN representative, providing Operators' vision on 5G scenarios & tech requirements to 3GPP & ITU.
- **ETSI NFV :**
  - Founding member of NOC; Extended NFV scope from CN only to E2E including RAN;
  - Contribution on NFV WP 1.0 to 4.0;
  - PoC contribution to demonstrate vRAN capability;
  - Prioritization on feature proposals for NFV 2016 planning, feedback on NFV stage 3 planning etc.
- **CCSA**
  - Lead in CCSA NGFI study Item, contribution on NGFI study report;
  - Actively involved in candidate high freq study, including channel measurements;
  - Actively involved in dedicated spectrum study for V2V.

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CMCC 5G Activities in 3GPP

中国移动 China Mobile

- **3GPP SA2, lead in the 5G network architecture design SI**
  - **"Study on Architecture for Next Generation System"** led by CMCC approved on Oct. 22, 2015 with 48 companies' co-signature(expected reach to 55 companies in SA plenary). It is the first large-project related to 5G standardization led by China;
  - Already developed 28 high-level requirements, 19 key issues (9 of them are basic), initial high level architecture, candidate solutions.
- **3GPP SA1, lead in "**SMARTER**-Network Operation (NEO)" SI**
  - SMARTER: New Services and Markets Technology Enablers
- **3GPP 5G RAN Standardization Timeline**
  - Sep. 2015, SI on high-freq channel modeling initiated;
  - **Dec. 2015, 5G requirements SI initiated (CMCC lead);**
  - Mar. 2016, 5G technology SI initiated (~50 submissions from RAN1 to RAN4);
  - Mar. 2016, "Study on Context Aware Service Delivery in RAN" Initiated (CMCC lead) in RAN3
- **Sep 2015, RAN 5G workshop:**
  - Phase 1 WI to be completed at the 2nd half of 2018, targeting network deployment at 2020;
  - Phase 2 WI to be completed at end of 2019, for ITU spec submission deadline with all the requirements satisfied.

RAN1~ RAN5 held in Nanjing, from 23 May to 27 May, hosted by CMCC and partners!

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Progress in 3GPP RAN1 (May, 2016)

中国移动 China Mobile

- Made agreements for *forward compatibility/*compatibility of different features, including
  - *Support of multiplexing different numerologies within a same NR carrier bandwidth*
- Made working assumptions/agreements on *NR numerology/frame structure*, including
  - *Support of flexible NW and UE channel bandwidth*
  - *Support of flexible HARQ scheduling timing and asynchronous DL/UL HARQ*
- Made agreements for *waveform/multiple access*, including
  - *Evaluation cases and evaluation assumptions for waveform*
  - *Support of synchronous/scheduling-based orthogonal multiple access for DL/UL transmission schemes at least targeting for eMBB*
  - *Evaluation assumptions for autonomous/grant-free/contention based UL non-orthogonal multiple access*
- Made agreements for *multi-antenna* schemes, including
  - *Study on potential technologies such as beamforming, RS structure and CSI acquisition, etc.*
- Made agreements for *evaluation assumptions*, including
  - *Evaluation assumptions for following deployment scenarios*
    - *Indoor hotspot, Dense urban, Rural, Urban macro, High speed, Extreme rural, Urban coverage for massive connectivity, Highway, Urban grid*
  - *Some other evaluation assumptions agreed in relation to:*
    - *mMTC, URLLC, V2X, MIMO & antenna modelling, UE PA model, Waveform evaluations, Multiple access evaluations*

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Summary of 5G NR RAN2#94 (May,2016)

中国移动 China Mobile

Standalone NR

Architecture:

Intra-NR aggregation :

1: Aggregation of NR carriers to be studied

2: As in LTE, NR shall study both lower layer aggregation (e.g. CA-like) and upper layer aggregation (e.g. DC-like)

3: User plane provides an in-sequence, secure and guaranteed delivery for transport of RRC signaling.

