中国移动 China Mobile

绿色通信研究中心 Green Communication Research Center

Quest for 5G
- Rethink Fundamentals

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

First International IEEE 5G Summit,
Princeton, NJ, May 26, 2015

www.10086.cn

New Era, New Challenges

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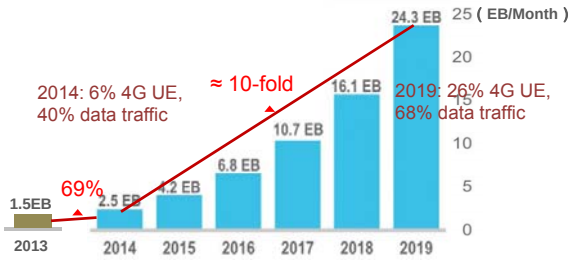
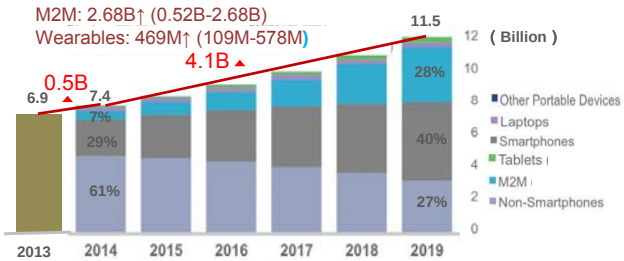
Global mobile data traffic



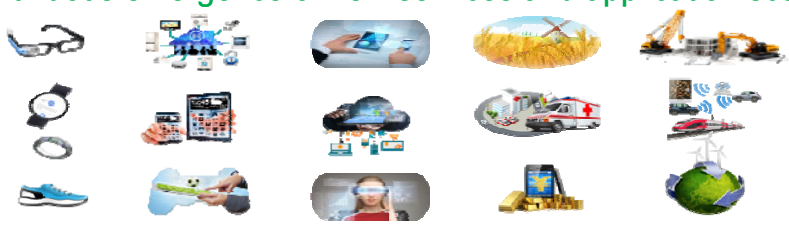
Source: Cisco VNI Mobile, Feb. 2015

Global Mobile Devices & Connections



Source: Cisco VNI Mobile, Feb. 2015

Continuous emergence of new services and application scenarios



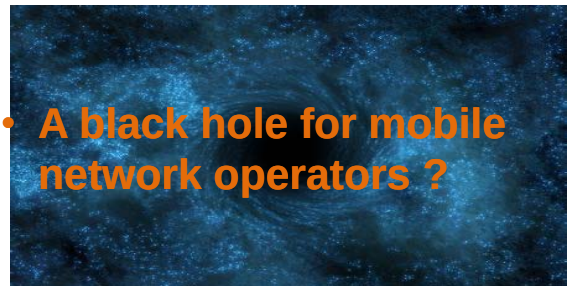
2

Two sides of Mobile Internet

Re-invention of the Mobile Phone trigger the era of Mobile Internet

- A brilliant future for the global community !

- A black hole for mobile network operators ?



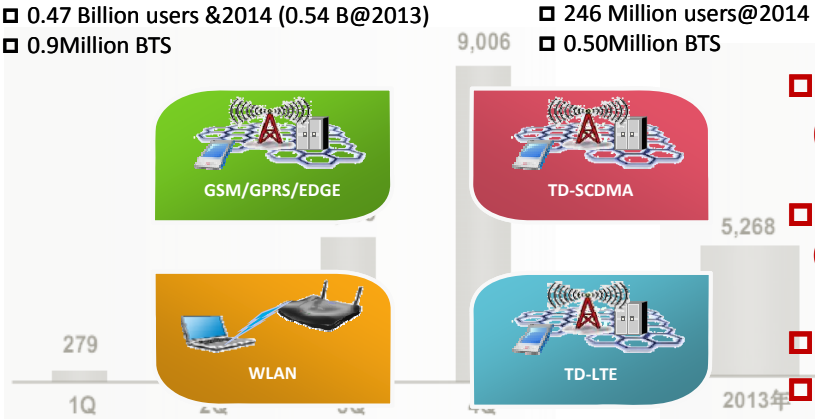
3

Explosive Growth of Mobile Data Traffic in CMCC

2014, CMCC' mobile data traffic has increased by **115.1%**

- 0.47 Billion users &2014 (0.54 B@2013)
- 0.9Million BTS

- 246 Million users@2014 (238 M@2013)
- 0.50Million BTS



- 4.41 Million AP@@2014

The largest 4G network worldwide

- **153 Million 4G users (10M@April)**
  - **DOU: 2.7x; ARPU: 1.4x**
- **0.86Million TD-LTE BS**
  (.685M Macro, 0.175M Indoor)
  Data by 2015.4
- **250 Million users**
- **1 Million TD-LTE BS**
  At the end of 2015

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Flattened Revenue

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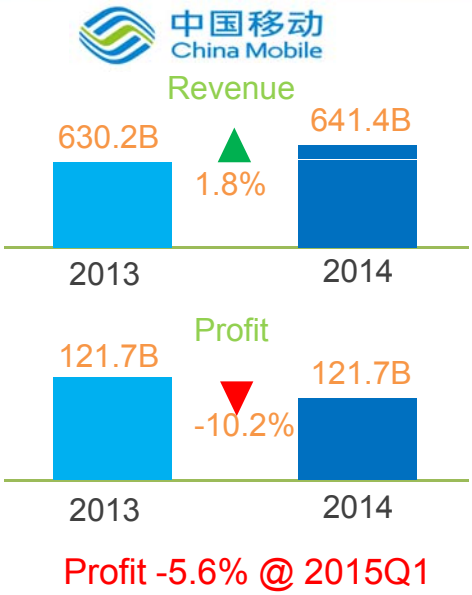

Profit -5.6% @ 2015Q1

Company	Revenue			Profit		
	2013	2014	IR	2013	2014	IR
China Telecom (RMB)	321.6 B	324.4 B	0.90%	17.55 B	17.7 B	0.80%
China Unicom (RMB)	295.04 B	284.7 B	-3.50%	10.41 B	12.06 B	15.80%
DoCoMo (Yen)	4461.203 B	4383.397 B	-1.70%	464.729 B	410.093 B	-11.80%
SKT (WON)	16602 B	17164 B	3.40%	1610 B	1799 B	11.80%
AT&T (USD)	128.752 B	132.447 B	2.87%	18.553 B	6.518 B	-64.90%
Verizon (USD)	120.550 B	127.079 B	5.41%	11.497 B	9.625 B	-16.30%
DEUTSCHE TELEKOM (EURO)	60.1 B	60.7 B	1.00%	2.8 B	2.4 B	-14.30%
Telefónica (EURO)	45.1 B	50.377 B	11.70%	2.23 B	3.001 B	34.70%

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Question on MNOs' Mind

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How to Embrace the New Era?

Era of Industry 4.0 & Internet+

New Markets
→ **New Services**
New Requirements
→ **New Technologies**
New Eco-system
→ **New Business Models**
New …

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New Requirements: Technical Challenges

Seamless Coverage, Hot Spot High Capacity, Low-power Massive-connection, Low-latency Ultra-reliable

New design principles, new key technologies, …

7

What 5G should Give Us?

