# Executive Panel on
# - 5G Research and System Design

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March 11, WCNC 2015, New Orleans, USA

www.10086.cn

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**Huawei:**

- 5G: New Air、New Architecture、New operation
     (Industry Defined Network Slicing)
- Air interface technologies：
     SCMA、F-OFDM、Full Duplex、PolarCode
- 13.5Gbps@E-band over the air demo
- 5G air interface able to adapt to service requirements



(3D calling、Driverless cars、IoT)

**Samsung:**
- mmW：pencilbeam, 7.5Gbps@ 28GHz

**ZTE:**

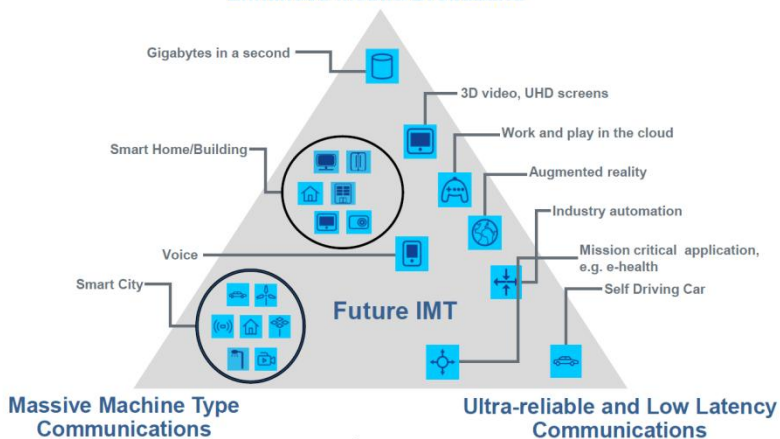Pre-5G concept
  - 128 antennas
  - All-in-one: BB/RF/Antennas



**Ericsson:**

5G Radio Test Bed：
- Dual Connectivity(LTE+5G)
   Multiple Connection
- Up to 5.8Gbps@15GHz

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Enhanced Mobile Broadband

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

Future IMT

Self Driving Car

Massive Machine Type Communications

Ultra-reliable and Low Latency Communications

Three major application scenarios

## Naming:

- IMT-2020
- IMT-2020 Connect (IMT-2020 in short)

| Traffic density | Connection density | Latency | Mobility | Energy efficiency | User experienced data rate | Spectrum efficiency | Peak data rate |
|---|---|---|---|---|---|---|---|
| 10Tbps/ Km2 | 1M/Km2 | 1ms AI | 500Km/ h | 100 times | 0.1~1G bps? | 2/3/5? | 20Gbps? |

KPI





Feature Diagrams

# Application Scenarios Identified by IMT-2020 PG
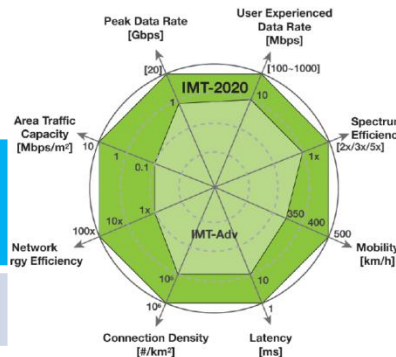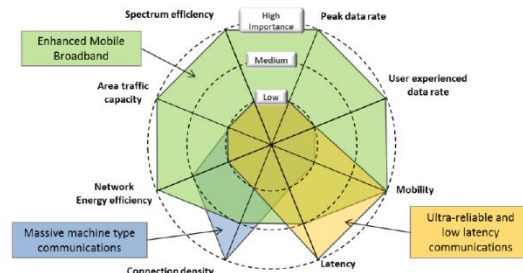
## Seamless Wide-Area Coverage

- User experienced data rate: 100 Mbps

## Low-Latency High-Reliability

- Air interface latency: 1 ms
- End-to-end latency: ms level
- Reliability: nearly 100%

## High-Capacity Hot-Spot

- User experienced data rate: 1 Gbps
- Peak data rate: Tens of Gbps
- Traffic volume density: Tens of Tbps/km$^2$

## Low-Power Massive-Connections

- Connection density: $10^6$ / km$^2$
- Ultra-low power consumption
- Ultra-low cost

