Towards Flexible Network and AI

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Designing the Flexible 5G System Architecture
The 2nd Global 5G Summit
Nov. 09, 2016, Roma, Italy

Rethink Fundamentals: SDAI + UCN

Green

Soft

Super Fast

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

- **Rethink Shannon**
  - To start a green journey of wireless systems
- **Rethink Ring & Young**
  - For no more "cells" via C-RAN (SDN/NFV)
- **Rethink Signaling & Control**
  - To make network application/load aware
- **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
- ***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

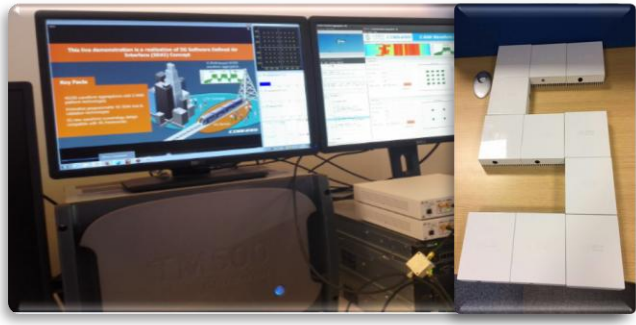
China Mobile 5G Prototype Demo (2014-2016)

中国移动 China Mobile

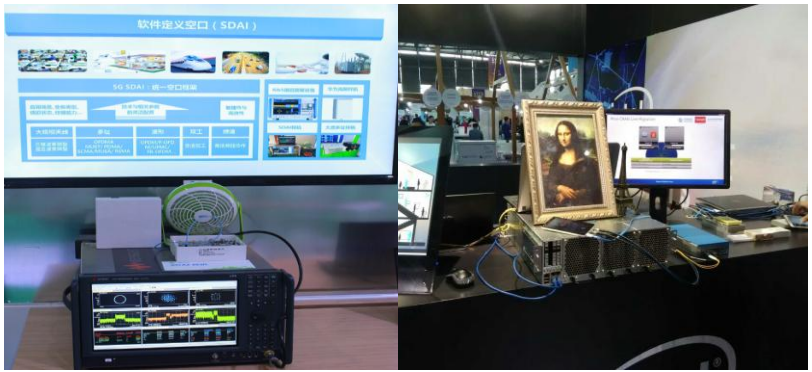
2014.2, Greener and Softer Network (MWC2014)

2015.3, C-RAN live carrier migration & SmarTile based Invisible BS(MWC2015)