Fiber-like access data rate

Consistent experience under diverse scenarios

"Zero" latency user experience

Smart optimization based on services and users sensing

Up to 100 Billion connections

100 times improvement in energy and cost per bit

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Worldwide Activities on 5G since Q4 2012

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EU FP7 and Horizon 2020

WWRF Vision 2020

3GPP Roadmap to Y'2020

UK "5G Innovation Center"

FuTure Forum 5G SIG

China IMT-2020 PG

Requirement study

Spectrum

Technology trends

5G new technology collect and evaluation

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5G Vision

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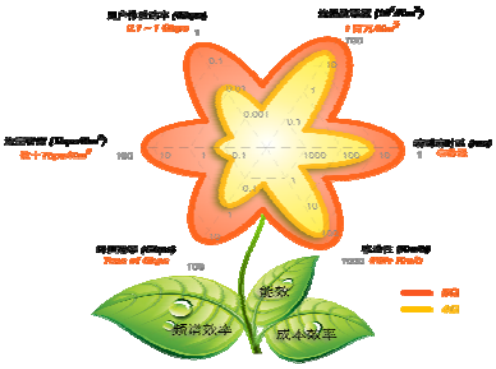
"Information a finger away, everything in touch"

"信息随心至， 万物触手及"



Whitepaper, IMT-2020 PG, 29 May 2014

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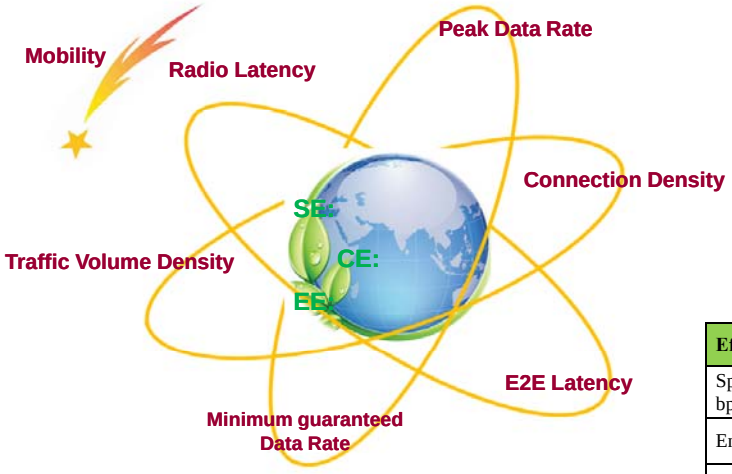
Wishlist in terms of KPIs



Performance KPI	KPI for 5G networks
Peak data rate	⩾ 10 Gbps
Minimum guaranteed user data rate	⩾ 100 Mbps
Connection density	1 million connections/km^2
Traffic density	⩾10 Tbps/ km^2
Radio latency	⩽ 1 millisecond
E2E latency	millisecond level
Mobility	up to 500 km/h

Efficiency KPI	compared with 4G
Spectrum efficiency (bps/Hz/cell or bps/Hz/Km2)	5 ~ 15 time
Energy efficiency (bit/J)	100+ times
Cost efficiency (bit/￥)	100+ times

Whitepaper, FuTURE Forum, 06 Nov. 2014

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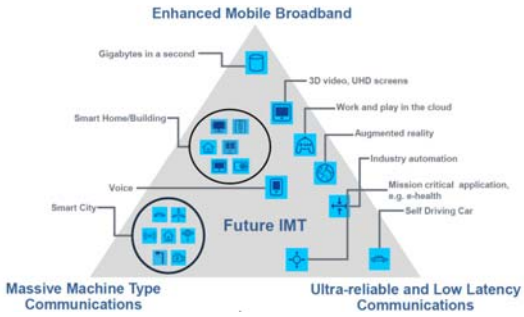
ITU Latest Progress on 5G



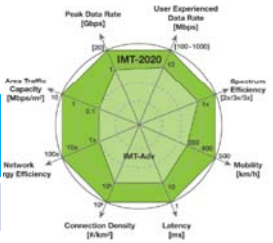
Three major application scenarios

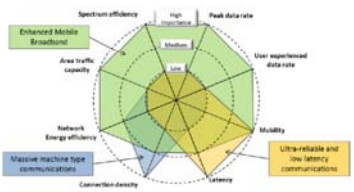
Naming:

- 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

Draft version of ITU-R M.[IMT.VISION]

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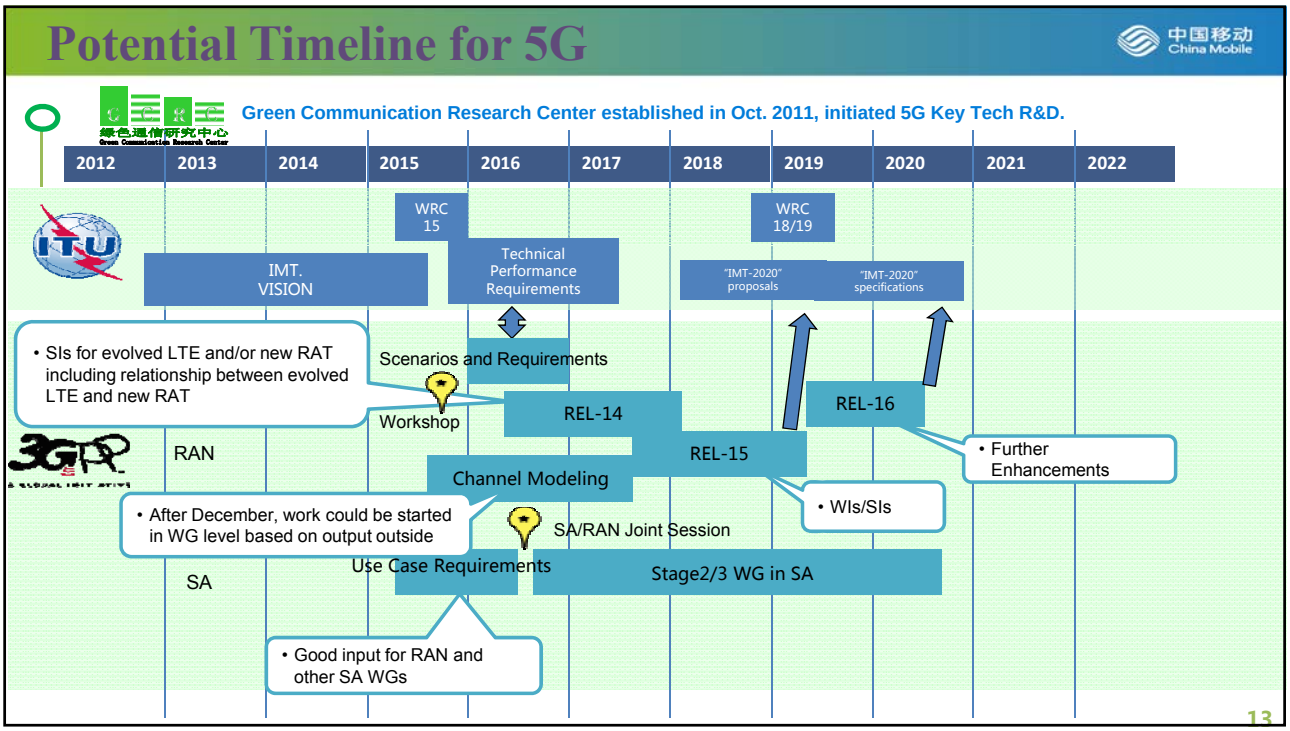
Potential Timeline for 5G
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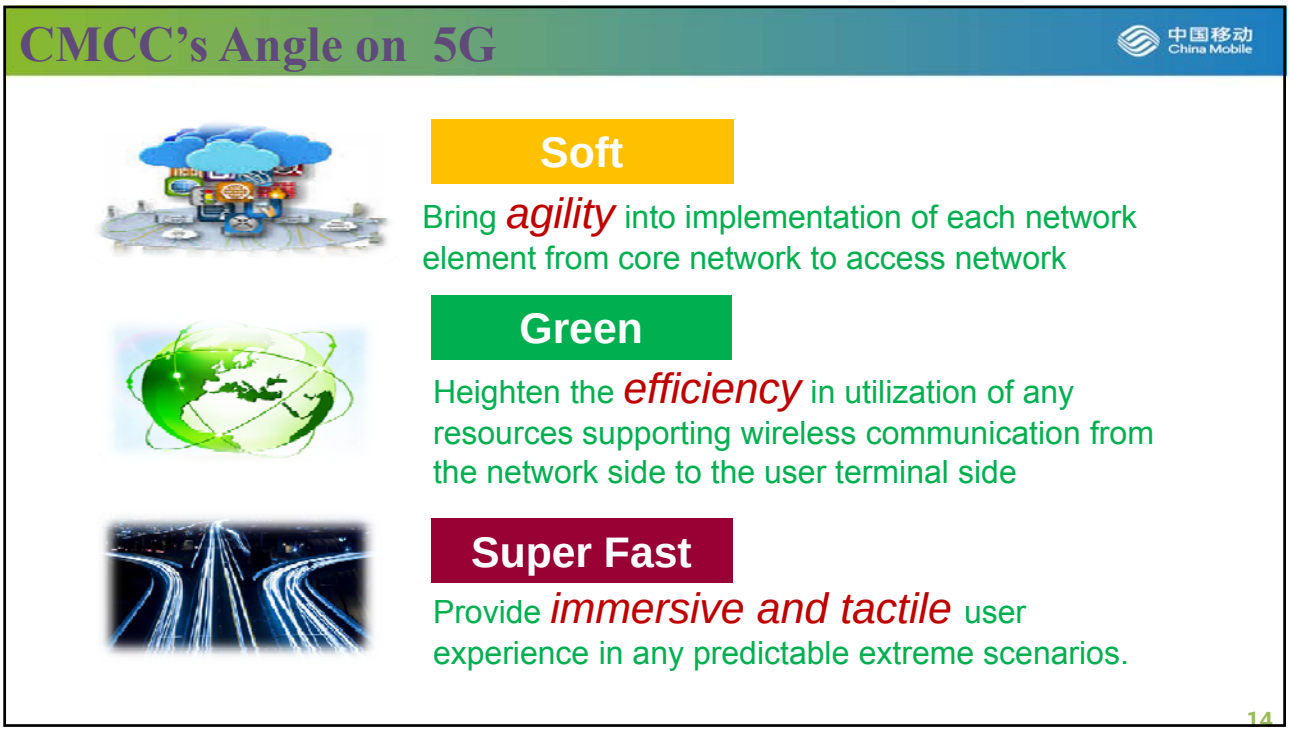
Green Communication Research Center established in Oct. 2011, initiated 5G Key Tech R&D.
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
WRC 15
WRC 18/19
IMT. VISION
Technical Performance Requirements
"IMT-2020" proposals
"IMT-2020" specifications
• SIs for evolved LTE and/or new RAT including relationship between evolved LTE and new RAT
Scenarios and Requirements
Workshop
REL-14
REL-15
REL-16
• Further Enhancements
RAN
Channel Modeling
• WIs/SIs
• After December, work could be started in WG level based on output outside
SA/RAN Joint Session
Use Case Requirements
Stage2/3 WG in SA
SA
• Good input for RAN and other SA WGs
13


