台灣資通產業標準協會
Taiwan Association of Information and Communication Standards

ITRI
Industrial Technology Research Institute

3GPP Progress Toward 5G: Technology Trends and Standard Activities

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2016/03/29@3GPP Rel-13國際標準最新動態分享會

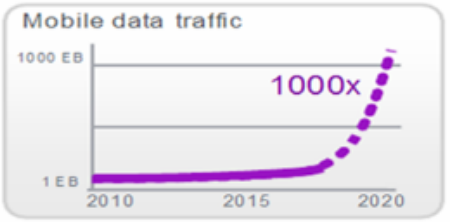
Outline

- 5G requirement and use cases
- 3GPP Progress Toward 5G
- Summary

5G行動通訊網路的挑戰與需求

行動應用驅動頻寬需求
Ultra HD (4K、8K…)

行動數據流量急速成長
2020年後將成長1000倍



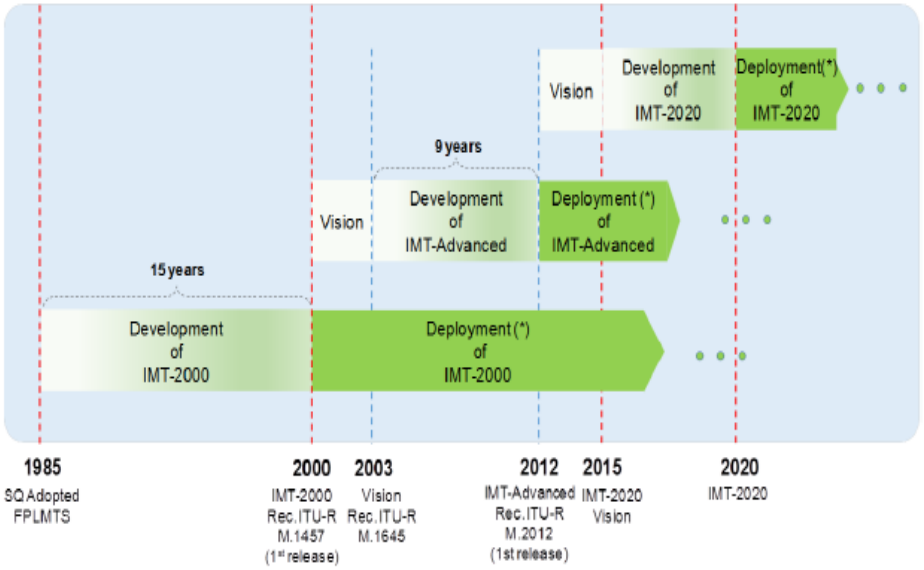
連網終端數量大幅度增加
2020年後將達500億

能源及頻譜使用效益低
2020年需求達10倍

大頻寬　大連結　高傳輸　高容量　低延遲　低功耗

International Telecommunication Union (ITU)

- **ITU is the United Nations specialized agency for information and communication technologies – ICTs.**
  - We allocate global radio spectrum and satellite orbits, develop the technical standards that ensure networks and technologies seamlessly interconnect, and strive to improve access to ICTs to underserved communities worldwide.