2016.2 SDAI&SmarTile 2.0, Mini C-RAN/NGFI (MWC2016)



2016.6 SDAI (Multiple Access), Mini C-RAN/MEC (MWCS2016)



2016.9 SDAI&Smar Tile 2.0, C-RAN multiple nodes server (PT/EXPOCHINA 2016)

World's Largest 4G Network

End of Sep, 2016

The Largest Scale

146M Base stations

34% of Global LTE base stations

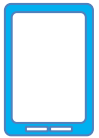
1.5M @2016e

The Biggest User Base

481M Subscribers

32% of Global LTE subscribers

500M@2016e



The Most Device Choices

2000+ Types of devices

70% are 1,000-Yuan smartphones

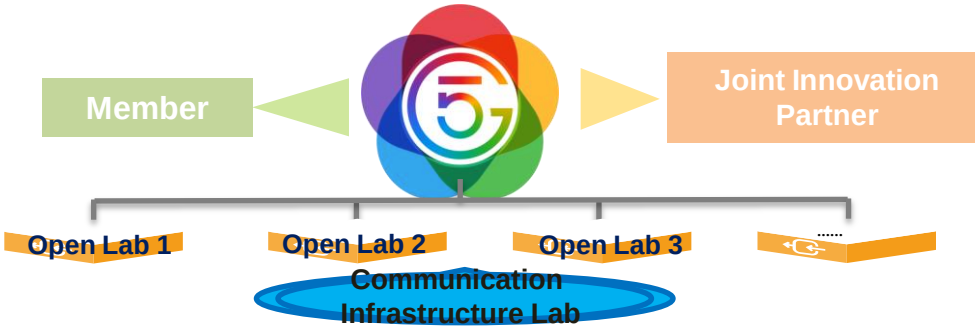
The Most Popular Network

~1.3B Pop coverage rate

99.7% of national population

Ecosystem : Collaborate for an Open and Innovative Platform

39 partners have already joined 5G Innovation Center



Member-Network Equipment	Member-Terminal chips	Member-Instrument	Member-Vertical Industry	Joint Innovation Partner
Huawei	Qualcomm	R& S	Haier	OVIPHONE
Ericsson	Intel	Keysight	Hisense	Polycis
Nokia	Leadcore	Cobham Wireless	Beijing Shougang Automation InfoTech	CloudMinds
ZTE	Spreadtrum	StarPoint	Wireless Car	Energizer
Datang	Samsung Electronics	Anite Telecoms	BYD	Wapwag
Xilinx	MediaTek		GAC ENGINEERING	
			DJI	
			Changhong	
			Neusoft	
			Goer Tek	
			SAFT SA	
			EVE Energy	
			Jinan Towngas	
			Qingdao IESlab	
			Philips Lighting	
			State Grid Smart Grid Research Institute	
			Audi China	

Open Lab to drive the research, test and joint innovation

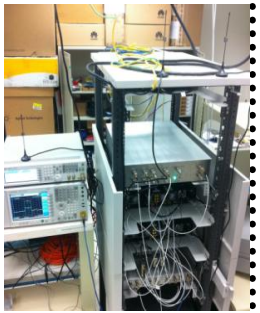
Beijng: Comm. Infrastructure Lab
Qingdao: IoT, Verticals

Tech Prototype Test Completed (IMT2020 PG, Sep, 2016)

2015Q1 | 2015Q2 | 2015Q3 | 2015Q4 | 2016Q1 | 2016Q2 | 2016Q3

3D-MIMO pre-commerial products

Full Duplex Prototype



High Freq Prototype

Massive MIMO (128TX)
- 3D-MIMO in single site (128TX, Huawei, ZTE)
- 3D-MIMO in scale (ZTE @ shenzhen, 2.6GHz, Nokia@Beijing, 3.5GHz, Datang Mobile@beijing, 3.5GHz) — 2016Q4

Full Dulplex (Interference cancellation 102dB)
- Huawei (Full duplex prototype R&D)
- Huawei (@ Chengdu, full duplex test on small cell) — 2015Q4
- Huawei (@ Chengdu, full duplex prototype test)

High Frequency (6GHz-30GHz)
- ZTE (@Shanghai , 15GHz) 、Ericsson (@Beijing , 15GHz) , Samsung@Beijing(28G) — 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, UDN prototype test) — 2016Q4
- Huawei(@Chengdu, polar code prototype test)

IMT-2020 PG

CMCC

Channel coding (Polar code)
- Ericsson、Nokia、Huawei (UCN) — 2016Q4

User Centric Network
- Cooperate with Huawei, ZTE, Datang Mobile, Cobham (SDAI) — 2016Q4