CMCC's Angle on 5G
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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.
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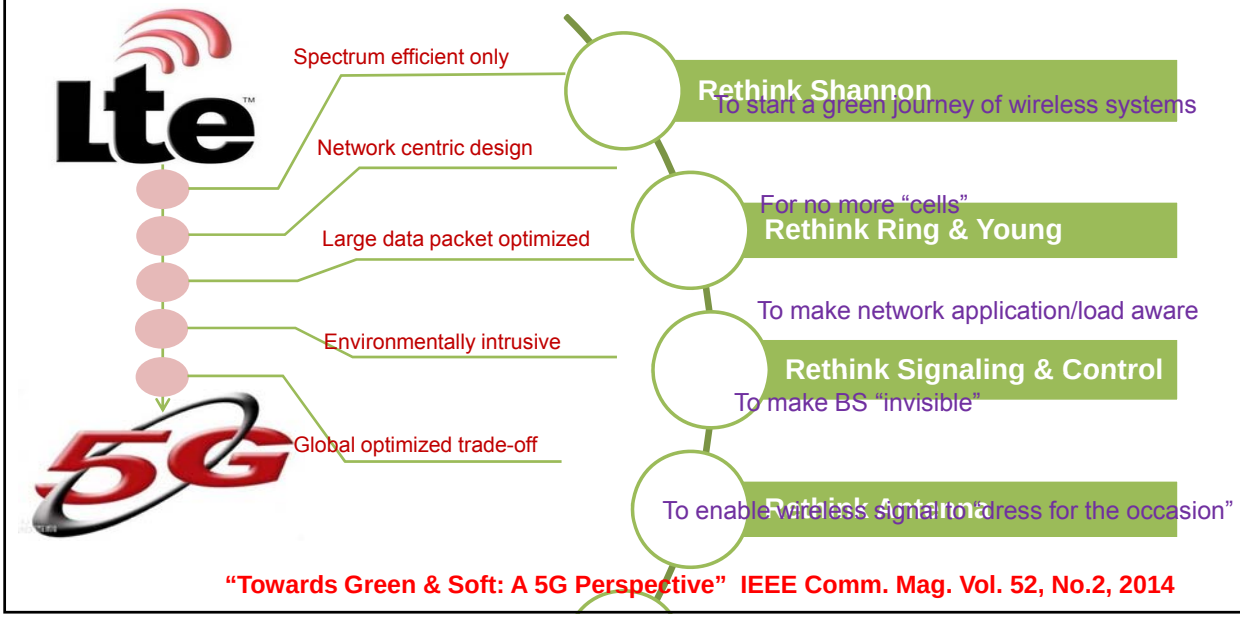
Rethink Fundamentals



"Towards Green & Soft: A 5G Perspective" IEEE Comm. Mag. Vol. 52, No.2, 2014

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Rethink Shannon: from C/SNR to EE/SE

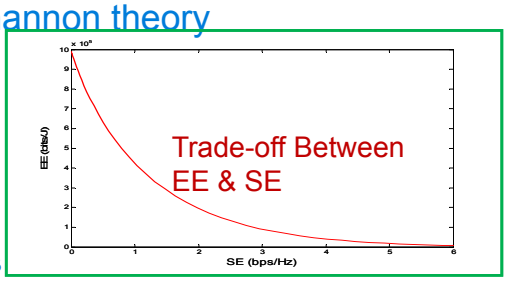
- EE and SE relationship from traditional Shannon theory

$$R = B\log_2\left(1+\frac{P}{N_0 B}\right)$$

$$\eta_{EE} = \frac{1}{N_0}\left(\frac{\eta_{SE}}{2^{\eta_{SE}}-1}\right)$$

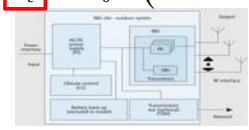
$$\eta_{EE} = \frac{R}{P}(bits/J)$$

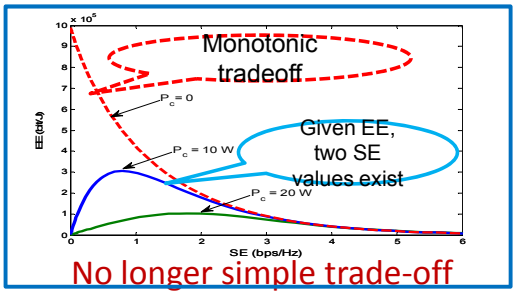
$$\eta_{SE} = \frac{R}{B}(bps/Hz)$$



- More factors exist in realistic systems
  - Circuit power
  - Transmission overhead

$$\eta_{EE} = \frac{B\eta_{SE}}{P_c + N_0 B\left(2^{\eta_{SE}}-1\right)/\rho}$$

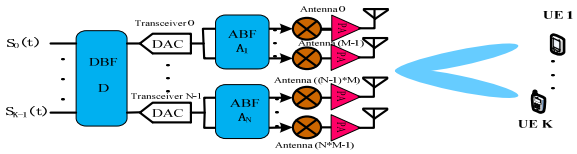


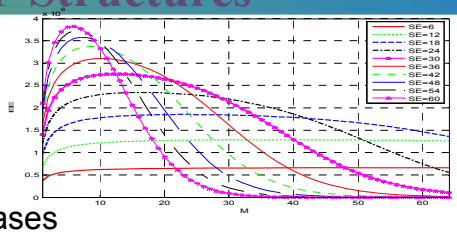


"Fundamental Properties of the EE-SE Relationship", IEEE WCNC2014,

16

EE/SE Co-design of Hybrid BF Structures





- For NM=L and independent N and M cases
  - Given SE, there exists optimal N which yields highest EE
  - Given SE, there exists optimal M which yields highest EE
  - Antenna/transceiver On/Off
    - The BS can be designed with the maximum number of N and M under given SE requirement range, and
    - Enhance EE performance via antenna /transceiver On/Off based on the SE requirements
- Green point EE optimization
  - For NM=L case
    - There exists optimal N which maximize the green point EE
  - For independent N and M case
    - The green point EE is monotonically increasing with N

"Large Scale Antenna System with Hybrid Digital and Analog BF Structure" in IEEE ICC 2014

