Test and Integration for 5G and Beyond -- an Operator's Perspective

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ITU-T ETSI IEEE Joint SDOs Brainstorming Workshop
on Testbeds Federations for 5G & Beyond: Interoperability, Standardization, Reference Model & APIs
March 16, Online

CMCC 5G Deployment

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Overcoming 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 90M+

100+ Nationwide projects
2000+ Provincial/regional projects

World's highest

5G base station at 6.5Km

Underground

5G private network at 534m

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

Pandemic: the necessity to accelerate 5G deployment

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5G ensures work resumption, accelerating the society & economy digitization, enabled new way of life:

Live, Learn, Work, Entertain, Govern!

5G HD live streaming

5G Telehealth

5G intelligent medical robots

5G unmanned epidemic prevention vehicles

Unmanned logistics vehicles

Unmanned epidemic prevention vehicles

Thermal imaging temp measurement system

Cloud Video

Cloud Trading

Cloud Classroom

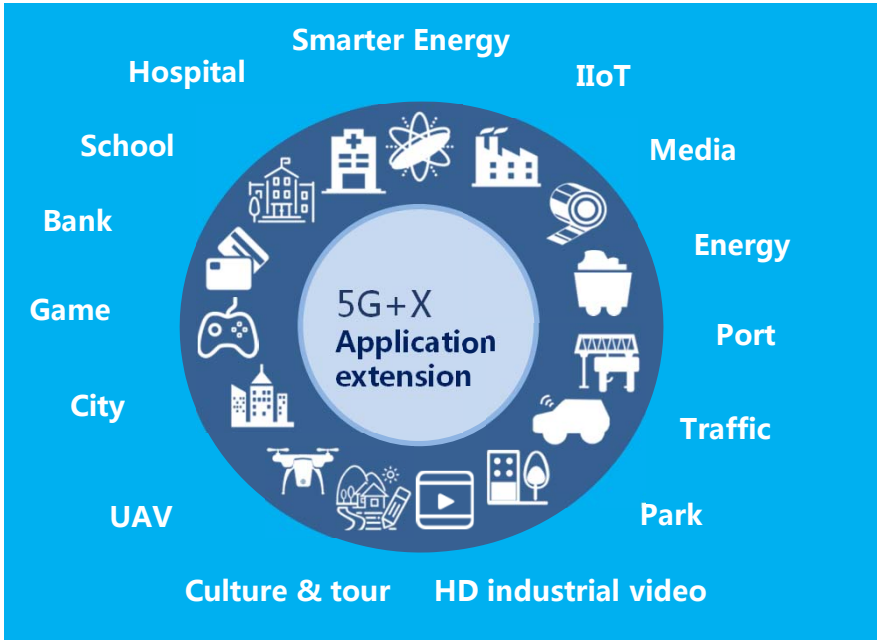
Cloud Office

Cloud Gaming

5G-enabled Ambulance

5G Trials on Vertical Markets

2019-2020，China Mobile has deployed 3 types of 5G customized enterprise networks for 100 leading enterprises, covering 15 vertical industrial markets and 100 typical use scenarios.



100+ Nationwide projects
2000+ Provincial/regional projects

The World's First 5G+Smart Logistics Product Yunnan2020.06

The First 5G+Intelligent Port of Full Scene in China Fujian2020.05

China's largest 5G road coordination demonstration area Wuhan 2019.12

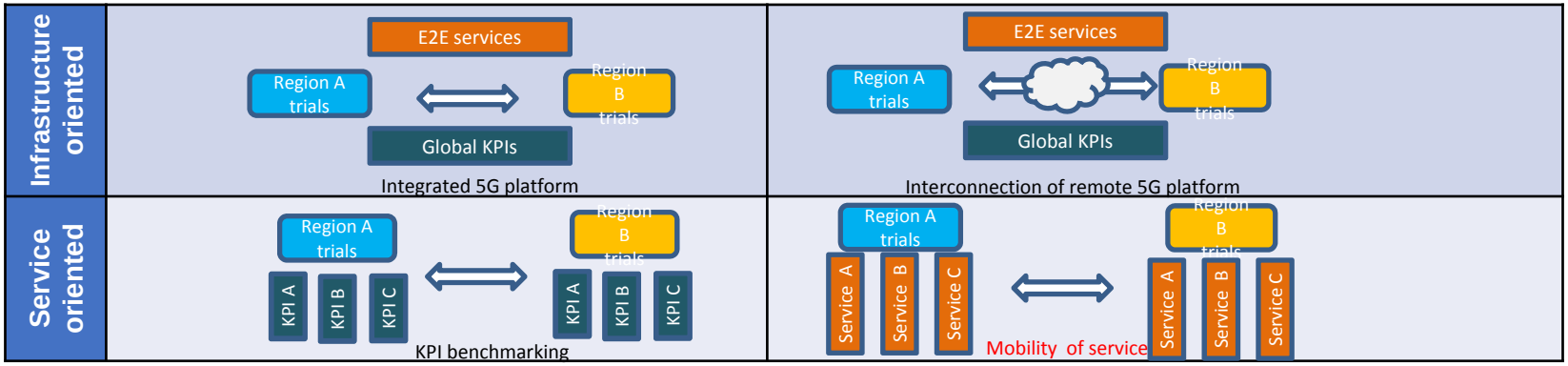
The First Multinational 5G+AR Remote Assembly in China Hunan 2020.04

5G novel coronavirus pneumonia critical consultation Beijing 2020.02

The First 5G High-end Manufacturing Cooperation with Europe in China Tianjin 2020.01

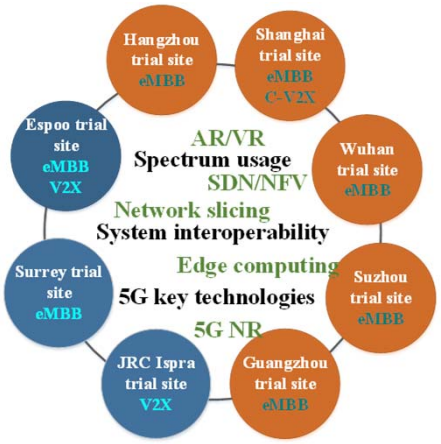
Inter-Regional 5G Test Collaboration (5GPPP)

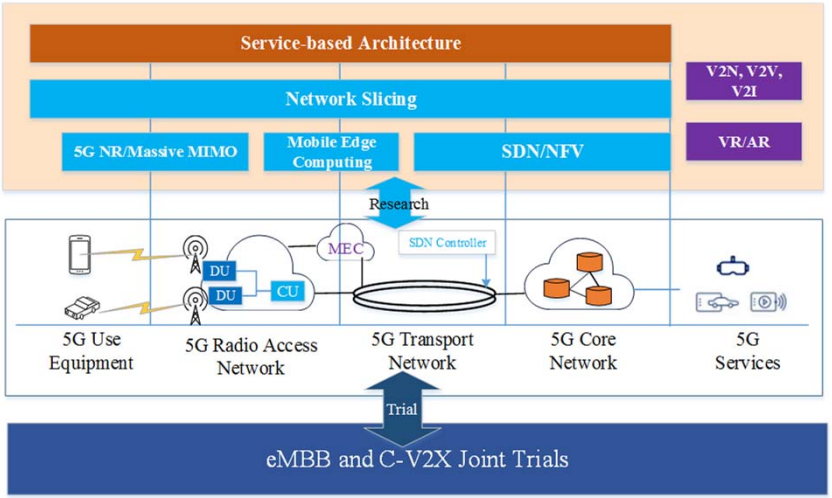
	Collaboration topics	Joint 5G trial projects
EU-China	• 5G eMBB trials and LTE-V2X trials o eMBB outdoor and indoor basic performance o Massive MIMO test o C-V2X GLOSA and intersection use case	5G Large-scale Trial 5G-DRIVE
EU-Japan	• Applications and trials with 5G networks • Beyond 5G, applicability of spectrum > 275 GHz	5G-Enhance
EU-Korea	Application trials at mm-wave bands Interoperability and integration of 5G vertical testbeds	PriMO-5G
EU-Taiwan	End-to-end testbeds for specific applications	5G coral