Timeline for IMT development and deployment

Source:
http://www.itu.int/en/about/Pages/overview.aspx

ITU 5G 系統需求

- **ITU 5G 系統八大需求規範 (2015 June)**

Expected to reach 10 Gbit/s and support up to 20 Gbit/s

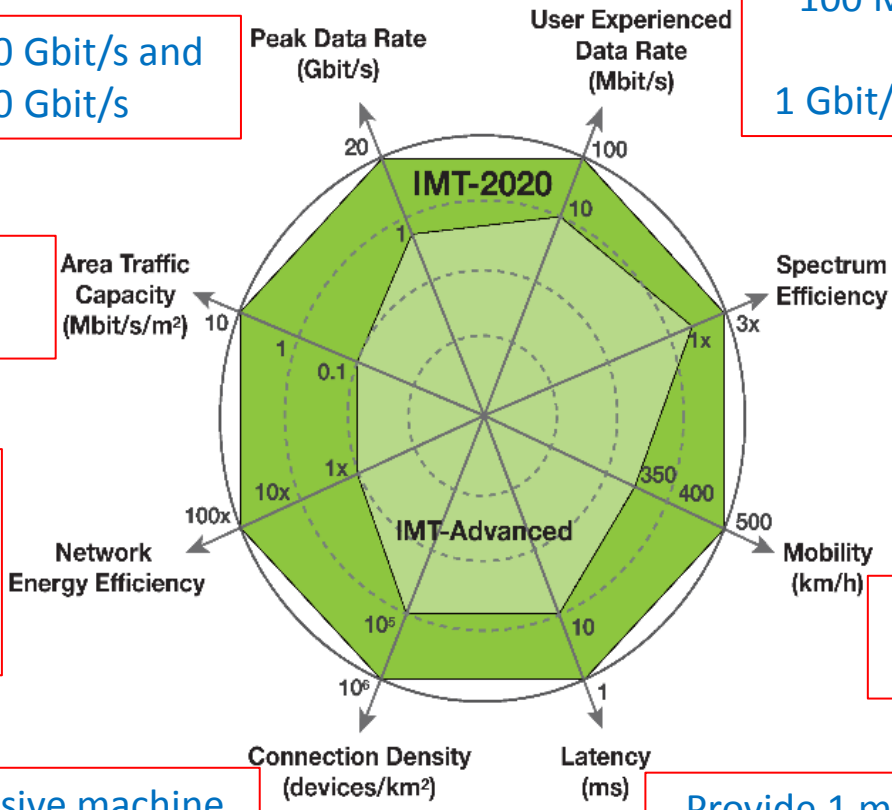
100 Mbit/s is expected in urban and suburban
1 Gbit/s can be reached in hotspot

10 Mbit/s/m² area traffic capacity in hotspot

3 times higher compared to IMT-Advanced
5 times subject to further research

Should not be greater than current IMT networks while delivering other enhanced capabilities