**Soft**

Bring *agility* into implementation of each network element from core network to access network
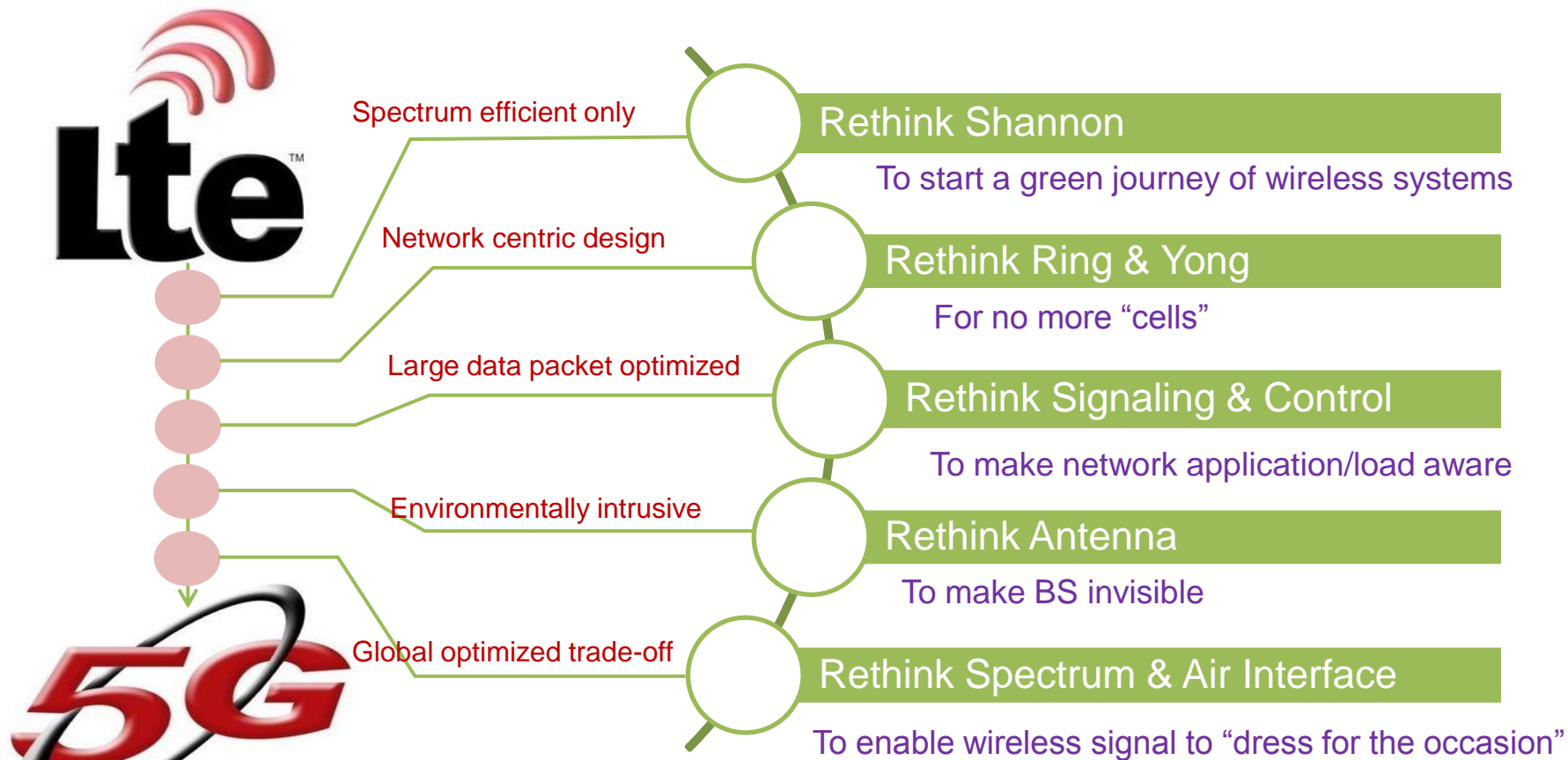
**Green**

Heighten the *efficiency* in utilization of any resources supporting wireless communication from the network side to the user terminal side

**Super Fast**

Provide *immersive and tactile* user experience in any predictable extreme scenarios.

# Rethink Fundamentals for 5G

Spectrum efficient only

**Rethink Shannon**

To start a green journey of wireless systems

Network centric design

**Rethink Ring & Yong**

For no more "cells"

Large data packet optimized

**Rethink Signaling & Control**

To make network application/load aware

Environmentally intrusive

**Rethink Antenna**

To make BS invisible

Global optimized trade-off

**Rethink Spectrum & Air Interface**

To enable wireless signal to "dress for the occasion"