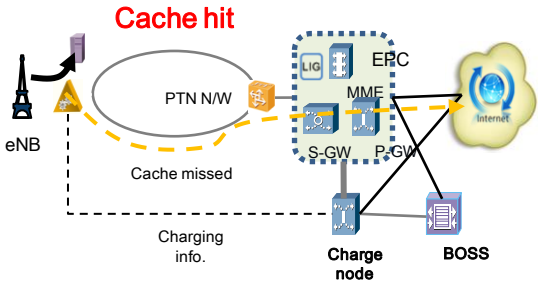
SDAI

Chipset Device (3D-MIMO、High frequency)
- TI、MACOM、Qorvo、 MURATA — 2016Q4

UCN Turbo Charged Edge: MEC Trials

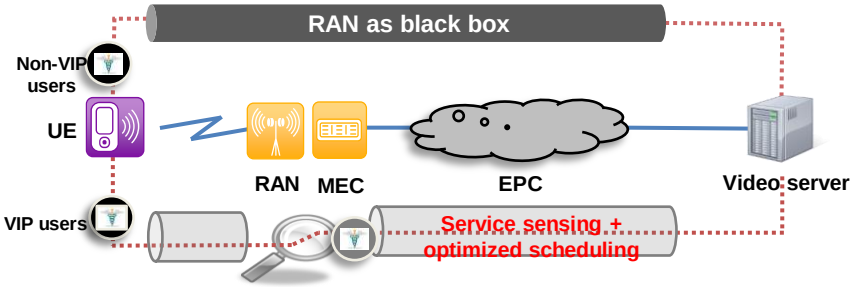
Field and Lab trial on Cache

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



- 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

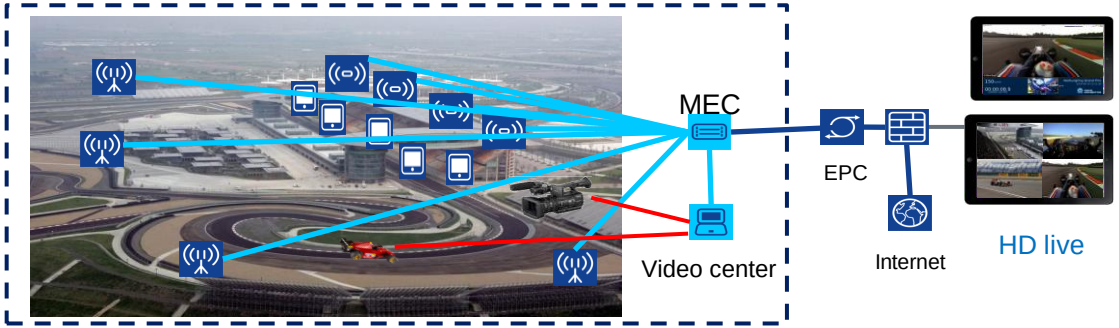


- Packet analysis by MEC to distinguish the service and VIP users, then BS informed
- Differentiated wireless BW and latency guarantee provided by BS

Local breakout: trial of Multi-visual-angle live program of competitive sports

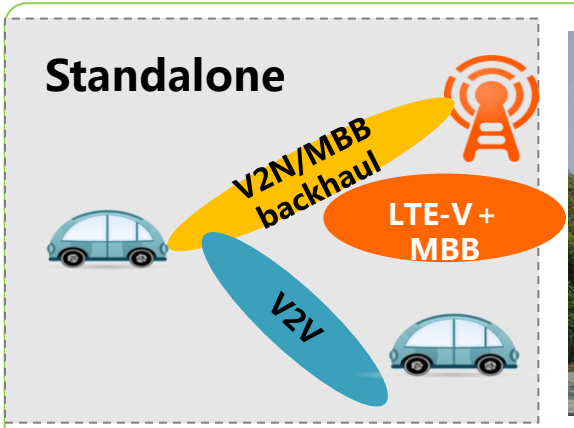
- Scenarios: smart gateway, local content forwarding etc.
- Solutions:
  - ✓ Service delivery by eNB
  - ✓ Service delivery by MEC
- Major advantage: latency reduction
- Key concerns: Security

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



Collaboration Demo with Verticals

LTE-V Demonstration in G20 (Sep, 2016)