User Plane:

LTE L2 functions are consider as a baseline for NR. Order, allocation to sublayers, and merger of functions needs to be considered depending on use cases

Control Plane:

Study the introduction of a RAN controlled "state" characterised by, at least:

1: UEs in RAN controlled state should minimise signalling, power consumption, and resource costs in the RAN/CN, which maximises the number of UEs utilising (and benefiting from) this state

2: Data transfer with low delay (as RAN requirements)

Tight interworking with LTE

Agreements:

1: DC approach for LTE-NR aggregation will be studied (FFS: 3c/1a-like or other UP architecture)

1a: Both LTE as master and NR as master will be studied..

2: The CA based LTE-NR aggregation will not be studied as part of the study item

UP : Study both split bearer (3C bearers) and direct routing (1A bearers) for LTE-NR multi-RAT.

Mobility

NR eNB corresponds to 1 or many TRPs

NR shall support a state with network controlled mobility handling and a state with UE controlled mobility

Two levels of network controlled mobility:

1: RRC driven at 'cell' level.

2: Zero/Minimum RRC involvement (e.g. at MAC /PHY)

FFS: definition of a cell

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3GPP RAN3 Progress - Internal RAN Logical Arch (May, 2016)

中国移动 China Mobile

- **Deploy scenarios (Agreed CU and DU deployment scenario, aligned with RCC and RRS architecture)**

Non-centralised deployment

Centralized deployment (CU and DU deployment)

Co-sited deployment with LTE

Shared RAN deployment

- **Agreed to study the options against LTE and NR, which is aligned with our study (NGFI)**

Preference

	Option 2 and 3 (Non-ideal Fronthaul)	Option 7 (Ideal Fronthaul, mMIMO)	Option 8 (Ideal Fronthaul)
BW UL	3024 Mb/s	15.2Gb/s	157.3 Gb/s
BW DL	4016Mb/s	9.8Gb/s	157.3 Gb/s
Latency	10ms	250us	250us

- **Agreed on the following evaluation criteria for functional split**

1) Protocol Split option; 2)Required bandwidth; 3) Max. allowed one way latency; 4) delay critical feature.

3GPP RAN Plenary #72 (Jun 13-16, 2016)

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RAN	类型	内容	rapporteur	支持公司数	运营商
R1	WI	Work Item on shortened TTI and processing time for LTE	Ericsson	34	14
	WI	Enhancements of NB-IoT	Vodafone	34	12
	WI	Further Enhanced MTC	Ericsson	29	10
	WI	LTE-based V2X Services	LG E, CATT, Huawei	28	6
R2	空				
R3	SI	Study on SON for eCoMP for LTE	Nokia	10	3
	SI	Multi-node tests for LAA	Huawei, Ericsson, Qualcomm	10	5
R4	SI	Study on NB-IoT RF requirement for coexistence with CDMA	China Telecom, Qualcomm, Samsung	10	3

Among 7 Approved Projects,
5 Projects have relations with IoT

16.3   17.3   18.6   19.12

| RAN R14 | RAN R15 | RAN R16 |

"Study on Next-Gen New Radio Access Tech"

| New Radio SI | New Radio SI |

For early 5G commercialization

| Phase 1 |

| SA1 SI | SA1 WI R15 |

| SA2 SI | WI R15 | WI R16 |

| Phase2 |

"IMT-2020" specification. Submitted to ITU

"Study on Arch for Next-Gen System"

Both NSA-NR and SA-NR to be supported for Phase 1

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5G Key tech. Validation, Prototype and Initial Trials

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	2015Q1	2015Q2	2015Q3	2015Q4	2016Q1	2016Q2	2016Q3	
Massive MIMO (128TX)		3D-MIMO in single site (128TX, Huawei, ZTE)			3D-MIMO in scale (ZTE @shanghai, Huawei@Shanghai, Datang Mobile@beijing)			2016Q4
Full Dulplex (Interference cancellation 102dB)		Prototype and tests (Huawei, UESTC @chengdu)						2015Q4
High Frequency (6GHz-30GHz)			ZTE (@Shanghai, 15GHz)、UESTC (@Chengdu, 26GHz)、Huawei@Chengdu(Ka/E/V band)					2016Q4
Multiple Access (SCMA, PDMA, MUSA)			ZTE (@shanghai, MUSA)、Huawei (@chengdu, SCMA)、Datang Mobile (@Beijing, PDMA)					2016Q4
Waveform (F-OFDM, FB-OFDM)			ZTE (@shanghai, FB-OFDM)、Huawei (@chengdu, F-OFDM)					2016Q4
UDN (≥8 eNBs，≥10 UEs)				Datang Mobile @Beijing				2016Q4
Channel coding (Polar code)				Huawei@Chengdu				2016Q4
User Centric Network		Ericsson、Nokia、Huawei						2016Q4
SDAI		Cooperate with Huawei, ZTE, Datang Mobile, Cobham						2016Q4
Chipset Device (3D-MIMO、High frequency)		TI、MACOM、Qorvo、MURATA						2016Q4