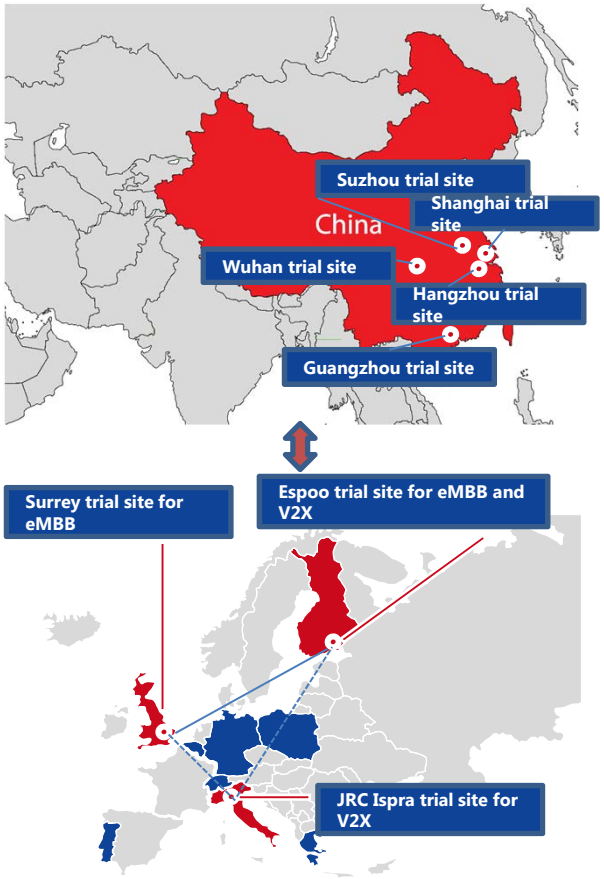


EU-China 5G Test Collaboration

- Joint trial activities by China 5G Large-scale Trial project and EU 5G-DRIVE project
  - Cover 5G tests from terminals, RAN, transport network, core network, and 5G services
  - 5 5G trial cities at the Chinese trial project
  - 3 5G testbeds in EU trial project
  - Joint eMBB trials and V2X trials
    - eMBB: 3.5GHz at Europe and 2.6GHz & 4.9 GHz at China
    - V2X: C-V2X at 5.9GHz
  - Joint tests between trial sites
    - End-to-end eMBB use cases







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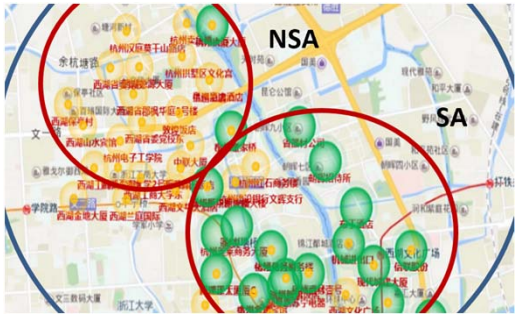
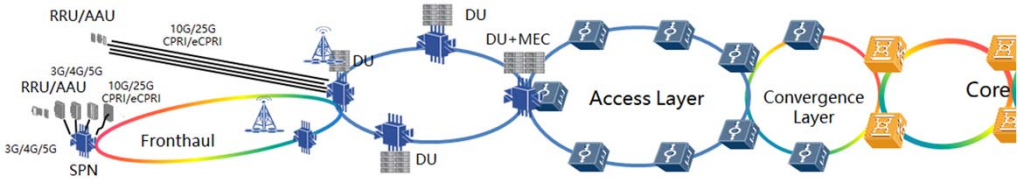
eMBB Testbeds in EU-China 5G Collaboration

China Mobile trial site

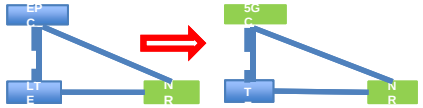


- Large scale outdoor and indoor deployment
- Support eMBB NSA & SA
- Spectrum at 2.6GHz, 4.9GHz
- Support massive MIMO
- Pre-commercial deployment



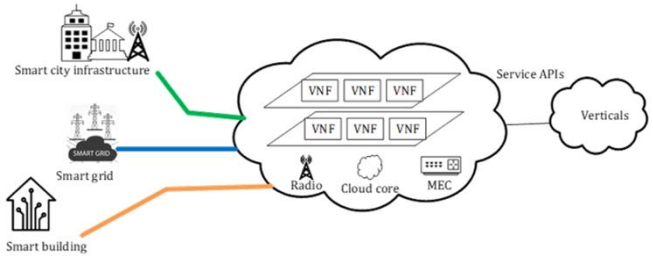
5GIC trial site

- C-RAN architecture for coordinated joint processing
- Support eMBB and URLLC
- Spectrum at 3.5GHz, 28GHz, and 60 GHz



Espoo trial site

- Outdoor and indoor deployment
- Very high accuracy timing facility
- Support eMBB and URLLC
- Spectrum at 2.6GHz, 3.5GHz, and 26GHz



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V2X Testbeds in EU-China 5G Collaboration

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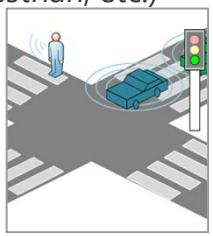
Shanghai V2X trial site

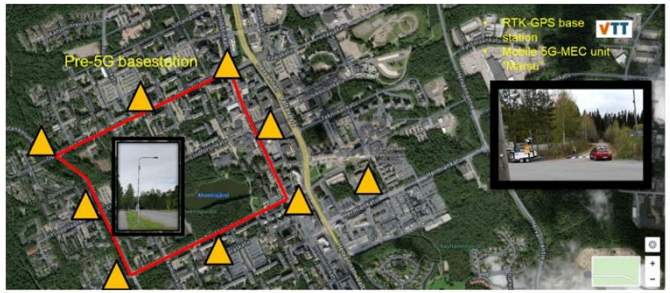
- 2 LTE-V base stations and 7 RSUs
- 3 types of DSRC
- Intelligent traffic lights
- GPS differential base stations
- High precision map (2-3 mm)
- Autonomous driving

Joint V2X test cases

- Green Light Optimal Speed Advisory (GLOSA) use case
- Intelligent intersection use case (protection of pedestrian, etc.)