**(IEEE Comm Mag, Feb. 2014)**

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**A New Eco-System for 5G**

Soft 5G

SDN/NFV

Cloud-RAN

Software Defined AI

"Invisible" BS

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

Verticals, Individual Consumers
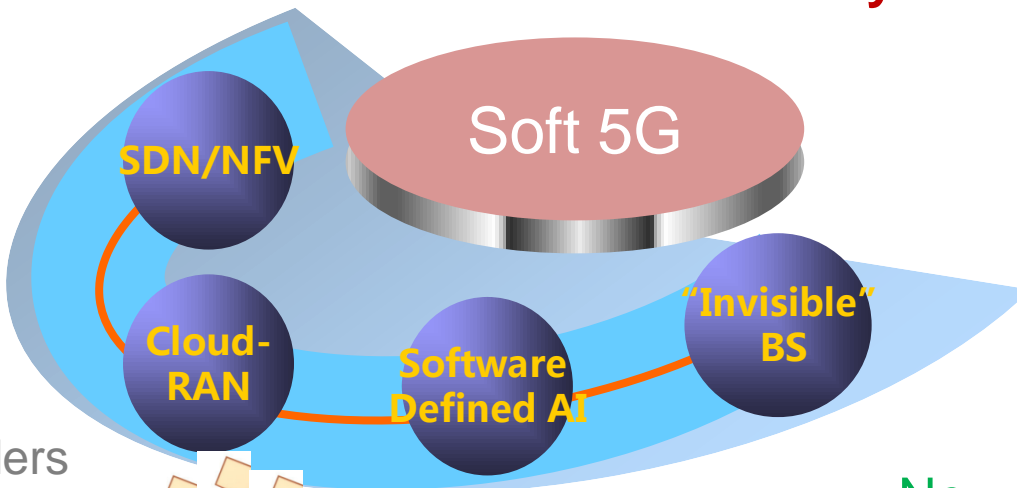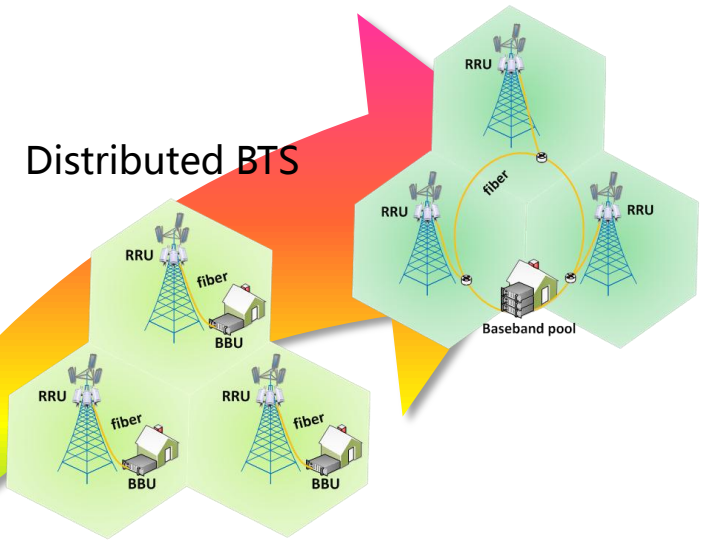
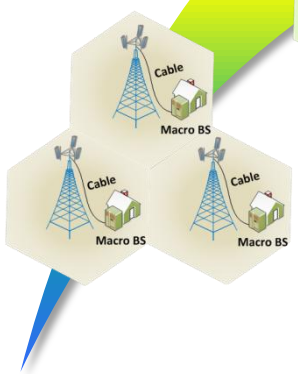Service venders on the soft/open platform (OTT, MVNO, …)

New stakeholders
- Intel, ARM, Xilinx, Altera, …
- IBM, Inspur, Lenove, Cisco…
- Windriver, Vmware,
- Open Source community
- Premises owner