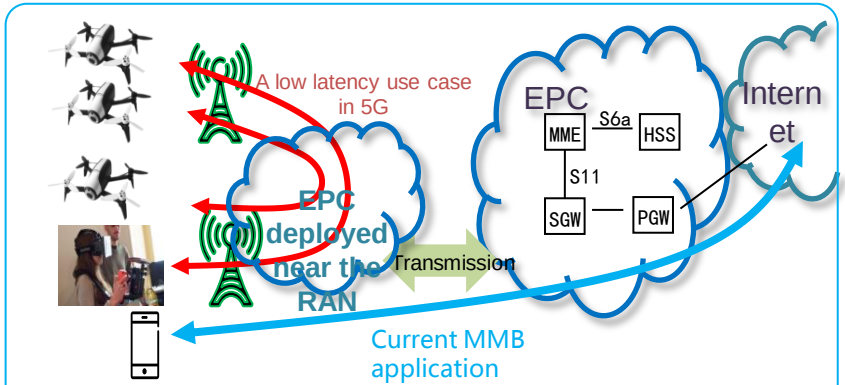
Small BS at lamppost

1 Macro BS, 33 Small BSs

- **V2N：20MHz@2.6GHz**
- **V2P/V2V/V2I: 10MHz@2.6GHz**
  (*only for demo in G20*)
- **RSRP≧-85dBm**
- **SINR ≧ 20dB**
- **Seamless coverage**
  (Inter-site distance ~140m)

CMCC, SAIC, Huawei, Ali *Initial Cellular V2X standard completed*

First Cellular based UAV Trial (Aug, 2016)



3GPP Progress in RAN1

Waveform/MA/Channel coding indentified for NR

Waveform < 40GHz

DL Waveform: CP-OFDM

UL waveform: DFT-S-OFDM + OFDM

- DFT-S-OFDM targeting for link budget limited scenario
- OFDM targeting for high data rate

Filter/window applied for each sub-band to support mixed numerologies design

Multiple Access

Orthogonal Multiple Access selected as the baseline for NR.

- Non-orthogonal MA will be studied further in Phase II.
- Unified MA framework agreed for understanding the non-MA schemes better.

Channel coding

LDPC for eMBB medium/long block size. For small block size (128<X<1024), to be identified in RAN1 #87 (Nov 14-18,2016)

- Channel coding on Control, URLLC，and mMTC needs further study

Currently focusing on initial access, control, MIMO design

NR Acceleration in RAN1 by reducing dedicated meeting time for above items

- The following items are put on hold until March 2017 (except for forward compatibility considerations):
  - Waveforms above 40GHz
  - mMTC
  - [Flexible duplex of paired spectrum]
  - Interworking with non-3GPP systems
  - Wireless relay
  - Satellite communication
  - Air-to-ground and light air craft communications
  - Extreme long distance coverage
  - Sidelink
  - V2V and V2X
  - Multimedia Broadcast/Multicast Service
  - Shared spectrum and unlicensed spectrum
  - [Location/positioning functionality]
  - Public warning/emergency alert
  - New SON functionality

3GPP Progress in RAN2

Protocol: Control Plane

- ***LTE-NR tight interworking***
  - Focusing RRC relationship between LTE and NR.
  - UE depends on a Master Node
- ***Discussion on New RRC state***
  - Besides IDLE and CONNECTED, *RRC_INACTIVE* is introduced.
  - DL/UL data transmission allowed in this state
- ***System Information***
  - Minimum SI for initial access, like SIB0/SIB1 in LTE
  - Other SI, *On-demand* transmission (periodic in LTE)

Protocol: User Plane

	LTE	NR
Retrans.(ARQ)	RLC (ARQ) PDCP (handover, split bearer)	RLC(ARQ) PDCP (handover, split bearer)
Reorder	RLC (always on) PDCP(dual connection, LWA)	RLC (TBD); PDCP (always on)
Concatenation	RLC	Being discussed if this function transferred into MAC
Segmentation	RLC: FI-based/SO-based	RLC: SO-based

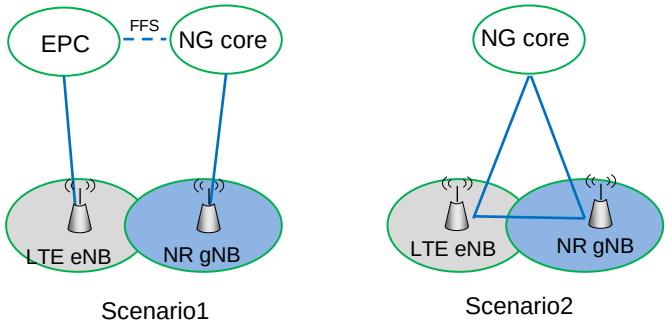
LTE-NR tight interwork on UP is also a hot topic and being discussed.