VTT V2X trial site



- MEC for vehicle data sensing
- LTE-V2X for V2I and V2N
- Demo vehicle available for autonomous driving test

JRC Ispra trial site

- 36 km road of real-life driving conditions
- 9 vehicle emissions laboratories
- High resolution localisation and mapping
- LTE/5G networks and V2X equipment
- MEC infrastructure
- PKI for security and trust in road transportation

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O-RAN: Open & Smart Ecosystem for RAN (Feb 27, 2018, MWC18)

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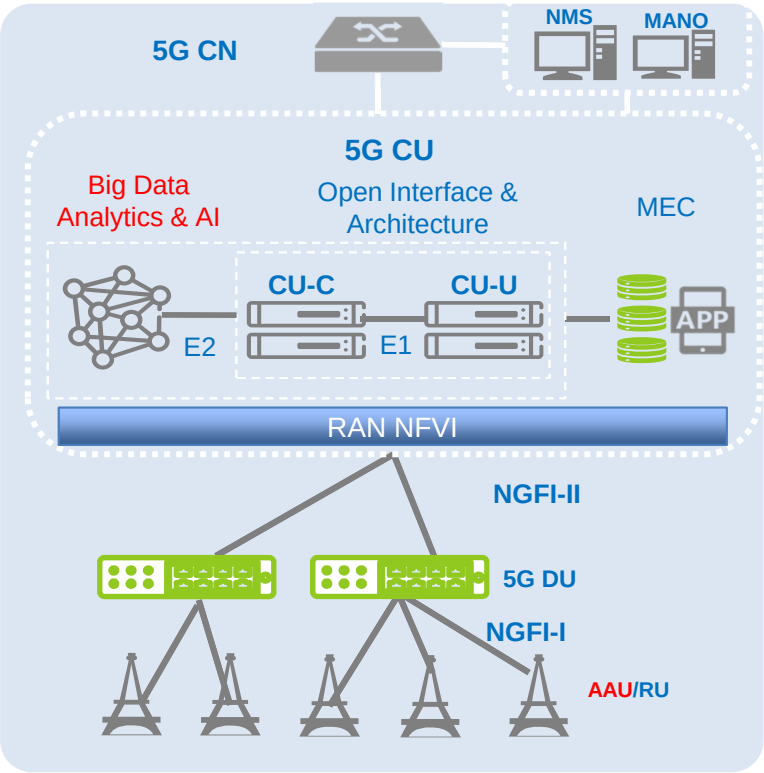
Vision of O-RAN



From Green & Soft to Open & Smart

AT&T | 中国移动 China Mobile

orange | docomo | T

Intelligence & Standardization

Open Source & Virtualization

whitebox & Reference design

Intelligent Management
- Big Data-based RRM
- ML/AI-based apps
- Open APIs

CU
- E2, E3 Interface Standardization
- Open Interface of protocol stack
- Open Capability of Edge Computing

DU
- Open Interface (NGFI-I/NGFI-II)

AAU/RU
- Open-source Software, Open reference design (white-box)

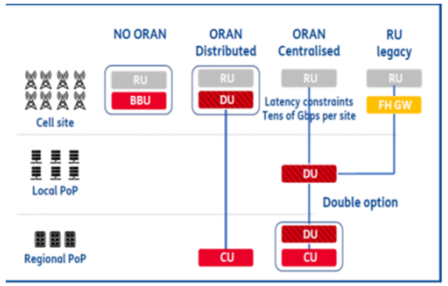
Great Momentum and Achievements Since Its Inception in Oct. 2018

- Total 101 specifications/50 current ver.
- 3 Open Source software release (https://wiki.o-ran-sc.org/)
- 2 Global Plugfest event
- 61 Demos in O-RAN virtual exhibition (https://www.virtualexhibition.o-ran.org/)

01.Specification Development

02. Test and Integration efforts

03.Open Source Development



270+ Companies/2900 Experts (Feb. 17, 2021)

2018

- 2018.2: Announcement of O-RAN foundation
- 2018.06: .Founding meeting
- 2018.09: O-RAN WP
- 2018.10: Official launch

2019

- 2019.02: 1st spec. published, MWCB demo and O-RAN seminar
- 2019.04: launch of O-RAN Software Community
- 2019.06: MWCS demo, O-RAN Board meeting, O-RAN Industry Forum,
- 2019.09: Establishment of OTIC, 1st Global Plugfest
- 2019.12: Amber Release

2020

- 2020.03: O-RAN virtual exhibition for MWC
- 2020.06: MWCS virtual demo, OSC Bronze release
- 2020.10: MWCNA virtual demo, 2nd Global Plugfest, Board re-election
- 2020.12: OSC Cherry release
- 2021.02: O-RAN Minimum Viable Product (to be released)

- Close collaboration with industry partners: ONF, SCF, TIP, GSMA, NGMN, ETSI, …
- Active interaction with 3GPP, ITU-T, IEEE, IETF, IANA, OCP, OAI, …

Open, Intelligent, Virtualized and Fully Interoperable RAN

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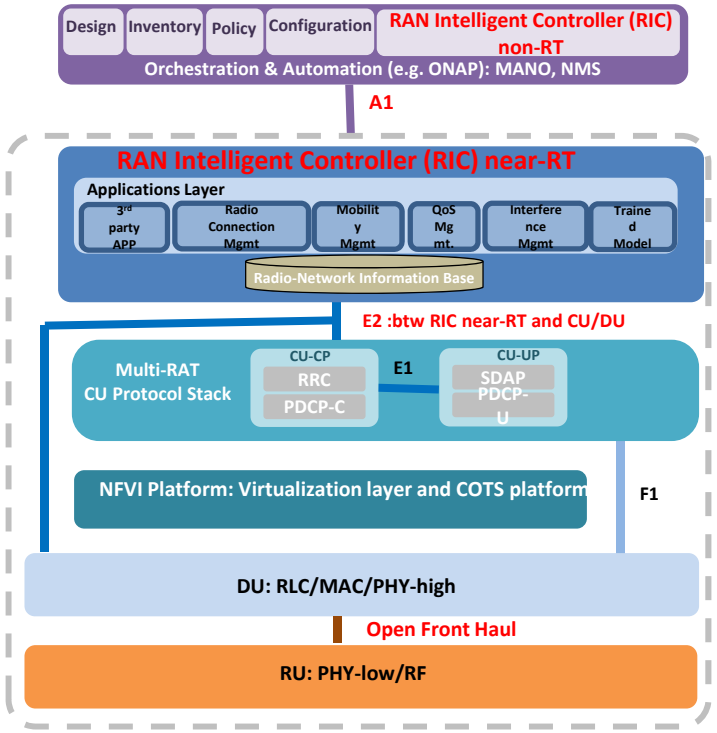
O-RAN Architecture