enable high mobility up to 500 km/h with acceptable QoS



up to 10^6 /km² in massive machine type communication scenario

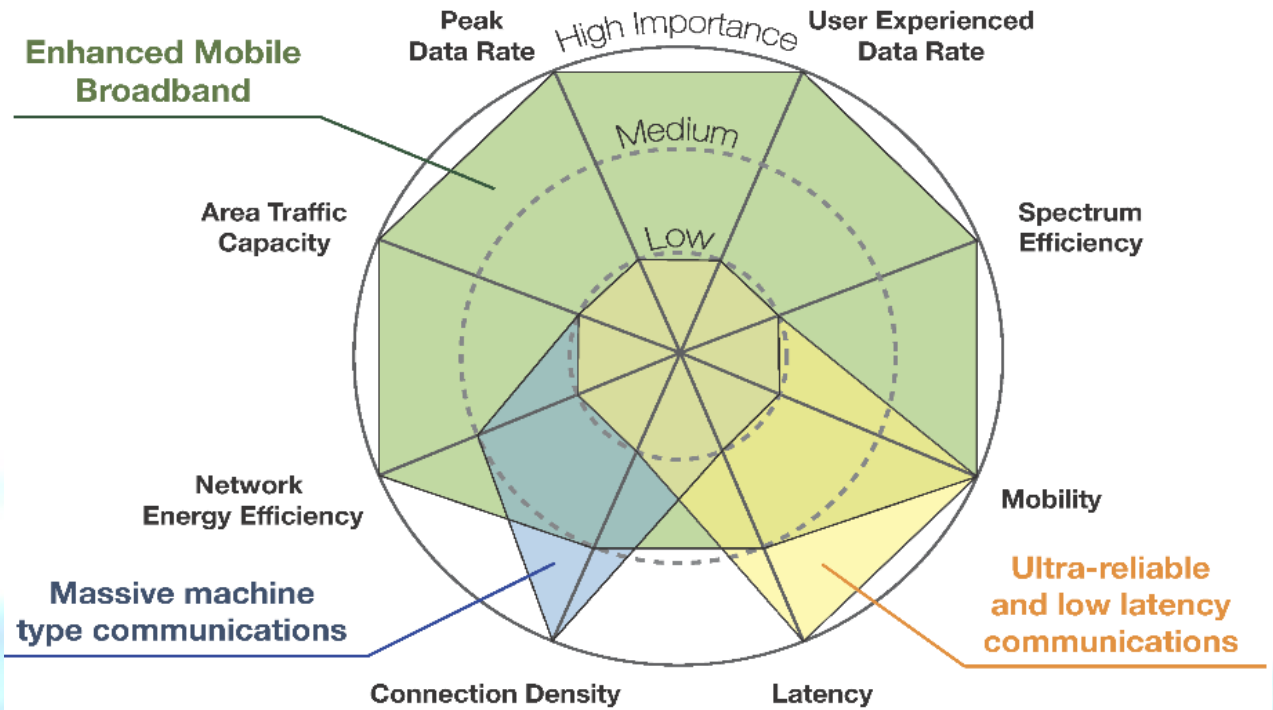
Provide 1 ms over-the-air latency

*4G: IMT-Advanced

Source: WP5D #22, June 2015

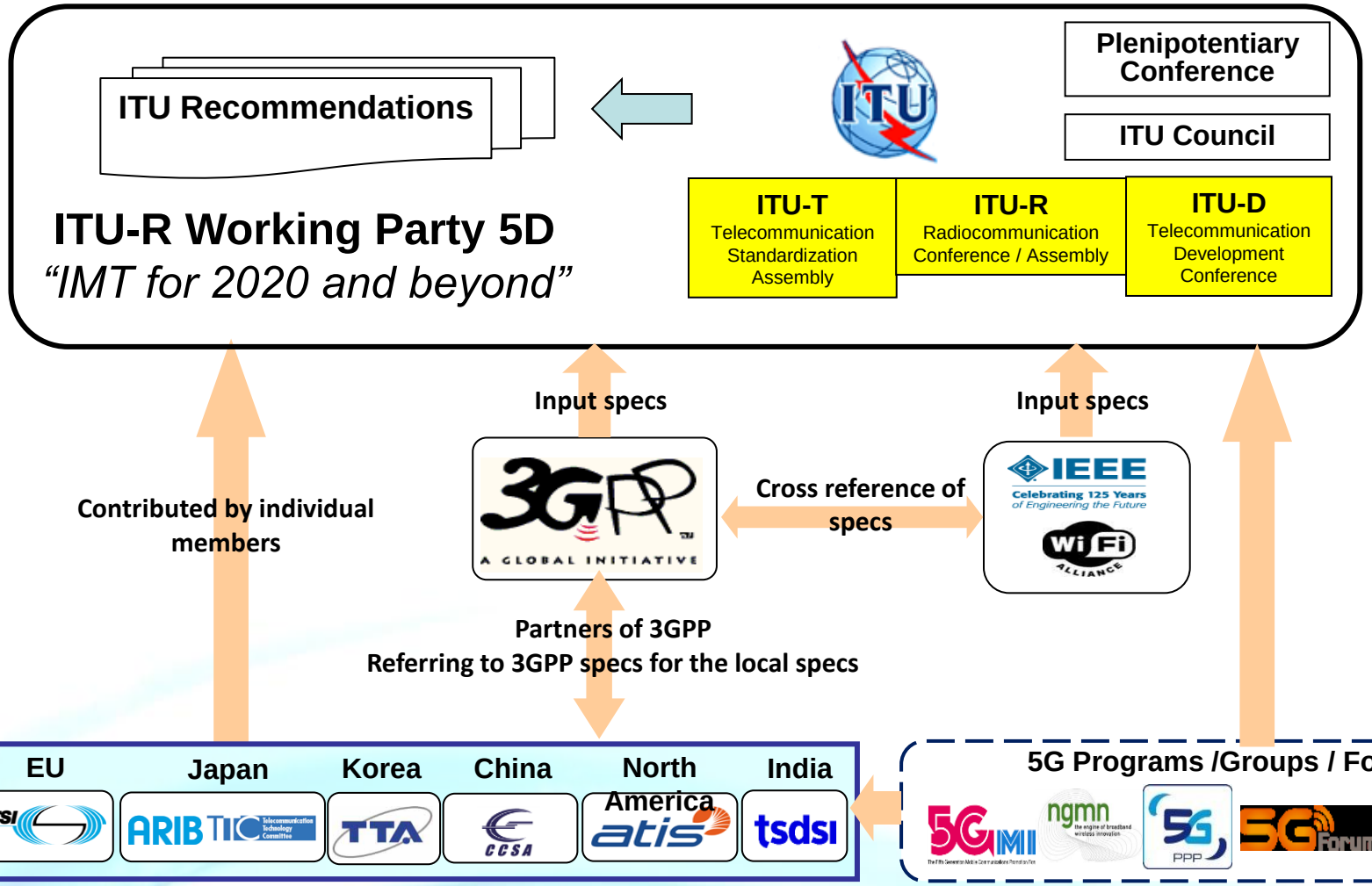
IMT-2020 應用需求

- 三大應用需求
  - 超大頻寬上網 (xBB: Extreme Mobile Broadband)
  - 巨量通訊 (mMTC: Massive Machine Type Communication)
  - 超可靠/低延遲通訊 (uRC: Ultra-reliable low latency Comm.)



Source: WP5D #22, June 2015

Standardization Organizations



- **5G requirement and use cases**
  - 5G Use Cases/Scenarios
    - From Organization
    - From Industrial

5GPPP (Europe)

Source: RWS-150007

5G-PPP leveraging EU Framework Program 7 results
Individual and independent projects

METIS
Mobile and wireless communications Enablers for Twenty-twenty (2020) Information Society

5GNOW
5th Generation Non-Orthogonal Waveforms for Asynchronous Signalling

iJOIN
Interworking and JOINt Design of an Open Access and Backhaul Network Architecture for Small Cells based on Cloud Networks

3

Tropic
DisTributed computing, storage and radio resource allocation over cooperative femtocells