Mobility: Intra-RAT

- ***Network control*** *(DL measurement based):*
  - *w/ RRC involvement*, e.g., handover between cells
  - *w/o RRC involvement, e.g., handover betweens beams in one cell*
    - *waiting for related progress/decision in RAN1*
- ***UE control*** *(DL measurement based)*
  - Cell selection/reselection
- Discussion on ***UL measurement*** based mobility
  - reducing UE power consumption on DL measurement
  - RRC-active, RRC-inactive, idle

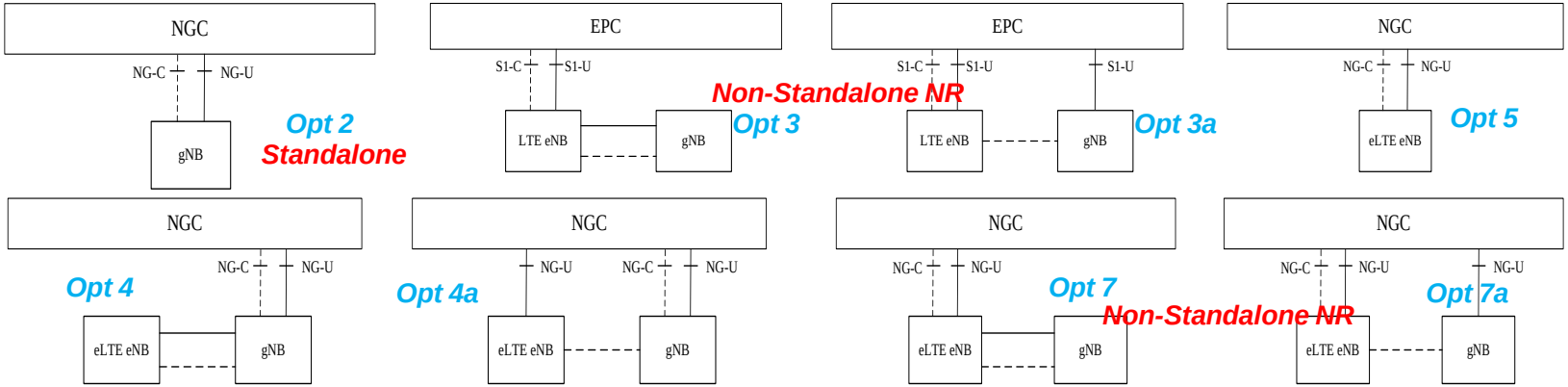
Mobility: Inter-RAT

Two scenarios indentified for inter-RAN mobility



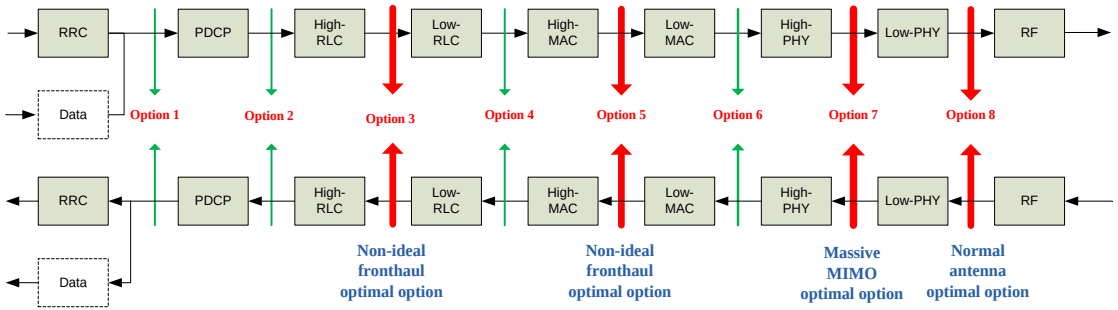
3GPP Progress in RAN3

- **RAN-CN Interface:** 8 architecture options + NG interface definition



Note: Option1 is LTE connected to EPC (4G); Option 6 is NR connected to EPC (neglected); Option 8 is NR connected to EPC and be anchor for LTE (neglected)