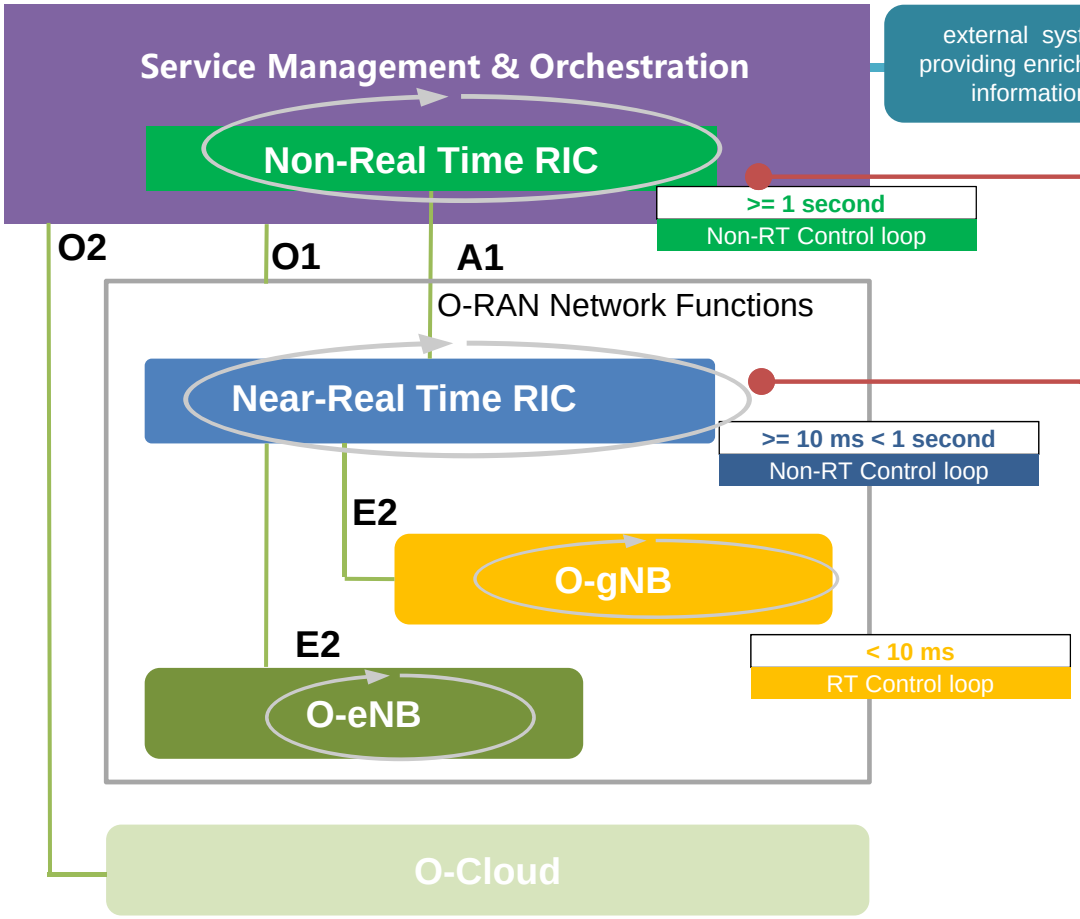


O-RAN Technical Steering Committee (TSC): 10 WGs, 4 FGs, OSC, MVP-C

WG1	Use cases & Overall architecture
WG2	RIC(non-RT) & A1 Interface
WG3	RIC(near-RT) & E2 Interface
WG4	Open FH Interface
WG5	Open F1/ W1/E1/X1/Xn int.
WG6	Cloudification & MANO Enhance
WG7	White-Box Hardware (ORD)
WG8	Stack reference design
WG9	Open X-haul transport
WG10	OAM

- Standards Dev. Focus Group (SDFG)
- Test & Integration Focus Group (TIFG)
- Open Source Focus Group (OSFG)
- O-RAN Software Community (OSC)
- Security Focus Group (SFG)
- Minimum Viable Plan Committee (MVP-C)

RAN Intelligent Controller (RIC): Bring embedded AI/ML into RAN



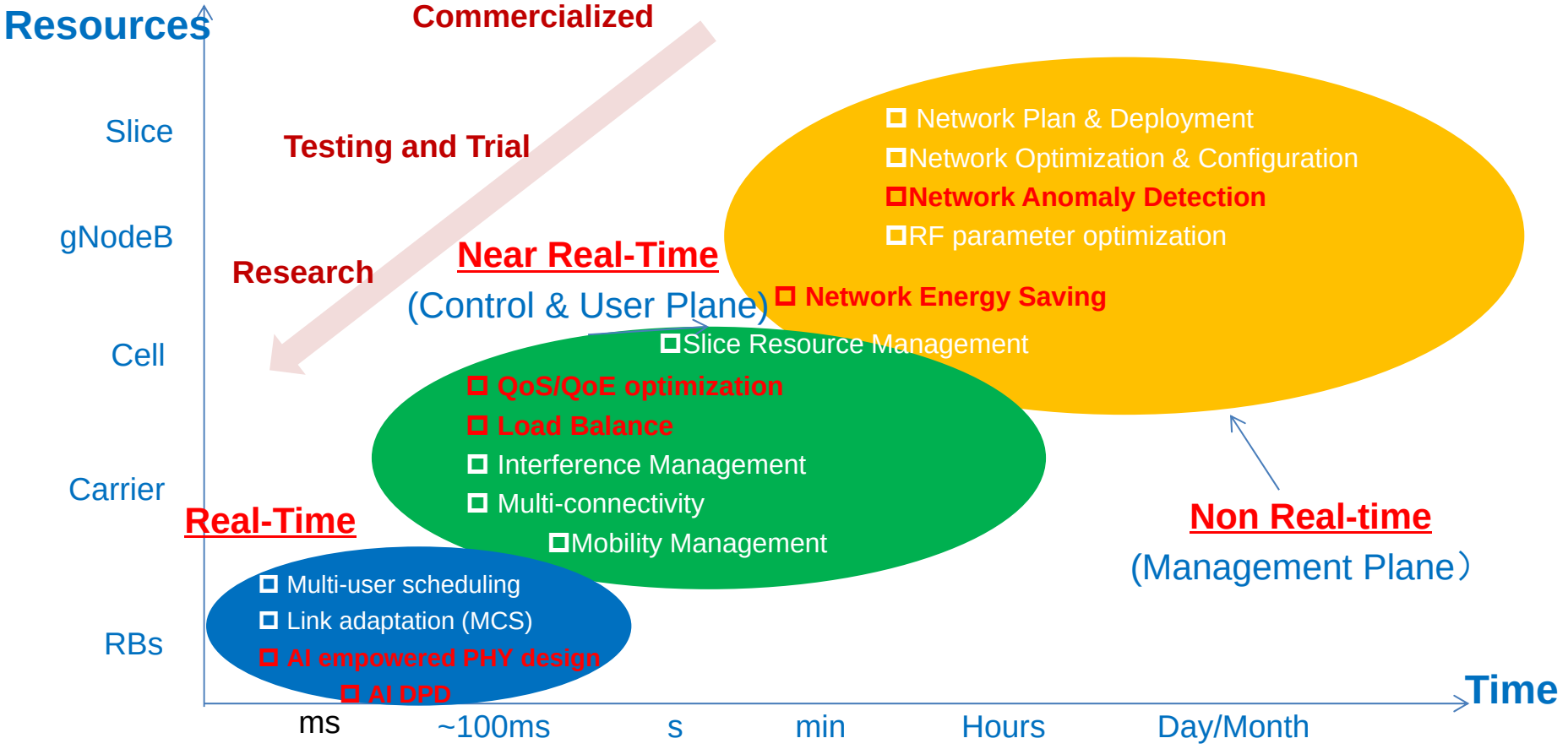
Non-RT Radio Intelligent Controller

Support non-real-time radio resource management, policy optimization in RAN and providing guidance, parameters, policies and AI/ML models to support the operation of near-RT RIC functions in the RAN.

Near-RT Radio Intelligent Controller

A logical function, targeted for near real-time control and optimization of E2 nodes (CU-CP, CU-UP, DU) functions and resources, by fine-grained data collection and actions over the E2 interface.