MiWaveS
Beyond 2020 **Heterogeneous Wireless Networks** with **Millimeter-Wave Small Cell** Access and Backhauling

PHYLAWS
PHYsical LAyer Wireless Security

Combo
COnvergence of fixed and Mobile BrOadband access/aggregation networks

MOTO
Evolving MObile internet with innovative terminal-To-terminal Offloading technologies

MCN
Mobile Cloud Networking

11/01/2016 3GPP RAN 5G Workshop, 17.-18.9.2015 3

Source: 5G Infrastructure Association.

NGMN (Europe)

Source: RWS-150088

ngmn
the engine of broadband wireless innovation

5G supports a wide range of services

Overview 5G Use Case Families and Use Case Examples

Focus of today's presentation (eMBB use case families)

Broadband access in dense areas	Broadband access everywhere	Higher user mobility	Massive Internet of Things
PERVASIVE VIDEO 	50+ MBPS EVERYWHERE 	HIGH SPEED TRAIN 	SENSOR NETWORKS 

Other use cases requirements are subject to discussions with verticals

Extreme real-time communications	Lifeline communications	Ultra-reliable communications	Broadcast-like services
TACTILE INTERNET 	NATURAL DISASTER 	E-HEALTH SERVICES 	BROADCAST SERVICES 