3D-MIMO pre-commerial products

Full Dulplex Prototype

High Frequency Prototype

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IMT-2020 PG 5G Tech R&D and Sys Trial Plan (Jan, 2016) 中国移动 China Mobile

2015	2016	2017	2018	2019	2020

3GPP A GLOBAL INITIATIVE — R14 5G SI — R15 Phase1 for 5G — R16 Phase2 for 5G — **5G Commercialization**

Key Tech Verification
Phase 1: Key Tech R&D and Trial

Solution Verification

System Verification
Phase 2: Product R&D & Trial

Led by CAICT; Operators, Manufactures & Scientific institutes actively involved.

Led by Operators in China; Manufactures & Scientific institutes actively involved.

- **Phase 1: key tech R&D and trial**
- **Phase 2: Product R&D and trial**
  - ➢ *Key Tech Verification (2015.9-2016.9): key tech prototype performance test*
  - ➢ *Solution Verification (2016.6-2017.9): 5G BS prototype performance test*
  - ➢ *System Verification (2017.6-2018.10): 5G networking performance test, and typical service demo.*

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5G Trial Plan towards 2020 中国移动 China Mobile

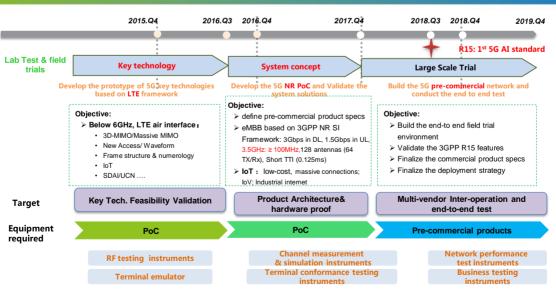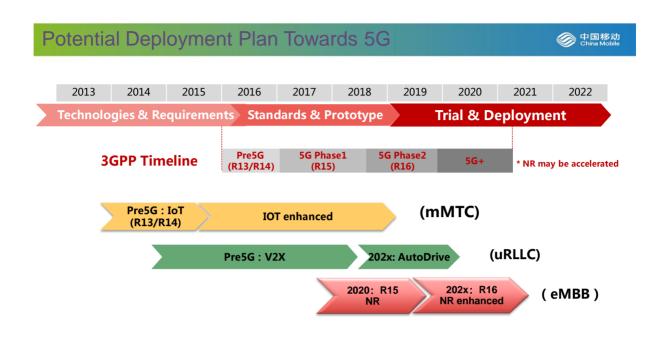| 2015.Q4	2016.Q3	2016.Q4	2017.Q4	2018.Q3	2018.Q4	2019.Q4

R15: 1st 5G AI standard

Lab Test & field trials

Key technology — **System concept** — **Large Scale Trial**

Develop the prototype of 5G key technologies based on LTE framework

Develop the 5G **NR PoC** and Validate the system solutions

Build the 5G **pre-commercial** network and conduct the end to end test

Objective:
➢ **Below 6GHz, LTE air interface：**
  - 3D-MIMO/Massive MIMO
  - New Access/ Waveform
  - Frame structure & numerology
  - IoT
  - SDAI/UCN ….