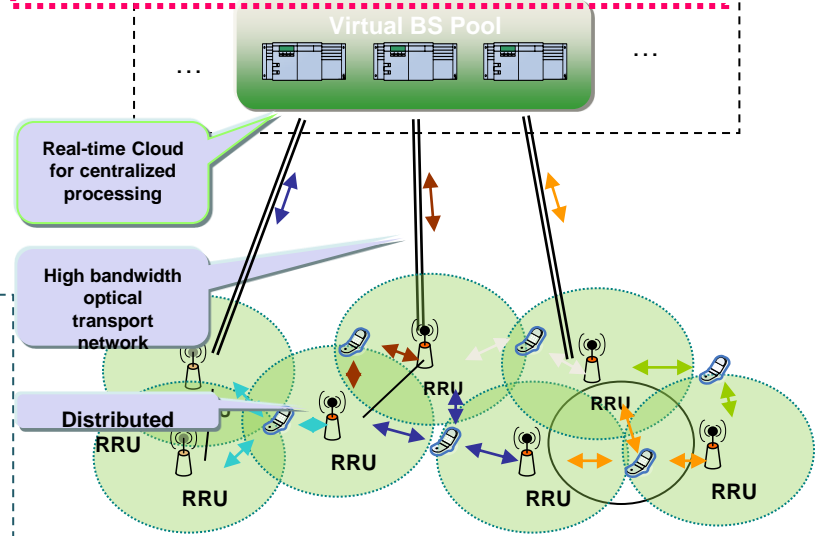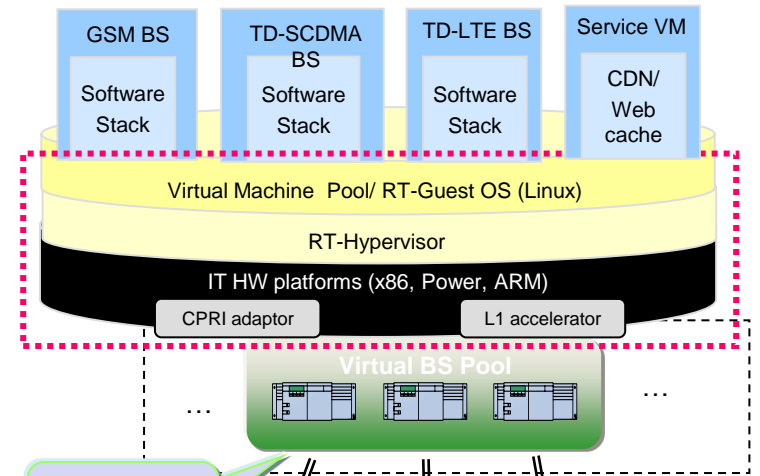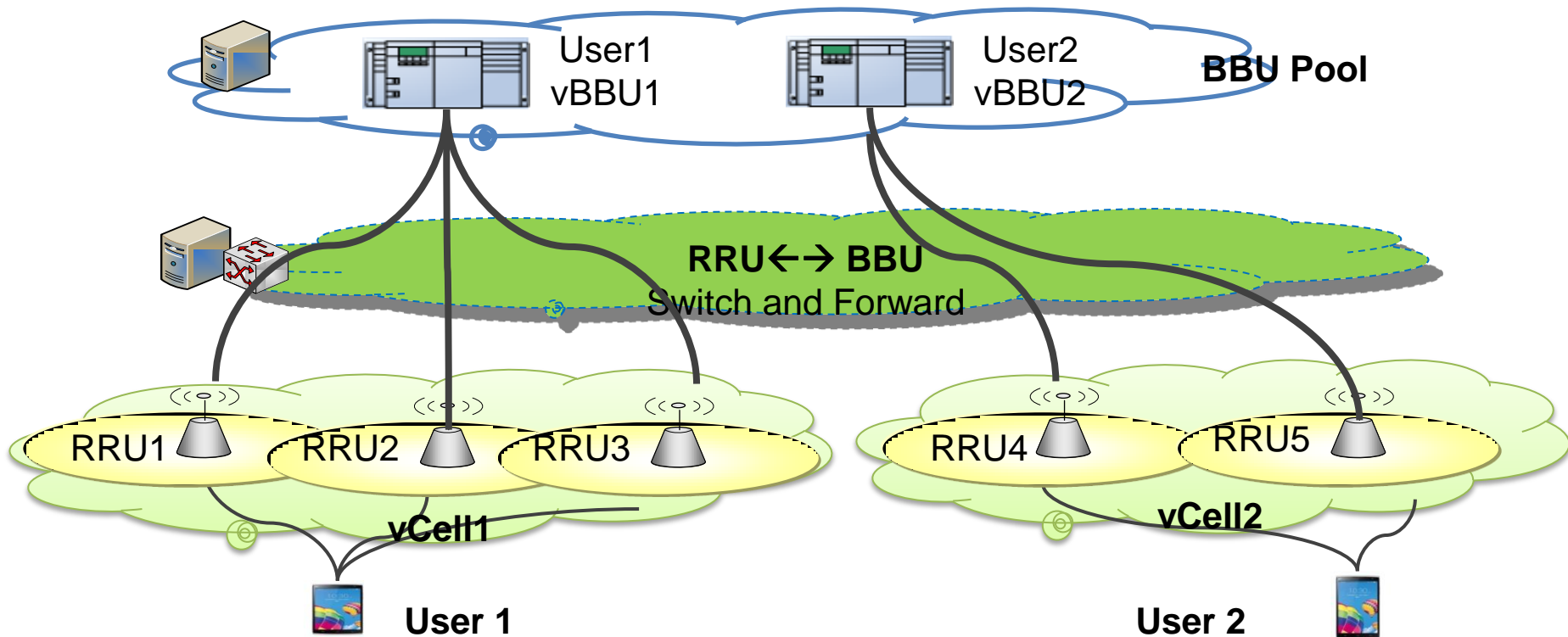# C-RAN: Essential Elements of 5G