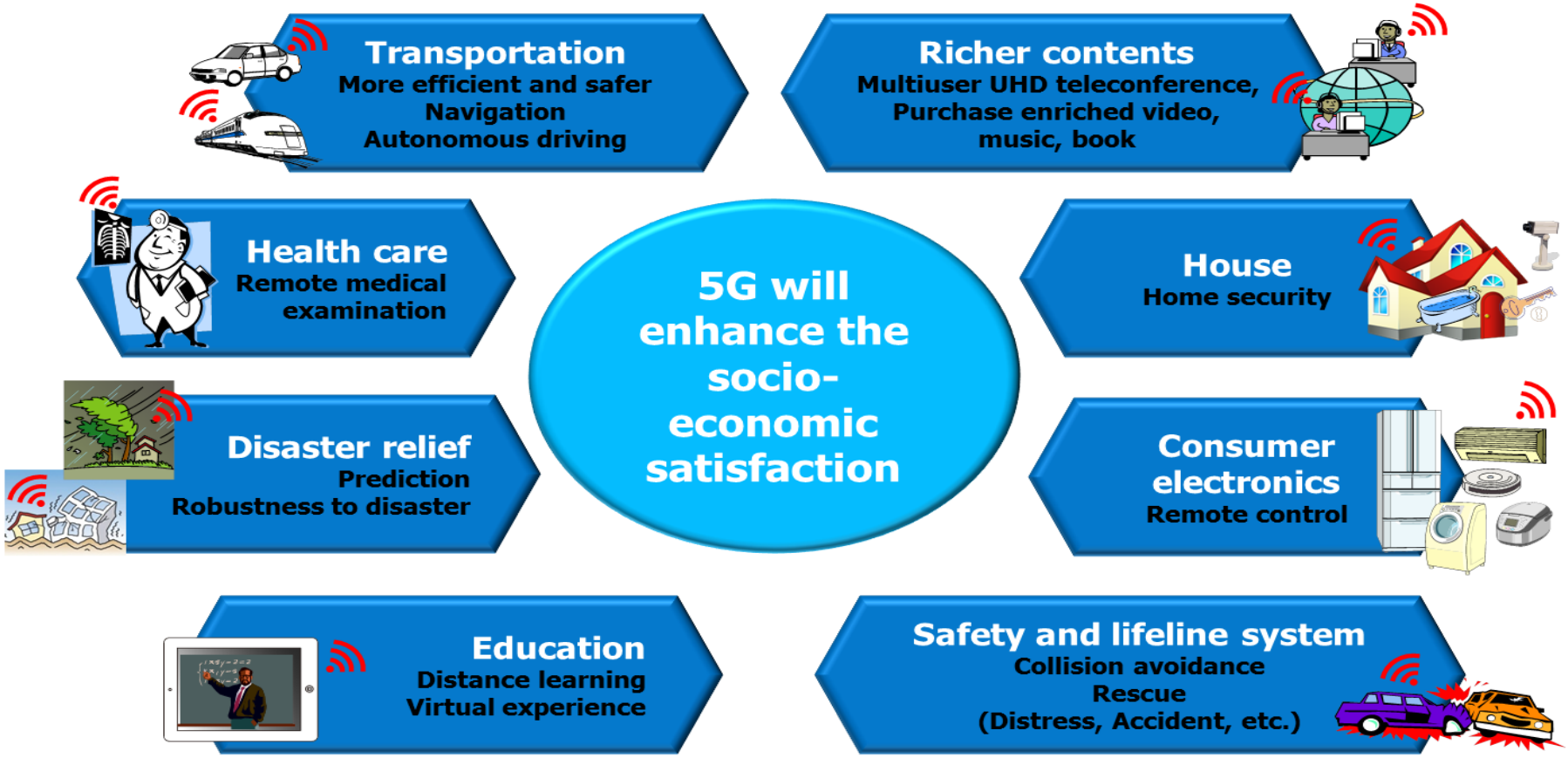
See the NGMN 5G White Paper for a detailed list of all NGMN use cases

5GMF (Japan)