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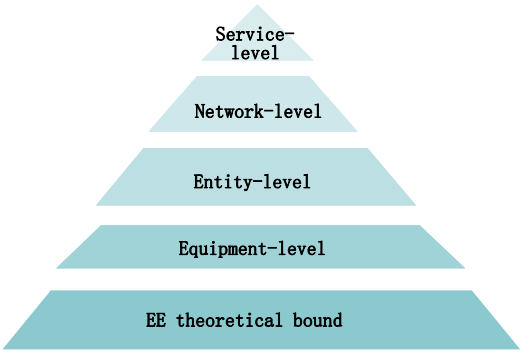
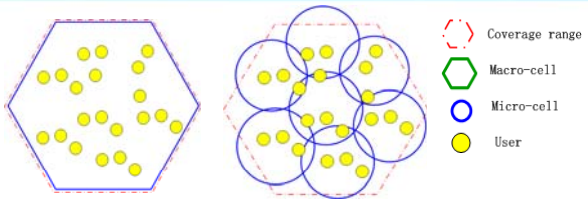
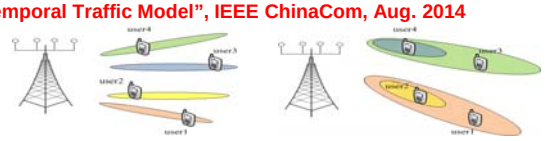
Rethink Shannon: from C/SNR to EE/SE

- EE/SE R&D Framework
  - From theory to practice
  - From equipment level to service level
  - Key technologies evaluation





"Network Deployment and Operation Based on Spatial and Temporal Traffic Model", IEEE ChinaCom, Aug. 2014



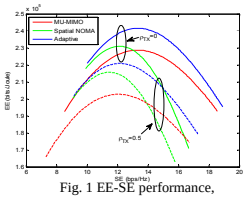


Fig. 1 EE-SE performance, MU-MIMO & Spatial NOMA

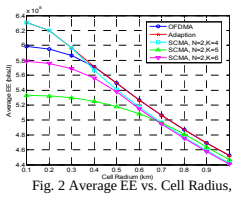


Fig. 2 Average EE vs. Cell Radius, SCMA &OFDM

"Energy Efficiency Optimization for Fading MIMO Non-Orthogonal Multiple Access Systems," ICC 2015.

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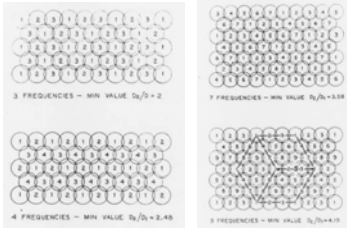
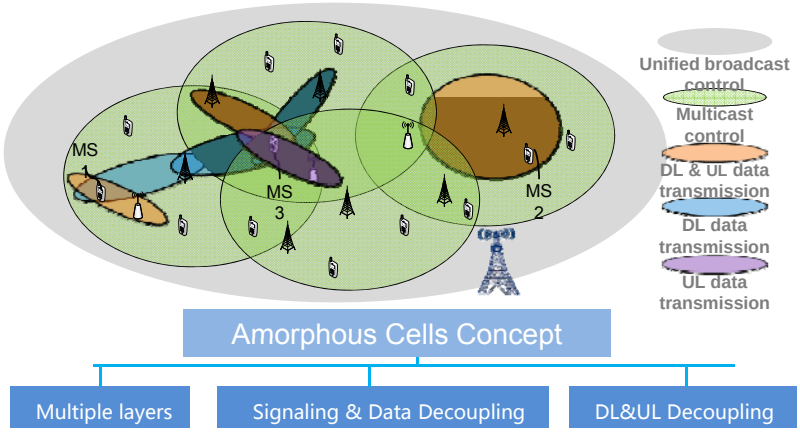
Rethink Ring & Young: No More "Cells"

Douglas H. Ring & W. Rae Young
1947 at Bell Lab





DAS, Relay, HetNet, CoMP…

From Network-Centric to User-Centric

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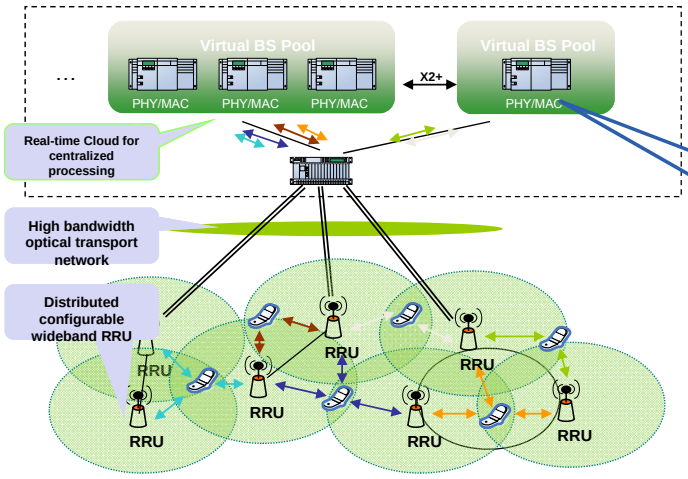
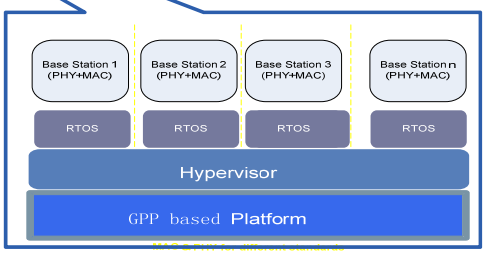
Rethink Ring & Young: No More "Cells"

C-RAN : Revolutionary Evolution of RAN



- Common platform, software based solution
- Live (soft) computation resource transition
- Inherent cooperation



BS virtualization

- Whiter Paper, "C-RAN: The Road towards Green RAN," V1.0, 2010; V3.0, 2014, China Mobile

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Rethinking Signaling/control

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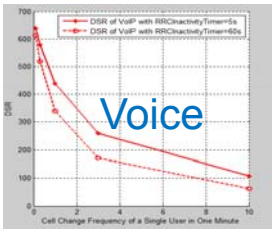
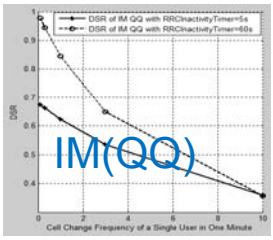
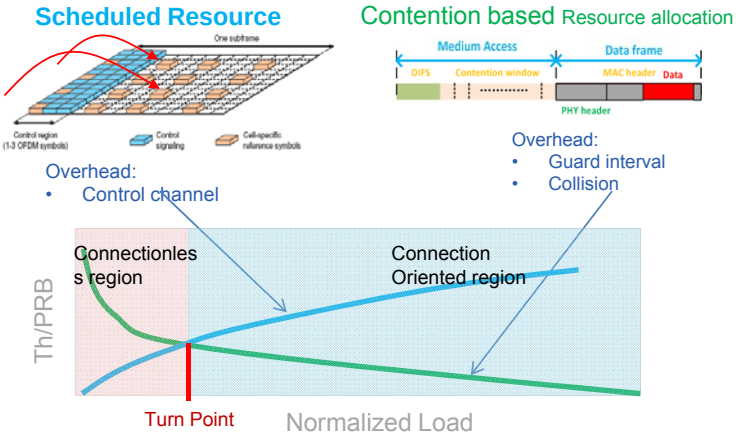
Load Aware Signaling Reconfiguration





DSR ratio of current network



"Small data optimized radio access network signaling/control design" ICC 2014

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Rethinking Signaling/control: Deal with IoT properly

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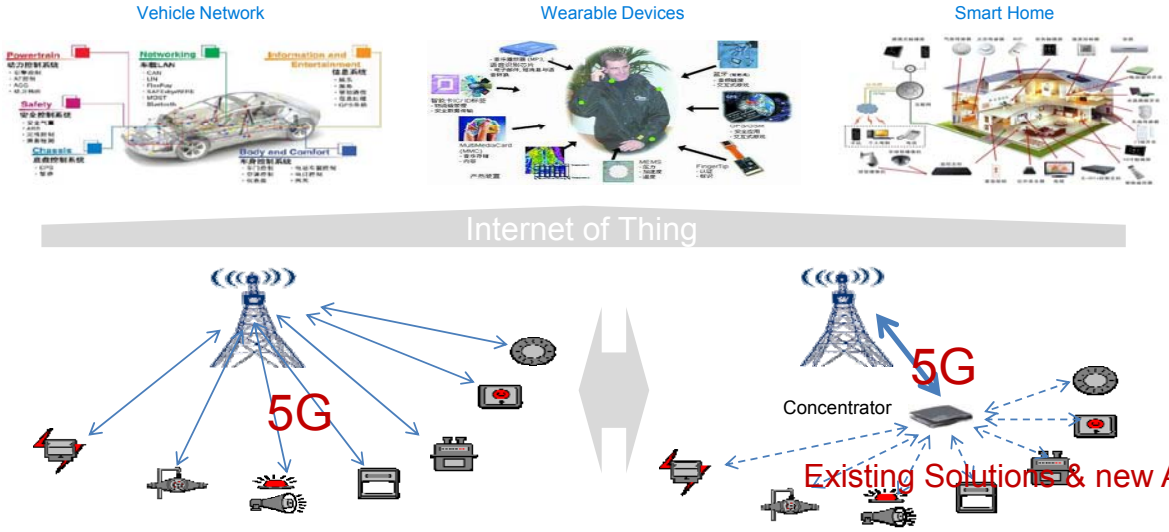