Objective:
➢ define pre-commercial product specs
➢ eMBB based on 3GPP NR SI
  Framework: 3Gbps in DL, 1.5Gbps in UL, 3.5GHz: ≥ 100MHz,128 antennas (64 TX/Rx), Short TTI (0.125ms)
➢ **IoT :** low-cost, massive connections; IoV; Industrial internet

Objective:
➢ Build the end-to end field trial environment
➢ Validate the 3GPP R15 features
➢ Finalize the commercial product specs
➢ Finalize the deployment strategy

Target | Key Tech. Feasibility Validation | Product Architecture& hardware proof | Multi-vendor Inter-operation and end-to-end test

Equipment required | PoC | PoC | Pre-commercial products

RF testing instruments
Terminal emulator

Channel measurement & simulation instruments
Terminal conformance testing instruments

Network performance test instruments
Business testing instruments

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Potential Deployment Plan Towards 5G

中国移动 China Mobile

2013	2014	2015	2016	2017	2018	2019	2020	2021	2022

Technologies & Requirements **Standards & Prototype** **Trial & Deployment**

3GPP Timeline   Pre5G (R13/R14)   5G Phase1 (R15)   5G Phase2 (R16)   5G+   * NR may be accelerated

Pre5G : IoT (R13/R14)   IOT enhanced   **(mMTC)**

Pre5G : V2X   202x: AutoDrive   **(uRLLC)**

2020：R15 NR   202x：R16 NR enhanced   **(eMBB)**

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China Mobile 5G Joint Innovation Center

中国移动 China Mobile

During the evolution from 4G to 5G, China Mobile will cooperate with the industry for applications and product joint innovation, to build a cross-industry ecosystem

Internet of Things   Internet of Vehicles   Industrial Internet   Cloud Robot   AR/VR

China Mobile 5G Innovation Center

Open Lab 1   Open Lab 2   Open Lab 3   ......

Communication Infrastructure Lab

eMBB
(Enhance Mobile Broadband)

uRLLC
(Ultra Reliable & Low Latency Communication)

mMTC
(Massive Machine Type Communication)

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Toward Sustainable 5G Ecosystems

中国移动 China Mobile

Open Source community
- Openfog, On.Lab
- TIP, Open5G, Open-O

Soft 5G

Big data

SDN/NFV

Cloud-RAN

Software defined AI

Traditional stakeholders
- CMCC, Vodafone, DoCoMo,…
- Ericsson, Huawei, ZTE, Nokia, …
- Qualcomm, MTK, SPR, …
- Freescale, Ti, …
- …

Verticals,
- Auto driving,
  e.g., BMW, Tesla,…
- Industrial control,
  e.g, Haier, …
- …

Service venders on the
soft/open platform (OTT, MVNO, …)
- Facebook, Google, Microsoft
-Tencent, Ali , …

New stakeholders
- Intel, ARM, Xilinx,…
- IBM, HP, Dell, Cisco…
- Windriver, Vmware,
-Premises owner

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Big Data Analytics for Network Optimization

中国移动 China Mobile

MCES (Multi-RAT Cooperation Energy-saving System)

Data Collection Module
Real-time information collection

Policy Decision Module
Collaborative energy saving algorithm is implemented to obtain the optimal traffic distribution scheme

Execution Module
The Base Stations are turned up /off according to policy decisions

Terminal

Multi-RAT Cooperation Energy-saving System

BTS — GSM BSC — GSM OMC/OSS
NodeB — TD-SCDMA RNC — TD-SCDMA OMC/OSS
eNodeB — TD-LTE OMC/OSS

INPUT

UE QoS
UE Location
Network configuration & traffic data
BSs Energy Model

OUTPUT

S-cell List
Traffic Distribution
Total Energy Forecast

Has been completed at the end of 2015

SSA (Smart Signaling Analyzer) Based on terminal road-test data

Original Signaling in Road test Data → Signaling Scanning → Problem location → Cause analysis? → Solutions

Associated with abnormal signaling

Abnormal signaling analysis

Possible solutions searching

Adapted with typical road-testing

Road test LOG analysis, including signaling contents &

Automatically &accurately match the network

Intelligent cause analysis, with nearly 300 regulations &

Proposes provided, integrated with programme, optimization

Has been completed in Oct. 2014

NETINCUBE LTE Network Performance Optimization

NETINCUBE

Signaling collection → Data cleaning → Data selection and integration → Data Storage → Data Mining → Solutions