## C-RAN

Distributed BTS

Traditional BTS

- Centralized Control and/or Processing
- Collaborative Radio
- Real-Time Cloud
- Clean System Target

GSM BS — Software Stack

TD-SCDMA BS — Software Stack

TD-LTE BS — Software Stack

Service VM — CDN/ Web cache

Virtual Machine Pool/ RT-Guest OS (Linux)

RT-Hypervisor

IT HW platforms (x86, Power, ARM)

CPRI adaptor

L1 accelerator

Virtual BS Pool

Real-time Cloud for centralized processing

High bandwidth optical transport network

Distributed RRU

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**Cell only exists when user comes**



User1
vBBU1

User2
vBBU2

**BBU Pool**

**RRU← → BBU**
Switch and Forward

RRU1

RRU2

RRU3

RRU4

RRU5

**vCell1**

**vCell2**

**User 1**

**User 2**

## Classical Network ApplianceApproach

Message Router

CDN

Session Border Controller

WAN Acceleration

DPI

Firewall

**Radio/Fixed Access Network Nodes**

Tester/QoE monitor

**SGSN/GGSN**

PE Router

BRAS

Carrier Grade NAT

## NFV Approach

Independent Software Vendors

Virtual Appliance

Virtual Appliance

Virtual Appliance

Virtual Appliance

Virtual Appliance

Virtual Appliance

Virtual Appliance

Competitive & Innovative Ecosystem

Vendors

Orchestrated, automatic & remote install.

High volume standard servers

High volume standard storage

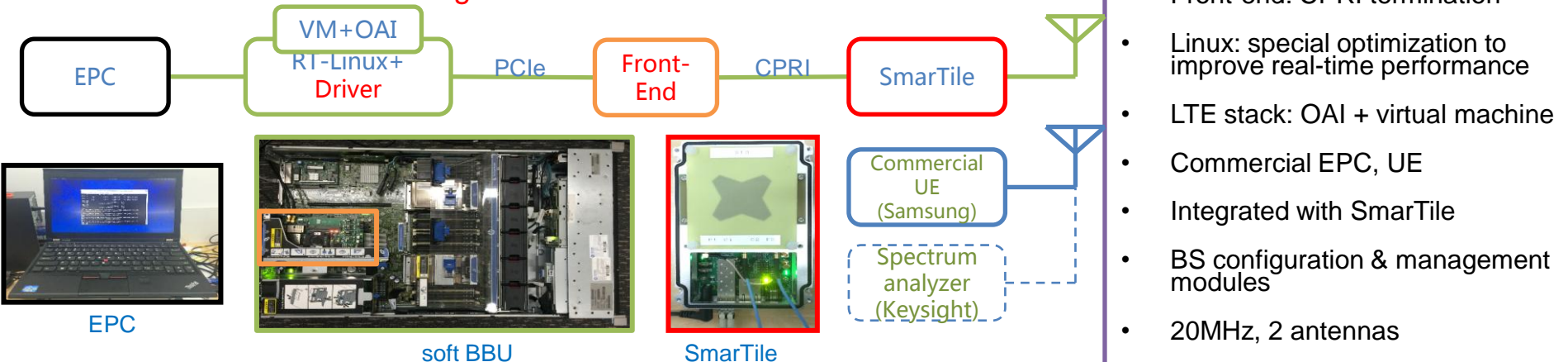High volume Ethernet switches

*Source: ETSI NFV ISG*

- 200 members from both IT and telecom industry since its foundation on Oct. of 2012
- Multiple WG/EGs, e.g INF, SWA., MANO, PER, REL and SEC.
- Have released 5 ISG-level documents to the industry, including architecture, use cases, terminologies, requirements and PoC promotion.