AI empowered RAN optimization: Time/Resource Categories



O-RAN RIC for Real-Time Cloud VR QoE Optimization (Shanghai, 2020)

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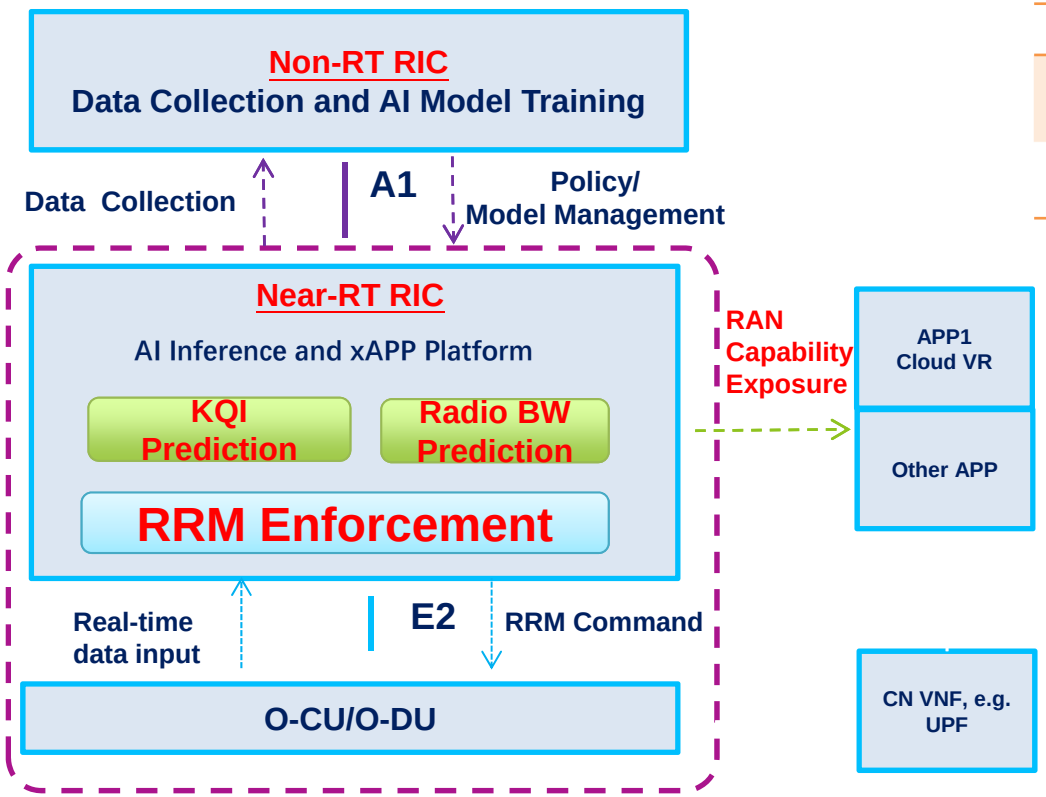
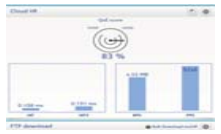
- RIC: a data-driven platform to provide customized RAN capabilities and exposure
- A1 and E2: Open interfaces for multi-vendors, enable more innovations



Core AI Models and Functions

KQI Prediction	Predict and score real-time KQI related QoE
Radio Bandwidth Prediction	Derive next **sub-second** level network status to optimize end-to-end data rate
RRM Enforcement	Derive optimal RRM enforcement for QoE guarantee



Field test in CMCC 5G network in Jan. 2019 (S1) and Jan,2020 (E2)

KQI/QoE prediction and Radio Bandwidth prediction with runtime radio data **(> 90% accuracy)**

E2E QoE guarantee for Cloud VR via KQI/QoE prediction, Radio BW estimation

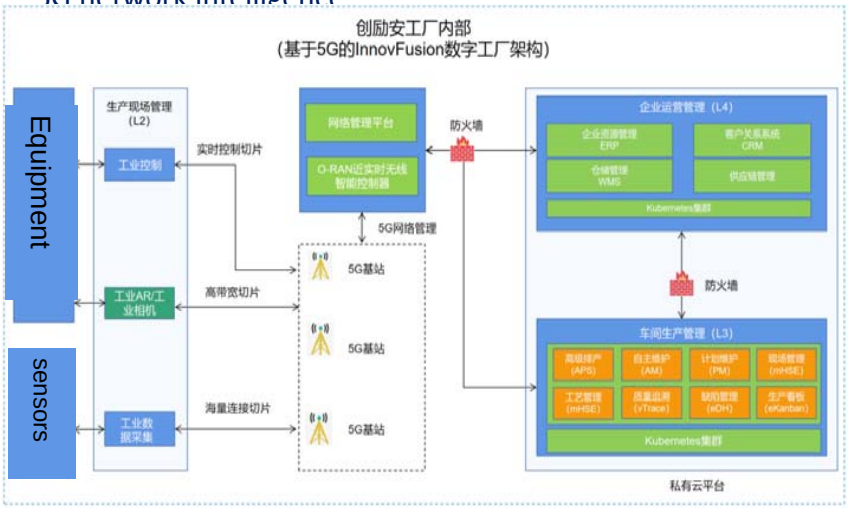
NOKIA

QoE guaranteed Cloud Gaming through AI enabled **rate adaptation**

Tencent 腾讯

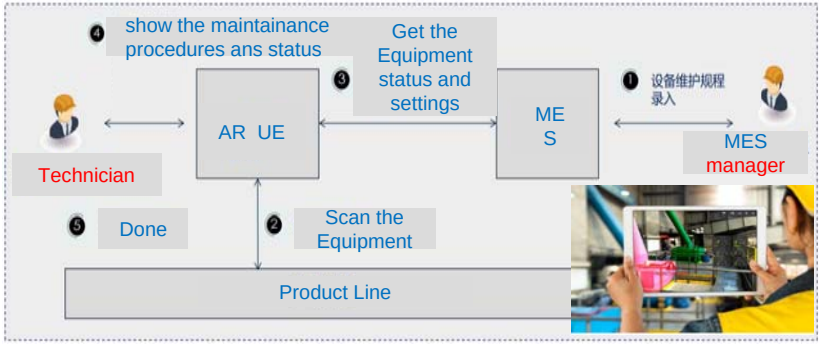
O-RAN RIC for Cloud AR for Smart Factory (Jiangsu, 2020)

- Build the smart factory based on the 5G O-RAN base stations to explore the 5G and innovative applications for the verticals
- Typical Usage Scenarios include: **Industrial vision, Industrial data acquisition, AR equipment patrol management**
- validate the close loop service experience assurance based on 5G network intelligence