Data classification

Data Modeling

Intelligent analysis

Data cleaning

End to end procedure association and KPI generation

Original and associated data clarification and storage

Full procedure analysis model Building

End to end procedure backtrack & Network optimization solutions

Has been completed at the end of 2015
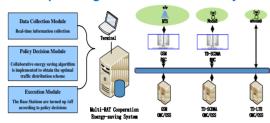
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NSFC: Theory and Application of Wireless Big Data

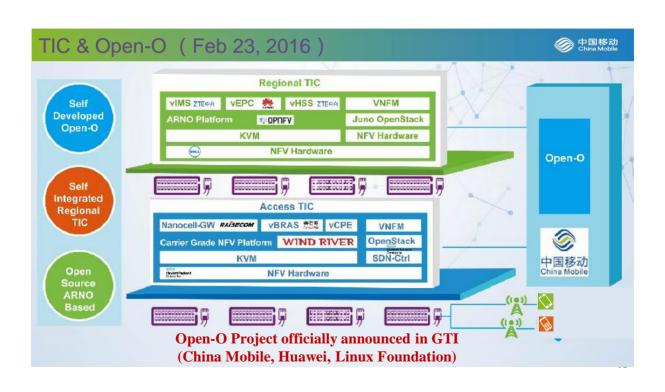**Example of wireless big data sources**

Example of big data based multi-RAT system

NSFC R&D Themes for big data (2017-2022)

- **Modeling of various big data:** user data, signaling, channel state information, user-context, application data, location, mobility, environments, weather, user behavior, etc, in various deployment scenarios

- Availability of accurate CSI with minimum overhead, to support advanced transmission schemes in **ultra dense network** with massive antennas and connections

- Big data based **massive multiple access** schemes with efficient coding/decoding, resource allocation and scheduling

- Big data based efficient **air interface** design, **radio access network architecture, network deployment and operation** for cost, spectrum and energy efficiency

- Big data platform to fully **test and demo** big data theories and applications.

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TIC & Open-O （Feb 23, 2016）

**Open-O Project officially announced in GTI
(China Mobile, Huawei, Linux Foundation)**

Open X: the Open Source Communities for Soft Networks   中国移动 China Mobile

OpenFog™

Accelerate the adoption of fog computing for IoT

- Architecture
- Communication
- Manageability
- Security
- SW infrastructure
- Testbeds

ON.LAB

Tools and platforms for SDN

- ONOS
- CORD
- OVX
- Mininet
- XOS

TELECOM INFRA PROJECT

Reimagine the traditional approach to building and deploying telecom network infrastructure

- Access
- Backhaul
- Core

Open5G 一起聚焦5G技术

Open platform&technologies for 5G

- Radio technologies
- Transport
- Core
- Security platform

NTT Communications · DELL · ERICSSON · intel · SK · AT&T · 中国移动 China Mobile · NOKIA · CISCO · NEC

ciena · verizon · Microsoft · HUAWEI · PRINCETON UNIVERSITY · FUJITSU · ARM

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Summary   中国移动 China Mobile

- **World's Largest 4G/4G+ Network: ~1.28M BSs, ~409M Subscribers**
- **Sustainability (5G perspective in 2011): Performance + Efficiency/Agility**
    - **Themes: Green, Soft, and Super Fast**
    - **Technology Pearls: Rethink Fundamentals**

- **E2E 5G: SDX (UCN + SDAI)**
    - **Enabling Tech: SDN/NFV, UCN (C-RAN/NGFI), and SDAI/MCD**
    - **Sample Demo:**
        - Service on Edge (MEC) on Greener & Softer Network (MWC2014)
        - Live Migration on Virtualized C-RAN, Invisible BS (mMIMO) with SmarTile (MWC2015)
        - SDAI /SmarTile 2.0 *(MWC2016),* Mini C-RAN/NGFI *(MWC2016)*

- **China Mobile 5G Joint Innovation Center, Test & Trials**

- **Verticals, Open 5G (Open-O) & Big Data (CMCC 7K TB/day)**

- **SDO's, Fora & Alliances**

- **LTE-A Pro v.s. NR**

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Thank you!

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