# MWC 2015: LTE VM-based L1+L2+L3 live migration

**World-first L1+L2+L3 live migration demonstration**

EPC → VM+OAI RT-Linux+ Driver —PCIe— Front-End —CPRI— SmarTile

Commercial UE (Samsung)

Spectrum analyzer (Keysight)

EPC

soft BBU
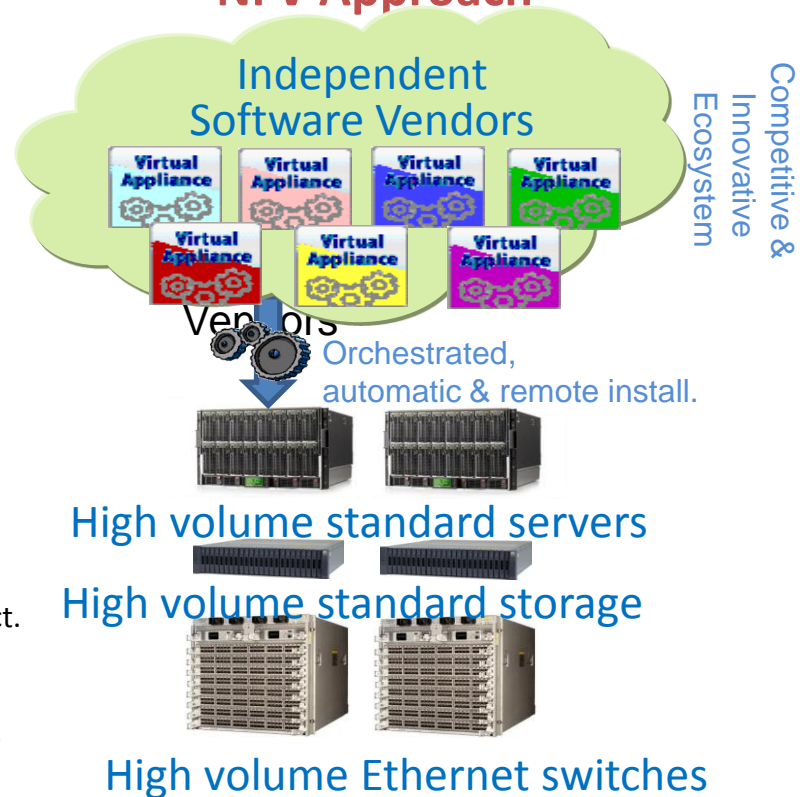
SmarTile

- Front-end: CPRI termination
- Linux: special optimization to improve real-time performance
- LTE stack: OAI + virtual machine
- Commercial EPC, UE
- Integrated with SmarTile
- BS configuration & management modules
- 20MHz, 2 antennas

- Based on OAI, yet significant improvements via SW architecture redesign & various optimization
  - 5MHz -> 20MHz LTE
  - Peak DL throughput (45Mbps, Config. 3, single port)
  - FFT module processing time saved by 1/3
  - Dynamic DL resource scheduling to support adaptive video coding (edge app.)
  - Host -> VM
- OAI setup a new branch for C-RAN (Sep. 2014, https://svn.eurecom.fr/openairsvn/openair4G/branches/cran)

Highlights:
- LTE in VM without acceleration
- World-first L1+L2+L3 live migration demonstration
- Optimized down-time performance of 10ms order of magnitude
- No service interruption during LM
- I/Q data soft handover during LM
- Memory sharing to allow high-speed communication b/w Front-end card, OS and

11

# Rethink fronthaul: NGRI

**BBU** — CPRI — **RRU**
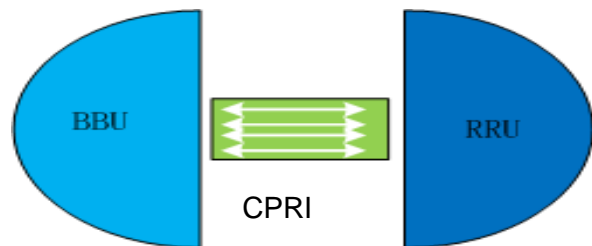
**①**

- *CPRI for 5G? Probably NOT*
  - Too high data bandwidth
  - Scalability issue to support 5G evolution
  - Lower efficiency due to TDM mode

**③**

Initial work in SDOs

- NGMN conducted initial function split solutions for LTE
- Newly founded TF in IEEE 1904 WG, to address the CPRI encapsulation in the form of Ethernet packet;
- Newly founded project in CCSA to study the requirements, scenarios and the key technologies
- Discussion in ITU-T and IEEE TSN recently

**②**

- Rethink FH
  - Traffic dependent to enjoy and enable statistical multiplexing for FH transport networks
  - Decoupling cell processing and UE processing
  - Decoupling UL and DL
  - Support key 5G technologies, e.g. LSAS, CoMP etc.

- A new FH requires joint design from both wireless and transport perspectives
  - Function split b/w BBU and RRU
  - Careful transport network design to address the latency, jitter and in particular, synchronization requirements

- *More radically, could we relax the critical CPRI requirements* (e.g. 0.002ppm sync. req.)?