"Trillions of nodes for 5G?!" IEEE ICC2014

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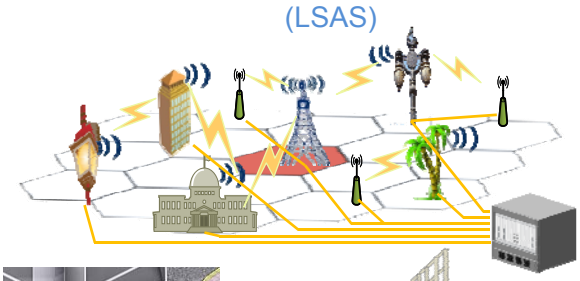
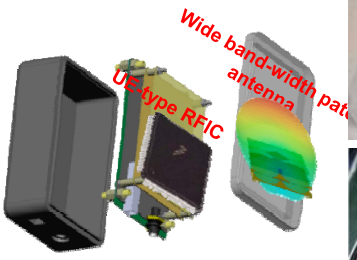
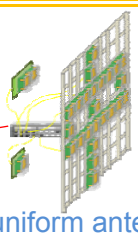
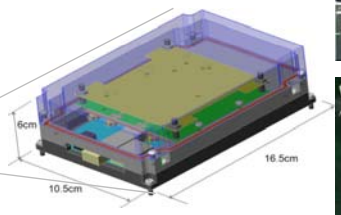
Rethink Antenna: "Invisible" Base Station

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









Non-uniform antenna array
→Pixel antenna for Chinese characters

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C-RAN + SmarTile in MWC2015

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Rethink Spectrum & Air-interface

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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

……

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New Air Interface @ High Frequency for Small Cell

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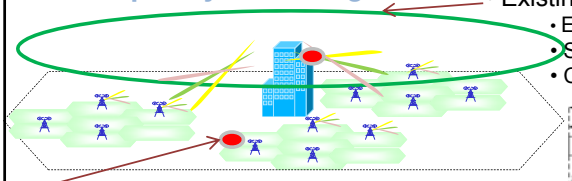
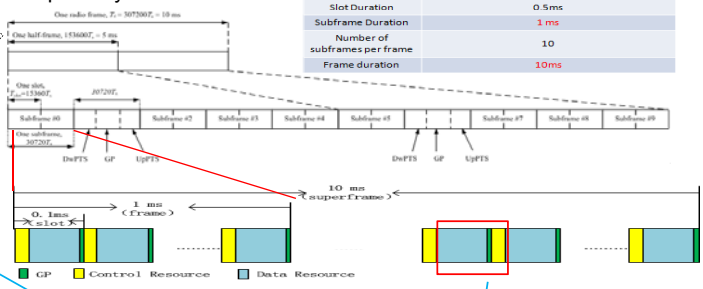
Typical network architecture for 5G:

--Multiple layer coverage



- Existing Frame Structure
  - Ensure coverage
  - Support robust mobility
  - Compatibility

System bandwidth		1.4MHz,3MHz,5MHz,10MHz,15MHz,20MHz
Subcarrier spacing		15kHz
Number of symbol per slot		7/6
CP duration	Normal	(4.69)x6, (5.21)x1 us
	Extended	(16.67)x6 us
Number of slots per subframe		2
Slot Duration		0.5ms
Subframe Duration		1 ms
Number of subframes per frame		10
Frame duration		10ms



- Disruptive Frame Structure

--- Satisfying 5G new requirements

- Low latency (<1ms)
- High data rate (10Gbps)

System bandwidth	75MHz,100MHz,5MHz,125MHz,250MHz,500MHz
Subcarrier spacing	300kHz
Number of symbol per slot	24
CP duration	0.83us
Number of slots per subframe	10
Slot Duration	0.1ms
frame Duration	1 ms
Number of frames per superframe	10
Superframe duration	10ms

5G requirements

High data rate | Large bandwidth | Low latency | Flexible | Coordination

……

"Perspective on New Air Waveform Design for 5G Small Cell" IEEE VTC2014 Spr

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High Freq. Band : "Data Only" Small Cell

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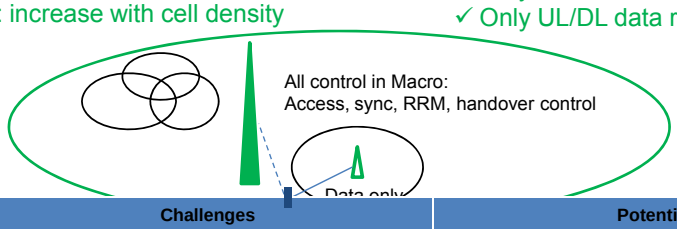
Low cost "Data Only" small cell carrier with the help of Macro

Dense small cells: Challenges
- Mobility support: frequent handovers
- Signaling overhead: increase with cell density

- Solution: Simple, low cost, "data only" small cell
  - ✓ Only UL/DL data channels
  - ✓ Only UL/DL data related reference signals



Target for	Challenges	Potential Solution
No PSS/SSS, No CRS	✓Coarse/Fine Synchronization; ✓Discovery and Selection, incl. carrier specific measurement supporting handover ✓Initial UL power setting	✓Utilize User-Specific RS for measurement and detection; ✓UL Listening and Calibration with help of Macro
No MIB/SIB	Small Cell Specific Info Delivery	Delivered from Macro by Specific Signaling or Broadcast
No PRACH	Initial and Continuous UL Sync	UL Listening and Calibration with help of Macro
No PDCCH/PHICH/PCFICH/PUCCH	✓User specific data scheduling ✓Small cell specific paging ✓Data transmission ACK ✓Channel measurement feedback	✓Transmitted via Macro ✓Small cells and Macro joint calibration

"Macro-Assisted Data-Only Carrier for 5G Green Cellular Systems" IEEE Comm Mag., May 2015

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XDD: Configurable Duplex

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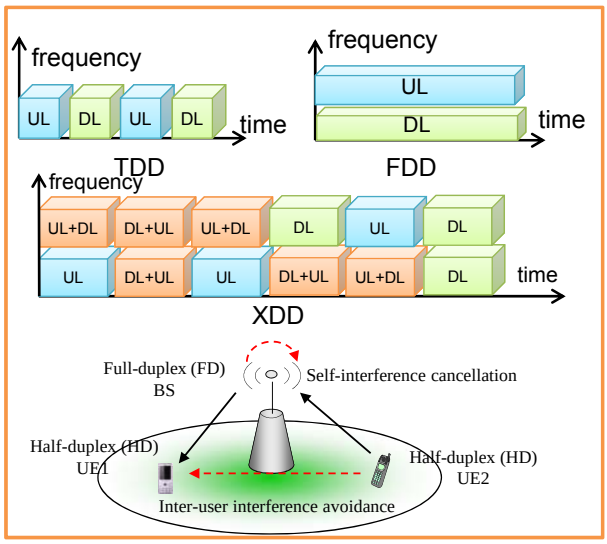
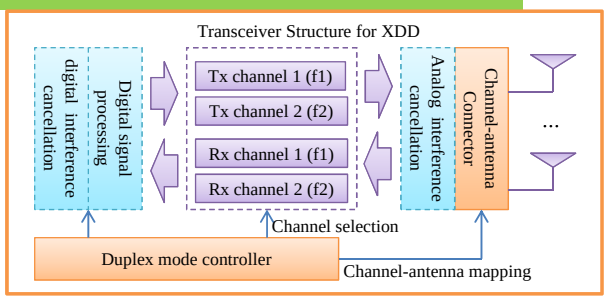
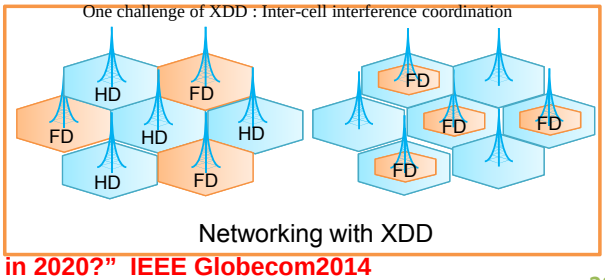
XDD: Remove the difference between TDD and FDD