- **CU/DU function split:** 8 architecture options + NG interface definition



CMCC's preferences:

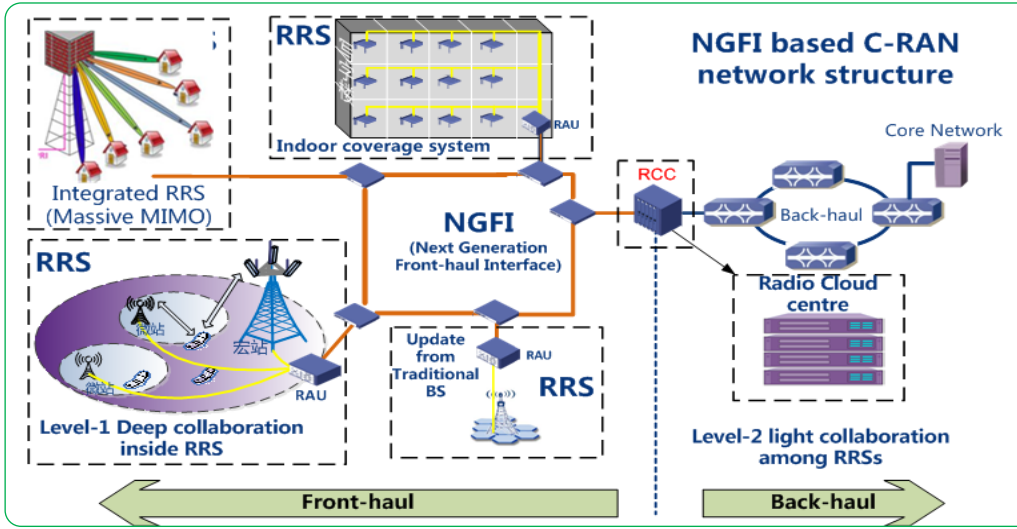
- **For ideal fronthaul**
  - *Normal antenna：option8*
  - *Massive MIMO：option7*
- **For non-ideal fronthaul**
  - *Option 3(UP)/5(CP)*

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

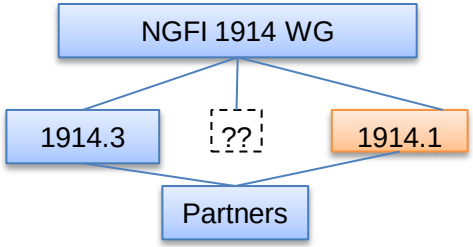
IEEE 1914 WG : http://grouper.ieee.org/groups/1914/

- 2015.06： 1st NGFI WS，NGFI WP released
- 2016.02： Officially approved, CMCC lead
  - Sponsor: IEEE COM/SDB
  - Objectives: High efficient and flexible FH for 5G
- 2016.04：The first meeting
- Potential collaboration with 802.1 CM