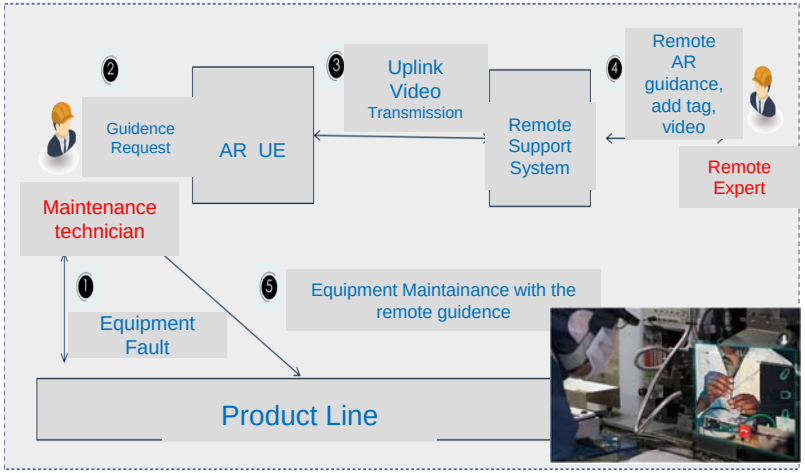


Field Trial Phase1 2020-6 to 2020-9	**Validation of high data rate, low latency of 5G network BS local break out**	**AR Equipment maintainance**
Field Trial Phase 2 2020-10 to 2021-12	**Validation of 5G service QoS/QoE assurance**	**AR Remot Guidence**

Usage Scenario1: AR Equipment Maintenance



Usage Scenario 2: AR Remote Repair Guidance



Sample AI/ML Deployment/Trials/Tests

QoE X-Layer Optimization	RAN aware Service Optimization	Radio bandwidth prediction for TCP receiving window adjustment or video coding rate selection.	Zhejiang
	Service aware QoE Optimization	Traffic classification, QoE prediction and RAN QoS enforcement for QoE optimzation	Fujian Shanghai
Network Management	Network Energy Saving	Traffic prediction and Coverage Overlapping analysis to enable dynamic cell on/off	24 Provinces
	Anomaly Detection	KPI clustering and automatic anomaly detection	Shan Xi
Radio Resource Management	Load Balancing	Prediction and radio finger based inter-frequecy load balancing to improve the resource efficiency	Fujian
Radio Tx Optimization	User Scheduling	User clustering to reduce the scheduling computation complexity	Zhejiang
	MCS/RI Optimization	ML enabled packet error rate modeling and prediction for accurate MCS/RI selection	

O-RAN Whitebox: Open Reference Design Hardware

- Architecture selection, function decomposition and requirements for BS WB
- POC 1st version prototype IN MWC Europe
- 1st WB RU POC demo at MWC Europe

- Release of 1st version of deployment scenarios and use case document
- WB reference architecture
- POC 2nd version prototype in MWC Shanghai 2020
- Release Schematic level reference design for RU and Accelerator for IPC

- Key component selection and building reference design
- Draft 4 specifications of the reference design of IPC white box

2019 Q1 | 2019 Q2 | 2019 Q3 | 2019 Q4 | 2020 Q1

RU characters:
•Operating band: 2.6GHz, 2.6GHz+2.3GHz
•Channel BW: 100MHz
•Port Num: 2T2R, 4T4R+2T2R(LTE)

Accelerator characters:
•Networking : NSA/SA
•Capacity : 3cell* 4T4R 100Mhz NR+ 5cell*4T4R 20MHz LTE
•Fronthaul : CPRI/eCPRI

Indoor Picocell (FR1) deployment scenario:
- **Release 4 specs**

Outdoor Macrocell(FR1)
- Develop HW architecture and requirement specifications
- Develop HW reference design Specs: one for FR1

Outdoor Picocell (FR2)
- Develop one HW architecture and requirement spec and reference design specifications

- O-RAN.WG7.DSC.0-v02.00
- O-RAN.WG7.IPC-HAR.0-v01.00
- O-RAN.WG7.IPC-HRD-Opt7-2.0-v01.00
- O-RAN.WG7.IPC-HRD-Opt7-8.0-v01.00

Indoor Picocell (FR1) deployment scenario:
- Release spec for HRD v1.0 for option 6
- Release spec for HRD v2.0 for option 8
- Release spec for HRD v2.0 for option 7-2

Brown field FHGW task group established

IPC reference design and hardware using ASIC

2020 Q2 | 2020 Q3 | 2020 Q4 | 2021 Q1 | 2021 Q2 | 2021 Q3

Outdoor Microcell(FR1)
- Develop HW architecture and requirement specifications
- Develop HW reference design Specs: one for FR1

Outdoor Microcell(FR1)
- Develop HW architecture and requirement specification V2
- Develop HW reference design Specs: V2 one for FR1

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O-RAN Software Community

- **Mission**: Joint establishment with LF; working software based on the O-RAN Spec, under hybrid IPR Policy in dual repository
- **Achievements**: 3 Releases since April 2019
  - Amber Release on Dec. 2, 2019,
  - Bronze Release on June 21, 2020,
  - Cherry Release in early Dec. 2020
  - Dawn Release targeting June/July 2021
  - E Release planned for Dec. 2021
- Technical Oversight Committee (TOC):
  - 9 of 12 seats filled
  - 12 projects PTLs
  - Subcommittee for software requirement and architecture (RSAC)
- Close collaboration with other open source communities, e.g. ONF, TIP, ONAP, OPNFV

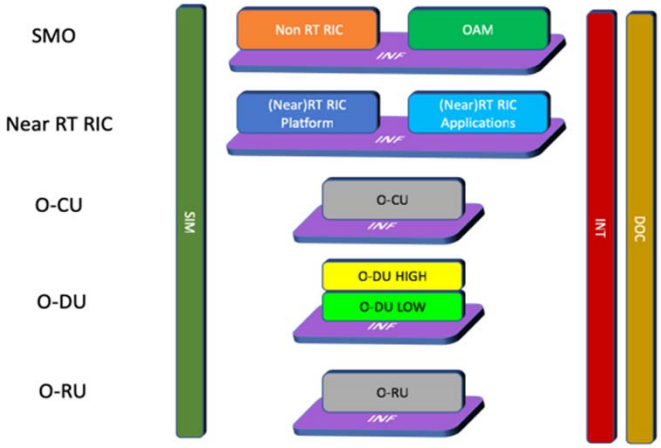
Company	Name
AT&T	Jack Murray, Co-Chair
China Mobile	Jinri Huang, Co-Chair
Deutsche Telekom	David Streibl
Ericsson	John-Paul Lane
NTT DOCOMO	Masafumi Masuda

Company	Name
Nokia	Juha Oravainen
Orange	William Diego
Radisys	Ganesh Shenbagaraman
Verizon	Viswanath Kumar
3 seats available	

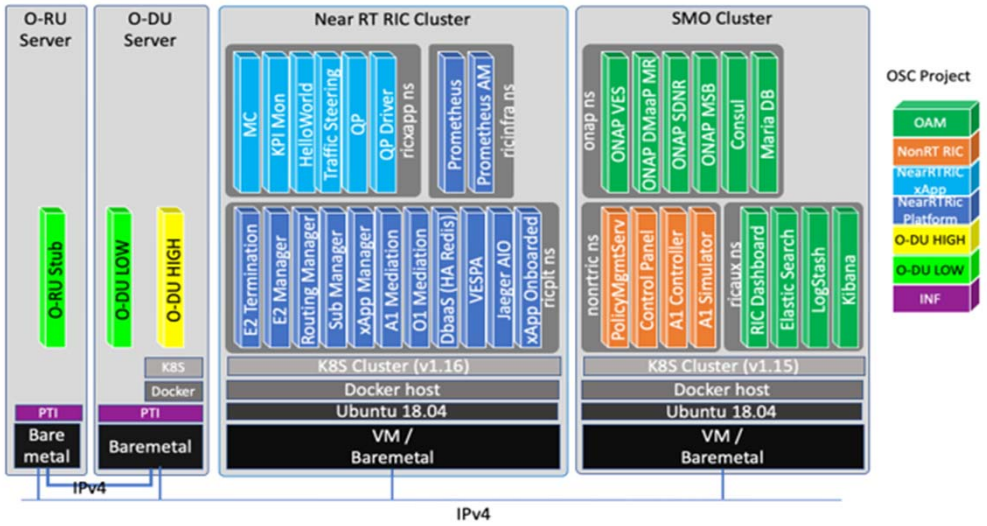
Project	PTL	Company
RICAPP	Matti Hiltunen	ATT
RIC Platform	Thoralf Czichy	Nokia
NONRTRIC	John Keeney	Ericson
OAM	Martin Skorupski	Highstreet-technologies
OCU	Su Gu	China Mobile
ODUHIGH	Sachin Srivastava	Radisys
ODULOW	Zhimin Yuan	Intel
INF	Zhang, Xiaohua	WindRiver.
SIM	Alex Stancu	Highstreet-technologies
INT	Felix Zhe Huang	ATT
DOC	Weichen Ni	China Mobile
SMO	Mahesh Jethanandani	VMware