"Full duplex, coming into reality in 2020?" IEEE Globecom2014

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R&D Strategy in CMCC

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R&D Theme： GREEN SOFT Super Fast

EE/SE based Green Theory — *Rethink Shannon* — **Fundamental Green Theory & Evaluation Framework**

Network Architecture → *Rethink Ring&Young*, *Rethink Signaling&Control* } ***No More cell***
- Platform related Tech. (C-RAN, RRS)
- NMC-Oriented NA& interface design
- UDN/UCN

5G New AI → *Rethink Spectrum& Air Interface*
Multi-Ant. System → *Rethink Antenna*
} ***SDAI***
- Duplex (XDD)
- New waveform
- Multiple access
- Massive MIMO

- SW simulation platform：New AI、New NA、New evaluation criteria, Link/System
- HW evaluation platform：Massive MIMO（SmarTile）、SDAI、Full-duplex

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5G RAN Framework: NMC + SDAI

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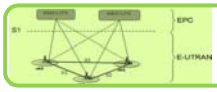
5G — NMC (UCN) + SDAI

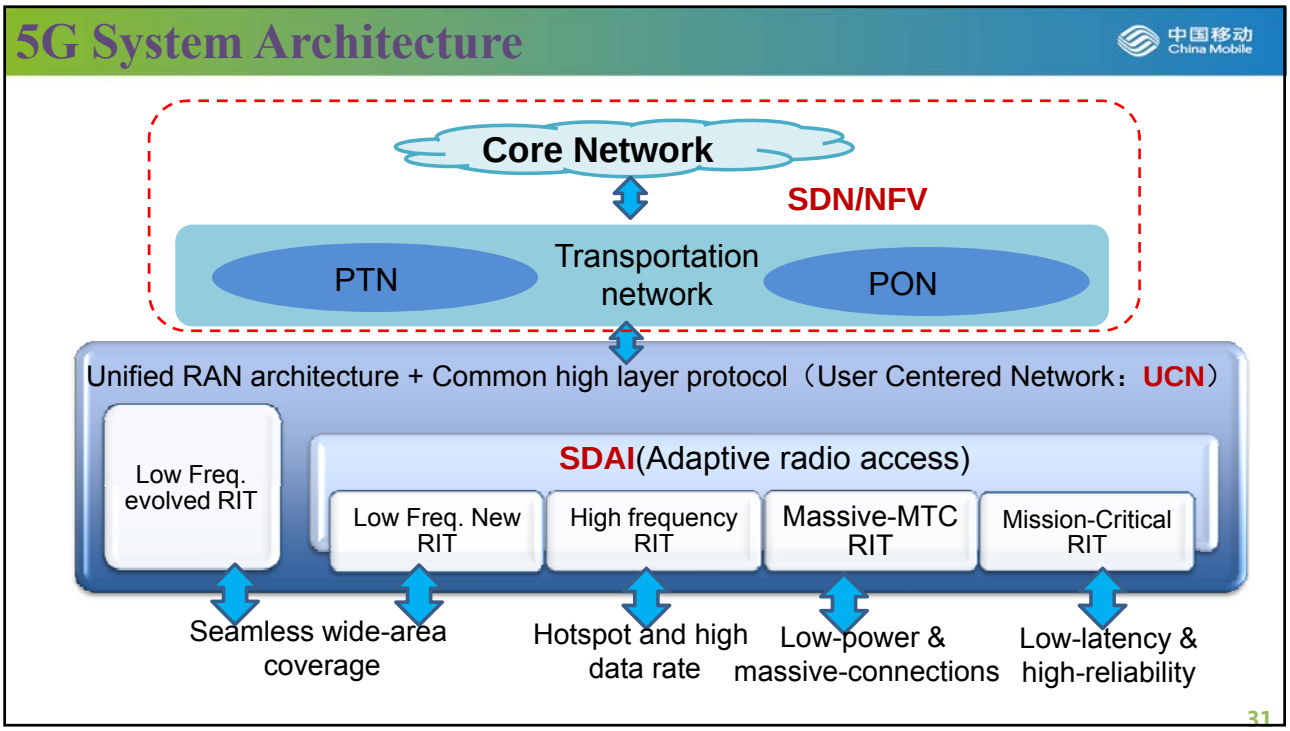
4G —  OFDM + MIMO

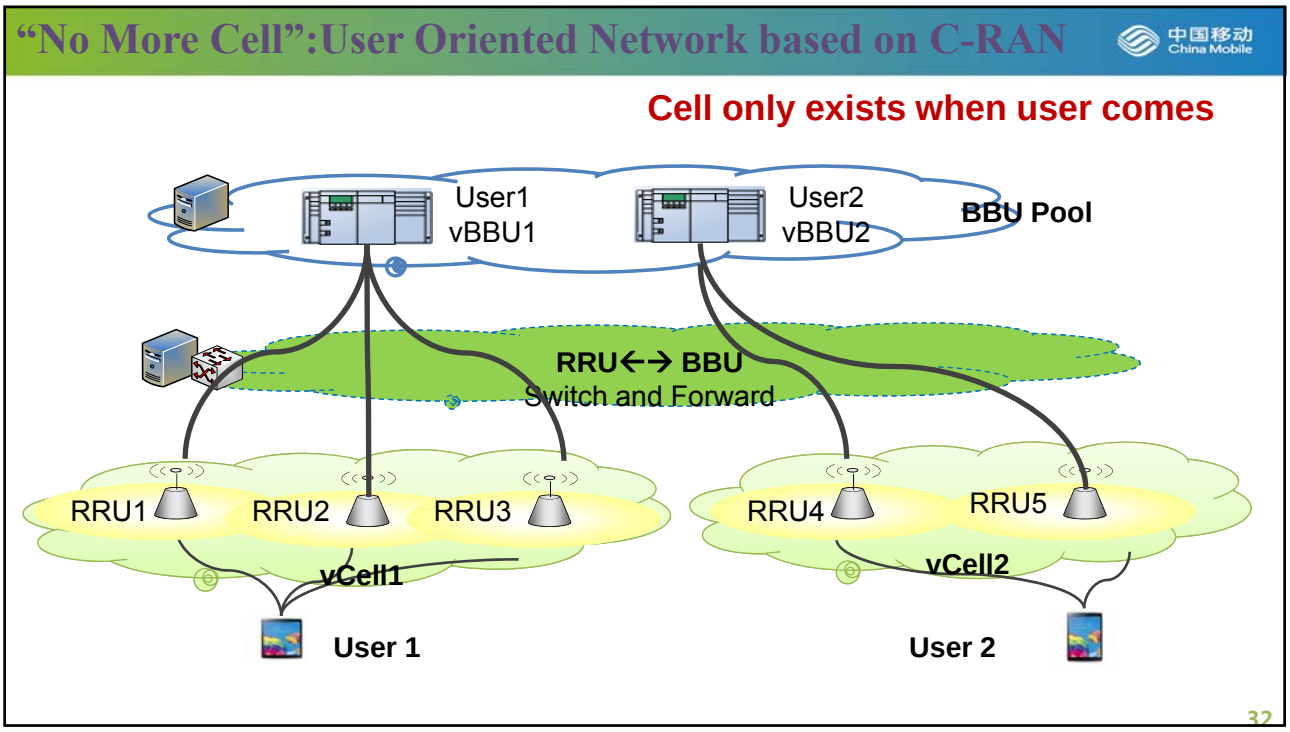
3G —  CDMA

2G —  TDMA

NMC: No More “Cell”
SDAI: Software Defined Air Interface

30


5G System Architecture
中国移动 China Mobile
Core Network
SDN/NFV
PTN
Transportation network
PON
Unified RAN architecture + Common high layer protocol（User Centered Network：UCN）
Low Freq. evolved RIT
SDAI(Adaptive radio access)
Low Freq. New RIT
High frequency RIT
Massive-MTC RIT
Mission-Critical RIT
Seamless wide-area coverage
Hotspot and high data rate
Low-power & massive-connections
Low-latency & high-reliability
31