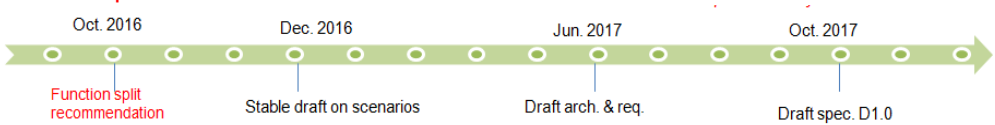
NGFI Framework



1914.1：Used cases, Architecture, and Requirements for NGFI



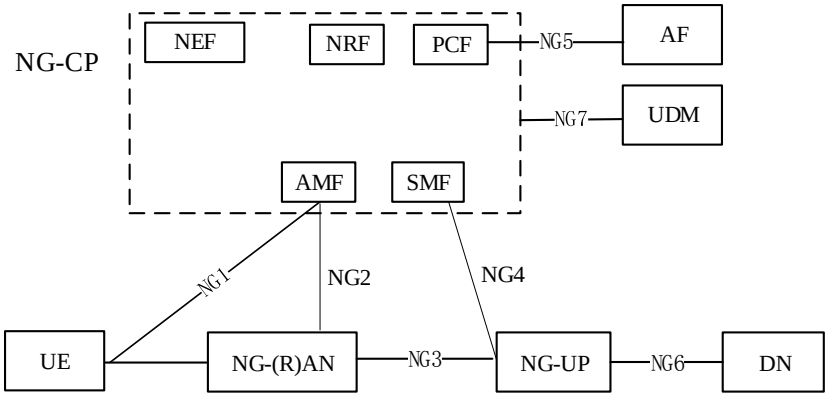
- 2016.04, 1st meeting : administrative framework, 1904.3 transferred into1914.3, LS with 3GPP & CCSA
- 2016.08, 2nd meeting : 802.1 CM, Capability gap analysis, and function split analysis
- 2016.10, 3rd meeting : Function split recommendation



3GPP Progress in SA2

Interim agreement has been achieved for the overall architecture and the key issues related with the system basis

- NF Repository Function (NRF)
- Access and Mobility Management Function (AMF)
- Session Management Function (SMF)
- Policy Control Function (PCF)
- UDM
- NG Core User Plane (NG-UP) function



Current interim agreed architecture (To be updated)

1	Support of network slicing
2	QoS framework
3	Mobility management framework
4	Session management
5	Enabling (re)selection of efficient user plane paths
6	Support for session and service continuity
7	Network function granularity and interactions between them
8	Next Generation core and access - functional division and interface
9	3GPP architecture impacts to support network capability exposure
10	Policy Framework
11	Charging
12	Security framework
13	Broadcast/Multicast Capabilities
14	Support for Off-Network Communication
15	NextGen core support for IMS
16	3GPP system aspects to support the connectivity of remote UEs via relay UEs
17	3GPP architecture impacts to support network discovery and selection
18	Interworking and Migration
19	Architecture impacts when using virtual environments
20	Traffic Steering, Switching and Splitting between 3GPP and non-3GPP Accesses
21	Minimal connectivity within extreme rural deployments
22	Support of “5G connectivity via satellite” use case

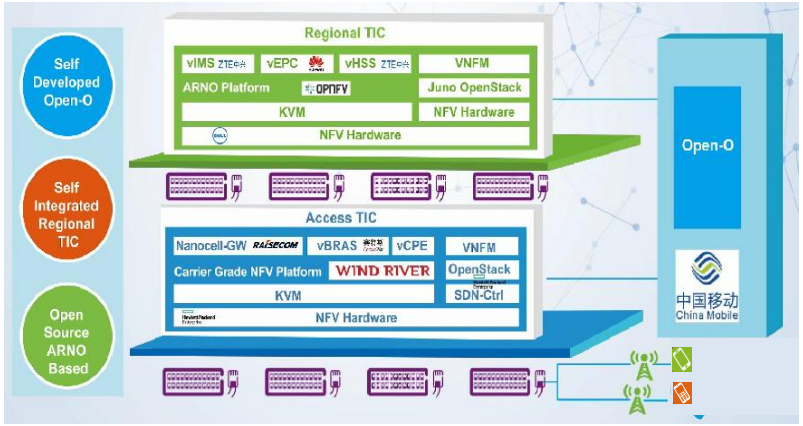
Summary and Recommendations

- 5G need a novel design and leverage NFV/SDN to achieve a well designed 5G network
- NFV/SDN and orchestration are the key enabler of the 5G network. 5G brings the best opportunity to deploy NFV/SDN in large scale.
- 3GPP has setup up the time plan of 5G considering the IMT-2020 requirement. Other SODs that related with 5G system are encouraged to also take the time plan into account.
- To address the technical challenging, the following issues should be taken into account :
  - NFV/SDN friendly when 3GPP/ITU design 5G
    - Enable Scale out performance, achieve cloud style resilience
    - C/U separation and SDN control mechanism
    - Modularized function design
  - 5G friendly when NFV related SDO develop NFV
    - Enable Near 100% reliability, 1 ms latency, >Tb/s high throughput
  - Collaborated work
    - Slicing management and Orchestrator
  - All in all, a service oriented design is the goal to make the network programmable, flexible and profitable