O-RAN Software Community Testing Framework (OTF)

OTF in Project INT: Developing a set of Virtual Test Heads (type of Microservice) which can be used to build various OTF test strategies for OSC component or service testing.



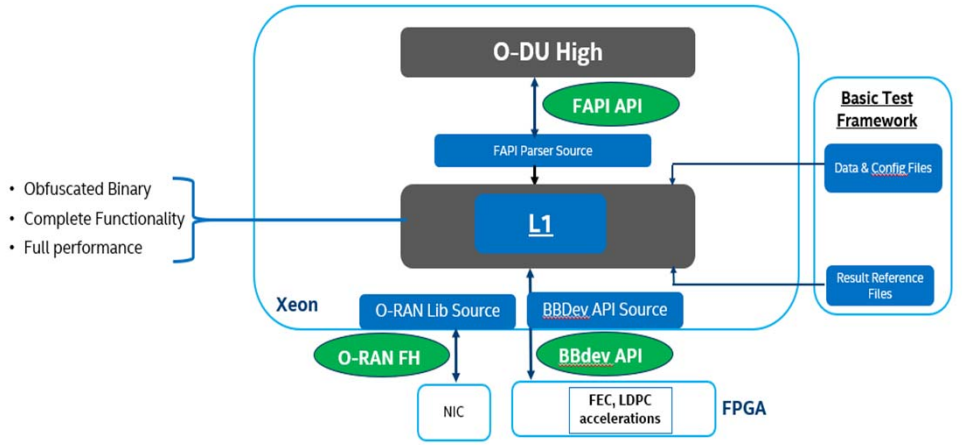
Relationship between OSC projects and O-RAN architecture components



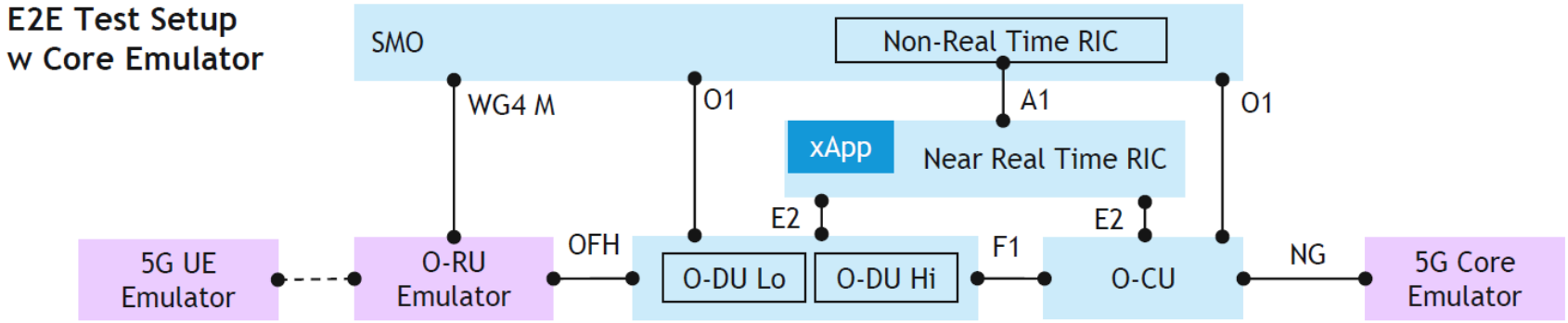
Deployment of OTF in the OSC Integration and Testing lab

OSC Integration and Testing Lab

- OSC integration lab being in Bedminster NJ, hosted by AT&T with open access to all
  - Comprises of all components in O-RAN architecture
  - Being used actively for testing Cherry release use cases



Example: O-DU Low (Intel) and O-DU High (Radisys) pairwise testing



Test and Integration Focus Group (TIFG)

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Addressing integration and multi-vendor interoperability

- Charter
  - Define O-RAN's overall approach for testing/integration including testing specs
  - Facilitate O-RAN product operationalization and commercialization
- Areas of work scope
  - Closely work and coordinate with O-RAN WGs on test specification development
    - ✓ Interface & subsystem / conformance & interoperability
  - Develop End-to-End test framework & specifications based on O-RAN architecture
  - Provide certification and badging guidelines
    - ✓ O-RAN interface conformance / IOT & E2E assessment
  - Provide guideline and accreditation for Open Test & Integration Centre (OTIC)
  - Conduct Global or Regional Plugfests
    - ✓ Validate the conformance and multi-vendor IoT of O-RAN based network equipment
    - ✓ Demonstrate the latest O-RAN compliant network and testing equipment for commercial deployment
- Co-Chairs from CMCC, AT&T, Reliance Jio, & Viavi

Open Testing and Integration Center (OTIC)

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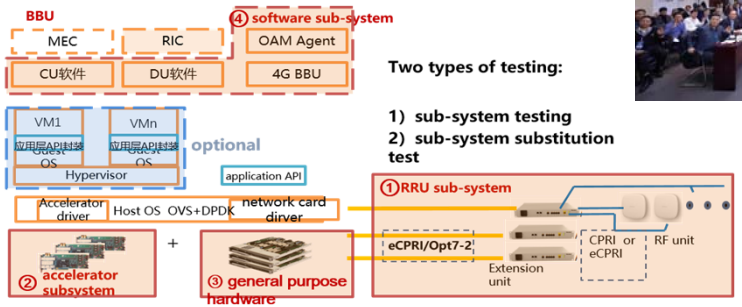
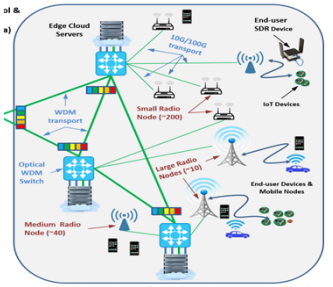
Asia OTIC Lab



- Asia OTIC in Beijing has been launched (9 Nov. 2019) by China Mobile, China Telecom & China Unicom)
  - achieve decoupling tiered commercial procurement capability
- Asia OTICs in Japan & India in planning

North America OTIC Lab

WINLAB Tech Center Facility



- Dec 2019, O-RAN OSC Amber Release, over 3 sites coordinated by AT&T
- Sep 2020 for O-RAN open interface specs w/ O-RAN OSC Bronze Release & real equipment & simulators.