"No More Cell":User Oriented Network based on C-RAN
中国移动 China Mobile
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
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NFV: Telecom Meets IT

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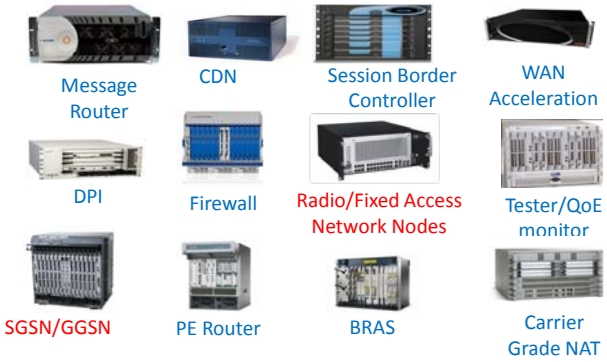
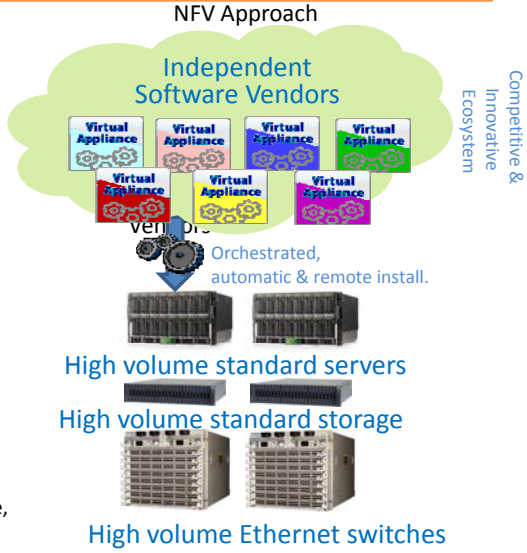
Proposed to extend NFV scope to include RAN

Classical Network Appliance Approach



NFV Approach



- More than 240 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 11 ISG-level documents to the industry, including architecture, use cases, terminologies, requirements, etc.
- Phase 1 finished, now under phase 2

Source: ETSI NFV ISG

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C-RAN Virtualization Architecture Evolution

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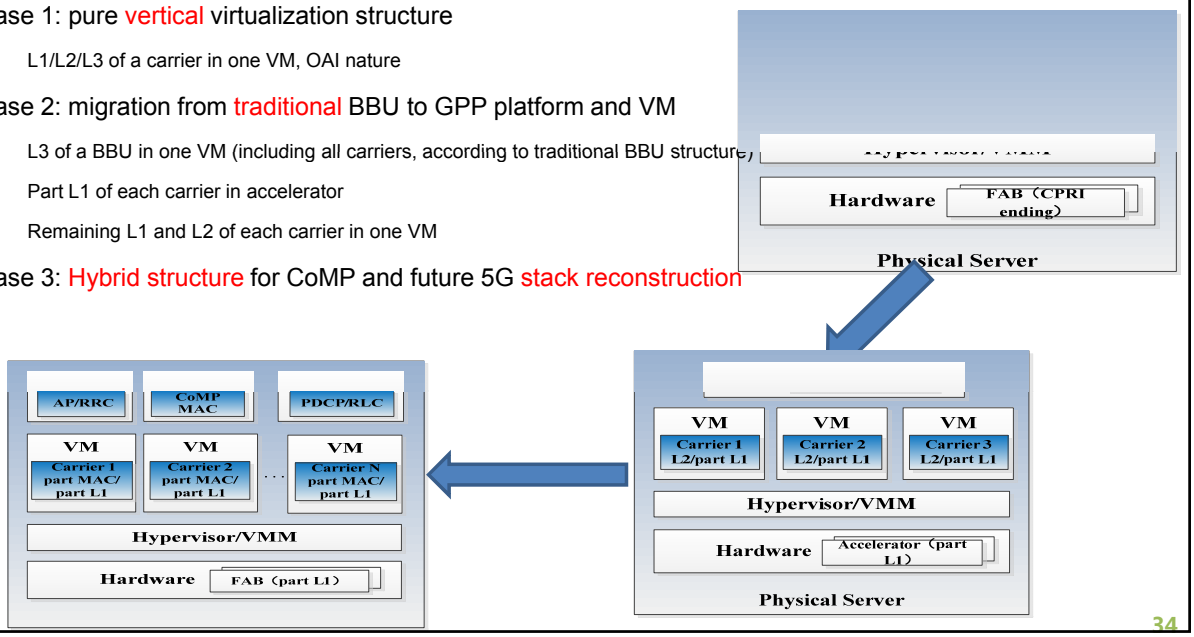
- Phase 1: pure vertical virtualization structure
  - L1/L2/L3 of a carrier in one VM, OAI nature
- Phase 2: migration from traditional BBU to GPP platform and VM
  - L3 of a BBU in one VM (including all carriers, according to traditional BBU structure)
  - Part L1 of each carrier in accelerator
  - Remaining L1 and L2 of each carrier in one VM
- Phase 3: Hybrid structure for CoMP and future 5G stack reconstruction



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C-RAN prototype: LTE VM-based L1+L2+L3 Live Migration

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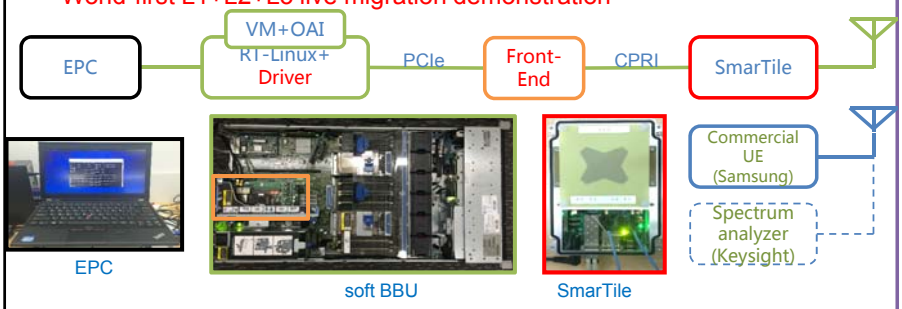
World-first L1+L2+L3 live migration demonstration



- 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

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SW Architecture Redesign of C-RAN Cloud Platform

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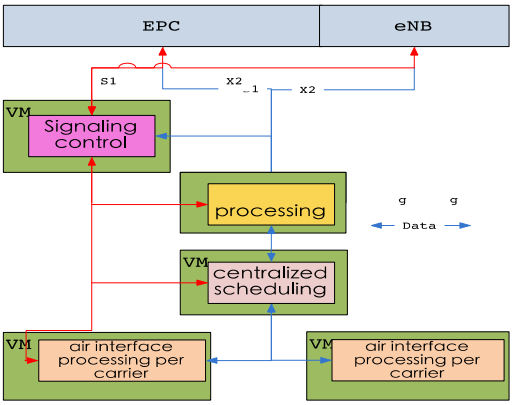
- Cloud platform brings great new possibilities with the ideally infinite capability and scalability by virtualization
- However, it requires redesigning SW architecture to exploit the potential

- Traditional SW architecture is not future-proof
  - Carrier as the basic processing unit
  - "Hard" nature: a small number of carriers for each channel card
  - Limited support for cell coordination
  - Poor support for 5G's "softness"
- Design principle
  - Scalability: to accommodate more carriers
  - Performance: in support of 5G tech.
  - Flexibility: to accommodate "No More *Cells*"
  - Multi-network support: basic architecture for SDAI (Software-defined air interface) realization

- Some ideas on the SW architecture for LTE in virtualization environment
  - Signaling control VM
  - Packet processing VM
  - Centralized scheduling VM
  - Air interface processing VM



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NGFI (Next Generation Fronthaul Interface)