- Initial study on BBU-RRU function split for LTE
- Design principle:
  - Traffic-dependent BW adaptation
  - Statistical multiplexing
  - Multiple mapping relationship b/w BBU and RRU
  - Independent of antenna number



Cell Processing

| R F | CP Rem. | F F T | Resource De-mapping | CE & Eq. |

| | CP Add. | iF F T | Resource Mapping |

UE Processing

| R x | UL | PUSCH Processing per UE | To MAC |
| | | PUCCH Processing per RB | |
| T x | DL | PDSCH Processing | From MAC |
| | | PDCCH/PBCH/PCFICH/PHICH | |

- Initial verification of the feasibility of CPRI over Ethernet
  - Simple point to point connection
  - CPRI I/Q sampling -> Ethernet packet of 512 Bytes
  - 1588v2 for RRU phase sync.
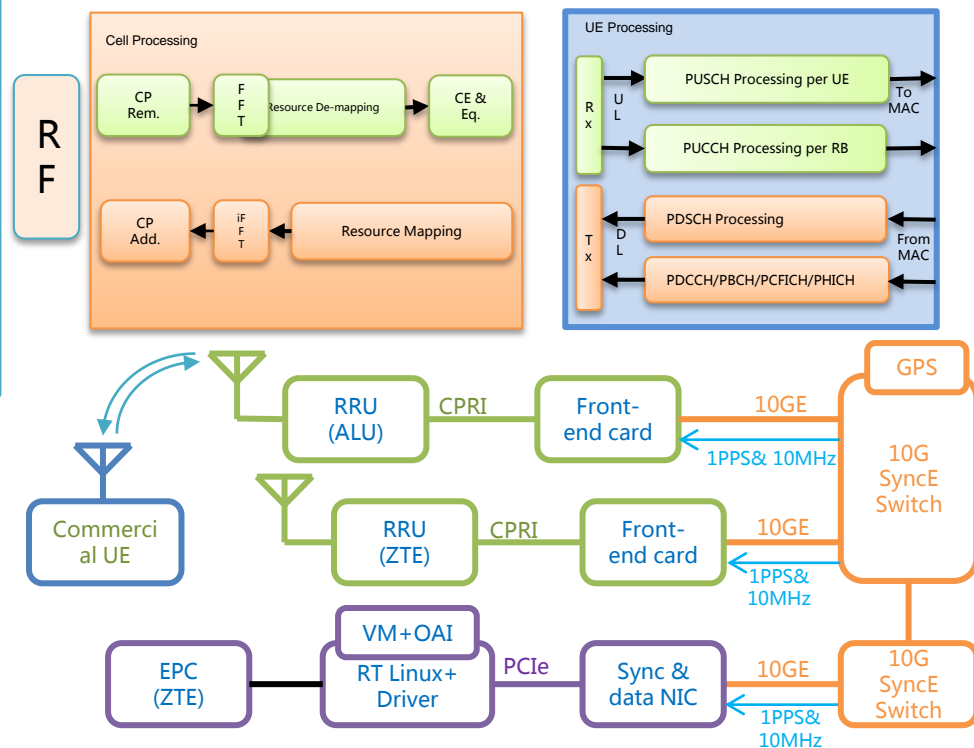


- WP on Next-generation Radio Interface (NGRI) ongoing, to be published by
- NGRI Forum planned for Q2 2015 (contact: huangjinri@chinamobile.com)

## 5G Air Interface

### All Spectrum Access

- Fragmented spectrum resource
- Various channel characteristics
- RF issues
- Antenna Size
- ......

### Diverse Scenarios

- IoT/MTC: massive small asynchronous burst connections
- Super-high-rate low-latency broadband
- Tactile Internet: real-time Cyber-physical control
- High Speed Train….

### Conflicting 5G metrics

- Energy Efficiency vs  Spectral Efficiency
- Peak data rate vs uniform user experience and latency
- Complexity vs Improved performance….