Host: China Mobile, IMT-2020, CAICT
Partners: 3GPP SA2, OPNFV, ITU-T, IMT-2020 FG, 5GPPP

Open-O Release 1.0 'SUN' Released on Nov 7, 2016

Open-O (Orchestrator) officially announced in GTI, Feb 2016
(China Mobile, Huawei, Linux Foundation)



OPEN-O

Open Orchestrator Project (OPEN-O)

Any Service Over Any Network

The Open-O 1.0 'SUN' with 2M codes released in Nov 2016

Bridging the gap between SDN and NFV, for both residential and enterprise virtualized customer premises equipment (vCPE) use cases.

(CMCC, CTC, HKT, Ericsson, Huawei, ZTE, Intel, Redhat, GigaSpaces, …)

C-RAN industrial Joint WG (Nov. 18, 2016)

Objective: Aligning with industry partners to unify the understanding of C-RAN, Driving the industry to enhance the maturity of C-RAN fit for operators' requirements. standardize the interface of SW/HW, north-interface of MANO for CU. Preparing to Pre-commercial PoC and Field trial. **Partners: Huawei, ZTE, Ericsson, Intel, RedHat, WR, Spirent, BroadCom and etc.**

Time schedule

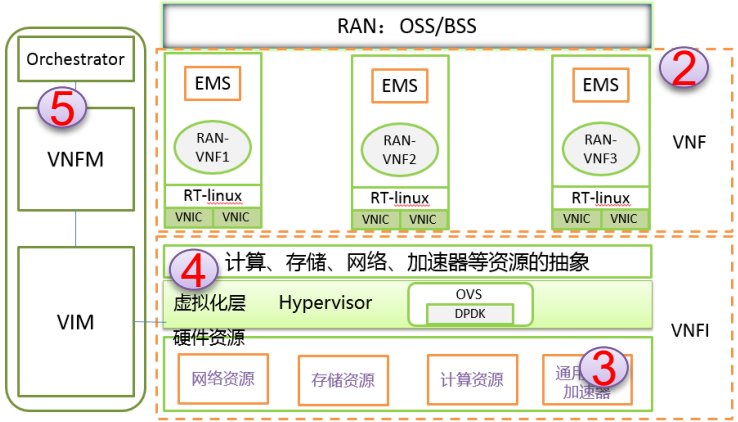
- 2016.11 white paper published and WG start up
- 2017.6 CU basic solution to de - coupling of SW/HW, Orchestration
- 2017.12~2018.6 PoC of Pre-commercial C-RAN
- 2018.6~ Small-scale Field trial

Base on the independence of research points, it can be split into 5 working groups：

1 **Use case definition**: define the radio orchestration requirement, C-RAN networking scenarios.

MANO: abstraction of RAN service model to achieve template extension and def.(NSD, VLD, VNFD, PNFD, FWGD)

Virtualization layer: Func. and Perf. enhancement to support RT-processing of RAN, definition of test specification



VNF Split and function definition: refine RAN split and VNF(CU/DU) function definition and interface requirement

Common HW platform: standardization of accelerator and common HW spec, to decouple SW and HW.

Summary: Era of CT+IT+DT

- World's Largest 4G/4G+ Network: ~1.46M BSs, ~481M 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/MEC/NGFI), and SDAI/MCD
  - 3GPP: (>200 NR submissions from CMCC)
    - SA2 (SDN/NFV)
    - RAN3/RAN2 (C-RAN/NGFI/MCD)
    - RAN1(SDAI/MCD)
- China Mobile 5G Joint Innovation Center: Vertical Industry & Ecosystem
- Gap analysis for NR and LTE-A Pro
- Wild Cards: Open 5G (Open-O) & Big Data (CMCC 7K TB/day)

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Thank you!

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