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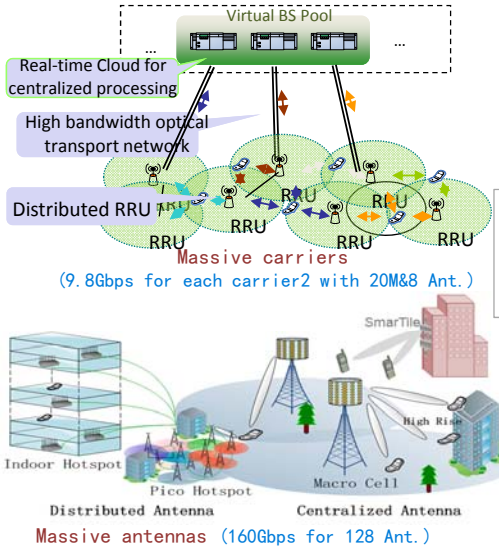
Challenges for future interface/transport network



CPRI →NGFI

P2P connection
Low-efficiency,
High consumption,
Inflexibility

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 WG
  (2-3 Jun in Beijing hosted by CMCC)
- Latency enhancement , TSN
- Synchronization, IEEE 1588WG & ITU-T

1st NGFI WS will be co-located on 4. June

ITU IEEE Advancing Technology for Humanity ngmn CCSA

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Software Defined Air Interface (SDAI)

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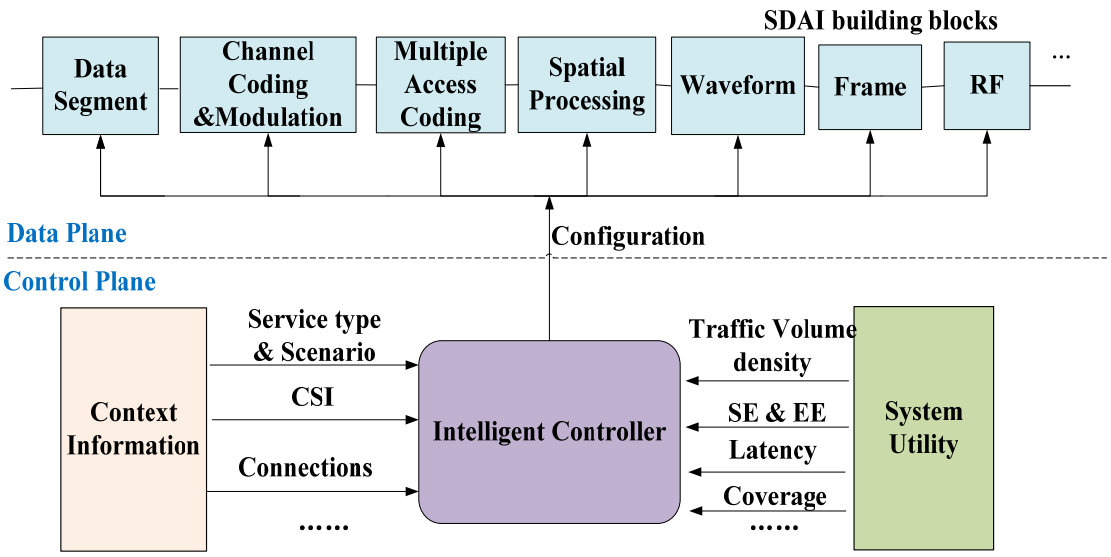

"Software Defined Air Interface: A Framework of 5G Air Interface" IEEE WCNC2015

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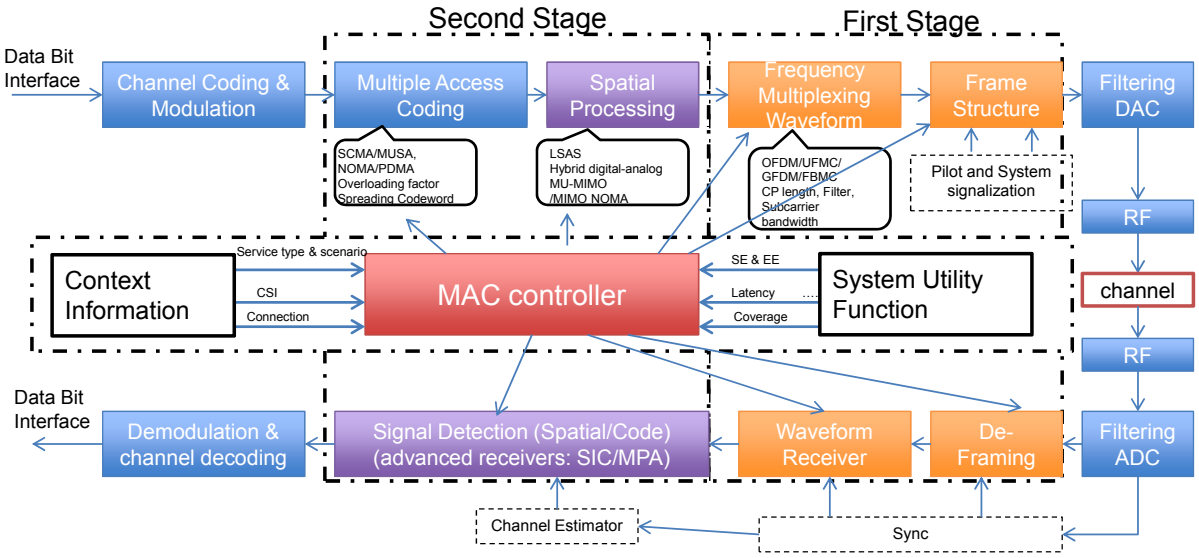
Demo SDAI Concept Step by Step (Target MWC2016)



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5G Standard ≠ 5G Era: 3GPP/ITU, IEEE, IETF, etc

Towards a collaborative 5G Era

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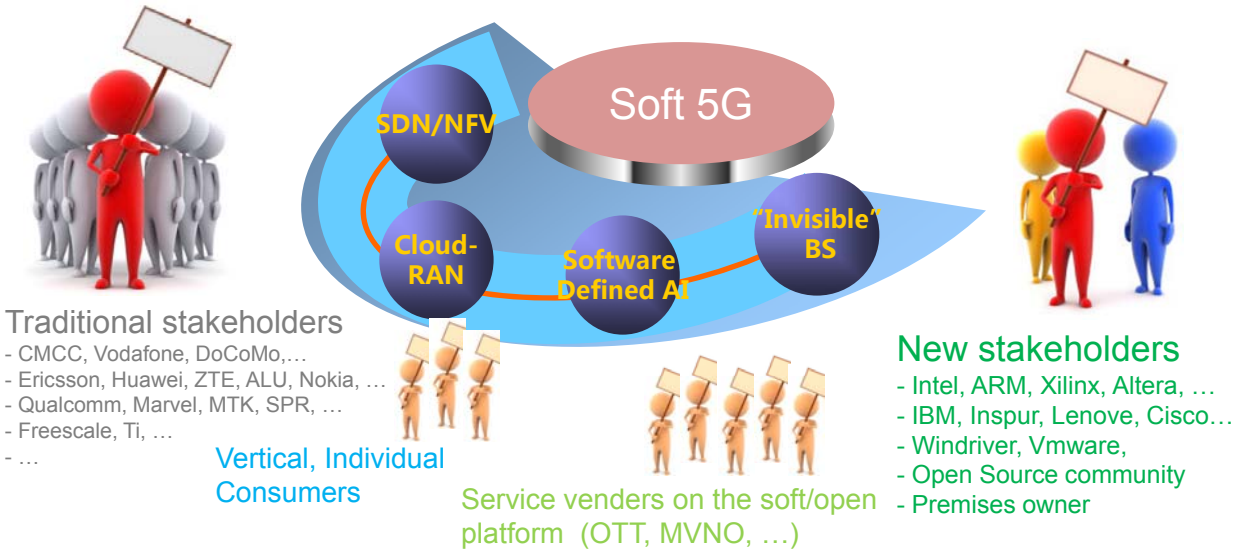
A New Eco-System for 5G



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Summary

- Mobilized & Connected: Internet & IoT or Industry 4.0 & Internet+
- KPIs: Performance + Efficiency/Agility
  - Themes: Green, Soft, and Super Fast
  - Technology Pearls: Rethink Fundamentals
- CMCC 5G Framework: SDN/NFV, NMC(UCN)+SDAI
- CMCC Strategic R&D Topics:
  - Greener & Softer Network (MWC2014)
  - Virtualized C-RAN (MWC2015)
  - LSAS with SmarTile (MWC2015)
  - NGRI/NGFI *(MWC2016)*
  - SDAI *(MWC2016)*

New Era → New Service & New Technologies &New Business Models! → New Eco-system

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Thank you!

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