# Software Defined Air Interface (SDAI)

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"One" for all

**Green & Soft**

**Software Defined Air Interface (SDAI)**

**Service-Oriented**

All programmable building blocks & parameters

Adaptive Frame structure

| Spectrum | Modulation and coding | Waveforms | Multiple Access |
|---|---|---|---|

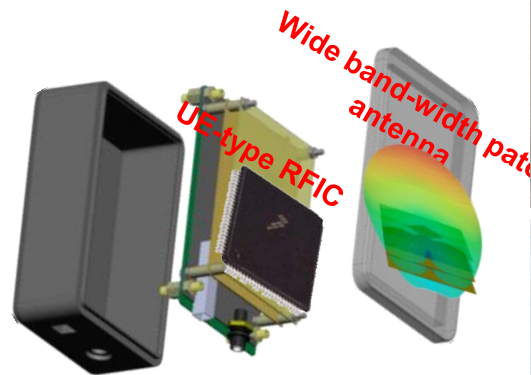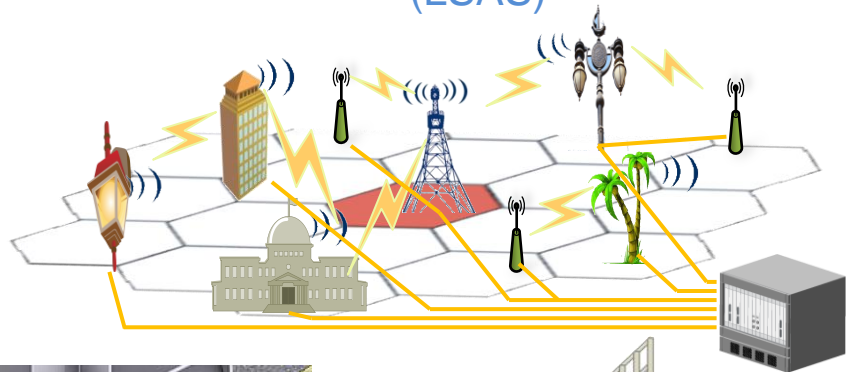| Spatial Processing | Duplex Mode | Antennas | Protocols |
|---|---|---|---|

……

Large scale cooperation over modules is necessary
→ Massive MIMO, Large Scale Antenna System (LSAS)

Wide band-width patch antenna

UE-type RFIC
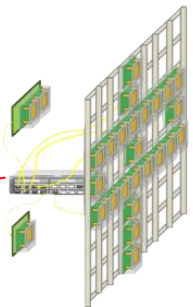
Non-uniform antenna array
→Pixel antenna for Chinese characters

6cm

16.5cm

10.5cm

# SmarTile in MWV2015
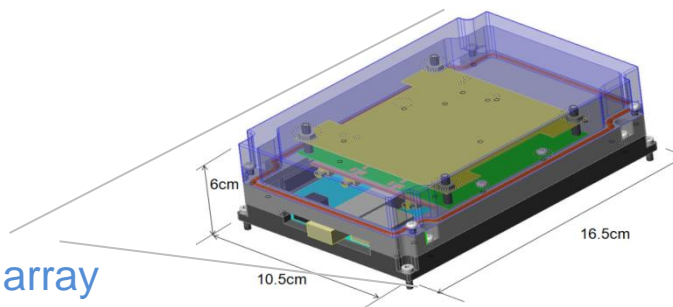
- ✓ Every SmarTile with 2 channels, 16.5cm×10.5cm in size
- ✓ 15 SmarTiles to form Chinese character "中"

**Multi-channel SA**

**LTE source and interface board**

**NO.1 : Beamforming demo**

- ✓ 8 Channels
- ✓ LTE source + Interface board + SmarTile + Multi-channel SA

**UE and PC**
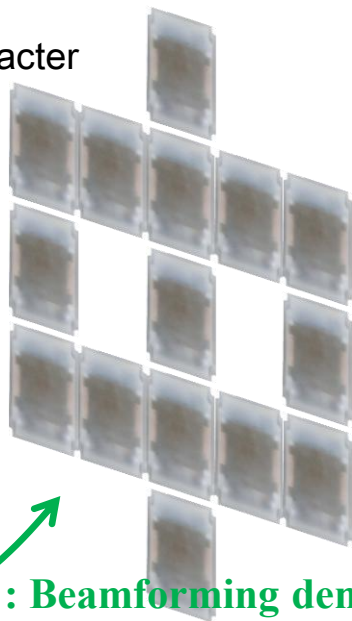
**NO.2 : Real time video transmission demo**

- ✓ BBU+ SmarTile+ 2 UEs
- ✓ Air interface or cable

**BBU and Camera**

17

# Planned Field Trial in Tianjin

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UDN

LSAS

LSAS: "Invisible BS"

Small cell
High-F, Large-BW

Hotspot

- **5G Vision: Mobile Internet + IoT**

- **5G KPIs: Performance + Efficiency**

- **5G Themes: Green, Soft, and Super Fast**

- **5G Technology Pearls: Rethink Fundamentals**

- **Our Strategic R&D Topics:**
    - **C-RAN**
    - **NGRI**
    - **SDAI**
    - **LSAS with SmarTile**

**New Era → New Service**

**→ New Technologies & New Business Models**