European OTIC Lab

- Supported by DT, Orange, Telefonica and TIM (and open for others…)
- Three physical locations currently:
  - Berlin in Germany (hosted by DT in partnership with Orange) & Torino in Italy (hosted by TIM)
  - Madrid in Spain (hosted by Telefonica)
- Collaboration with TIP based on recent O-RAN/TIP LA (initially joint lab in Berlin)
- On Open FH interface (O-RU/O-DU) and ONAP - O-RAN integration & testing (O1)
- Virtualized RAN solutions testing and integration
- Non-RT and Near-RT RIC co-development and testing (E2, A1)

2nd O-RAN Global Plugfest (Sep. 2020)

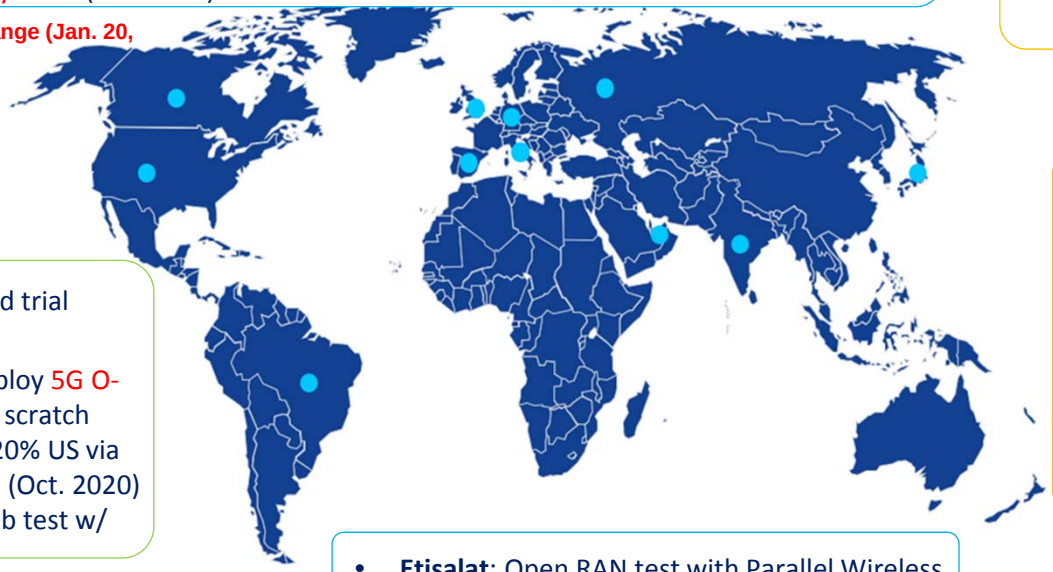
- 78 participating companies in all Plugfest venues (10) hosted by 11 operators in 7 countries
- 16 individual sessions & 1 joint session in the final demonstration
- **RIC-related PoCs**
  - E2E Network Slicing with both Non-RT and near-RT RIC RRM (East Asia)
  - near-RT RIC Interworking with O-eNB/MLB xApp (India)
  - ML based network configuration optimization – Non-RT RIC (North America & India)

Region	Plugfest Venue	Hosts	Key Areas & Focuses
Asia	**East Asia**	NTT DOCOMO, KDDI, SoftBank, China OTIC Lab	• *Multi-vendor IOT & PoC for open interfaces (OFH/X2)* • *RIC application PoC*
	India	Airtel	• *Multi-vendor IOT & PoC for open interfaces (OFH/X2)* • *RIC application PoC*
Europe	**Europe**	British Telecom, Facebook, Deutsche Telekom (EANTC), Orange, Telecom Italia, Telefonica	• *Joint **O-RAN & TIP** Plugfest/PoC* • *Multi-vendor IOT, functional and performance testing* • *PoC of remote IOT of non-time critical interfaces* • *Transport layer testing*
America	**North America**	AT&T, Verizon OTIC east (OTIC/E) candidate: FCC innovation Zone NYC metro area NSF PAWR sites: COSMOS and POWDER platform	• ***O-RAN & OSC** Plugfest/PoC in Innovation Zone East / Innovation Zone West* • *A1 interface with OSC components* • *O1/OAM + SMO with O-RAN early adopters*

Global landscape of O-RAN trials/deployment

- **Vodafone:** announce to purchase >100,000 OpenRAN BSs in 14 countries (Nov. 2019); Commercial deployment of open RAN solutions in Rural area (Oct. 2020); 2.6k sites in UK (Dec. 2020)
- **Deutsche Telekom:** Plan on **Evenstar** RRU with **Mavenir**, **Parallel wireless** (Feb. 2020); To build an O-RAN city **Neubrandenburg** with 150 BS (Dec. 2020)
- **Turkcell:** plan to deploy OpenRAN/vRAN (Feb. 2020)
- **Telefonica:** 50% market to adopt open RAN by 2025 (Sep. 2020); 1K sites in Germany (Jan. 2021)
- **Orange**: Only O-RAN by 2025 (Jan. 2021)

• **Vodafone, DT, Telefonia, Orange (Jan. 20, 2021)**



- **China Mobile:** O-RAN Field trials of LTE ORD (2019), NR ORD (2020), and RIC since 2019
- **China Unicom**: MoU on OpenRAN 5G NR with **TIP**; NRT-RIC test with solution provided by **ONF** in 2020

- **Rakuten:** 4G O-RAN network has been deployed (Feb. 2019); 5G O-RAN commercialization in Oct. 2020; 3M subs (Mar. 2021)
- **NTT DOCOMO:** 5G network with Open interface commercialized in Sep 2019;
  5G Open RAN Ecosystem (Feb. 2021)

• **AT&T**: nRT-RIC/FH test and trial (2020)

• ***DISH network***: plan to deploy 5G O-RAN network starting from scratch (Feb. 2020); plan to cover 20% US via open RAN solution by 2022 (Oct. 2020)

• **Verizon**: open interface lab test w/ 5G equipment (2019)

- **Etisalat**: Open RAN test with Parallel Wireless in the Middle East, Africa, Aisa. (Feb. 2020)

Summary

- **Operators Past: In-house Test → Field trial → Pre-commercial → Massive Deployment**
- **Operators Future: Verticals, AI/ML, Open Ecosystems & Fast Innovation**
  - **Inter-Regional Test & Trial collaborations**
  - **OSC, ORD, OTICs**
- **ITU ETSI IEEE Federation of Platforms & Testbeds**
  - **Vertical/Network KPIs?**
  - **Testbeds as a Service!**
  - Jointly define use cases and test specifications to align test targets and procedures.
  - Allow comparing the performance of same use cases under different deployment schemes, network configurations, and spectrum setting in different regions
    - China Mobile: 2.6 GHz + 4.9 GHz, urban dense deployment, highway coverage, SA+NSA
    - Europe: 3.5 GHz, campus area coverage, NSA
    - China and Europe tests same V2X cases using different RSU and OBUs.
  - Complementary tests to extend test capability of single site
    - Joint NSA and SA test between China and Europe projects.
    - Visit and conduct tests at the twin project's test sites.
  - Good information sharing between testbeds
    - Test methods, problem troubleshooting, results sharing.
  - Allow studying interoperability problems at service and application level.
  - Allow joint tests cross testbeds to develop better technical solutions
    - VR applications over 5G networks
  - Potential impact on technical and regulation alignments between different regions

中国移动
China Mobile

Thank You!

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