Source: RWS-150081

5GMF
The Fifth Generation Mobile Communications Promotion Forum

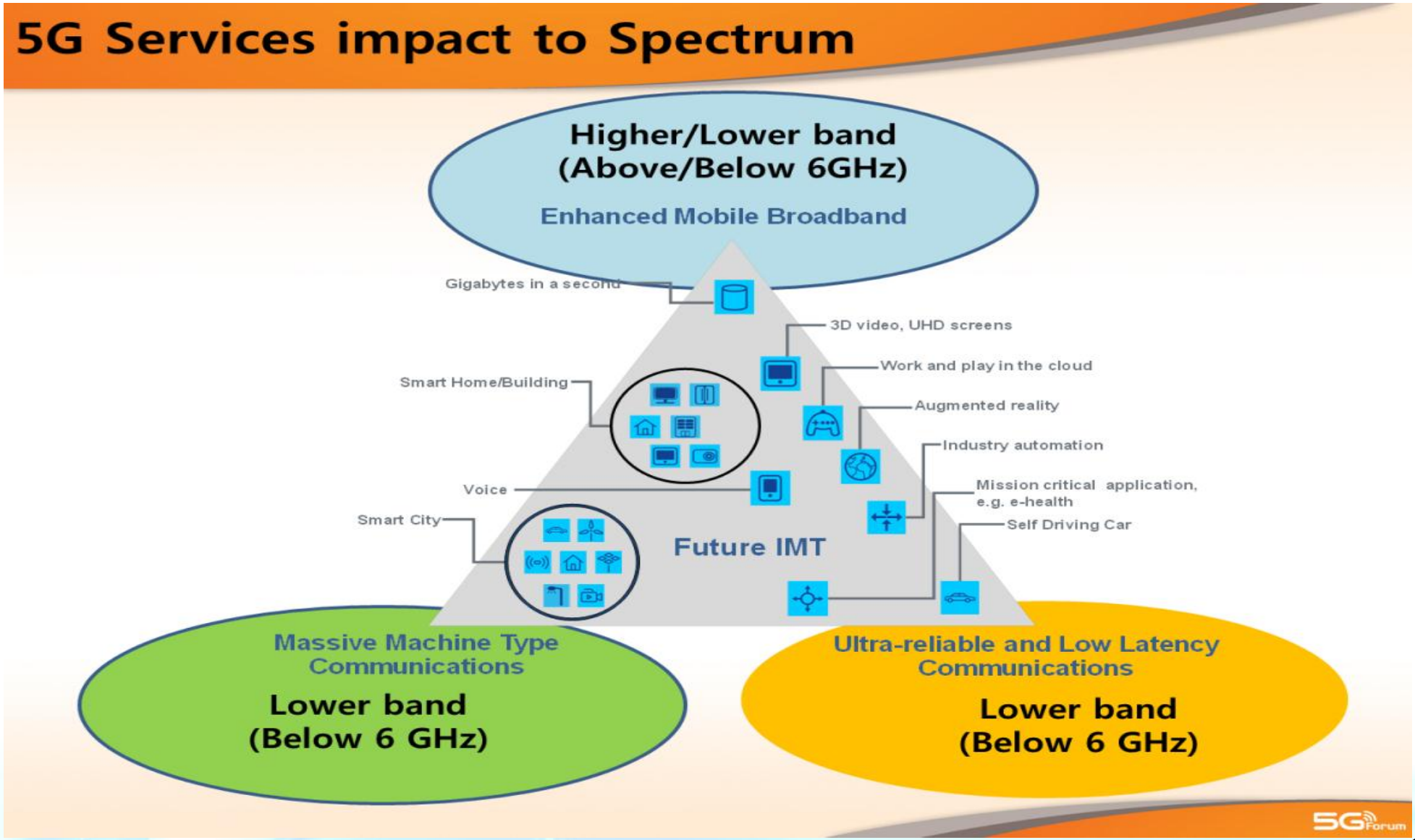
Typical usage scenarios of 5G



"Mobile Communications Systems for 2020 and beyond", ARIB 2020 and Beyond Ad Hoc Group White Paper, October 2014.

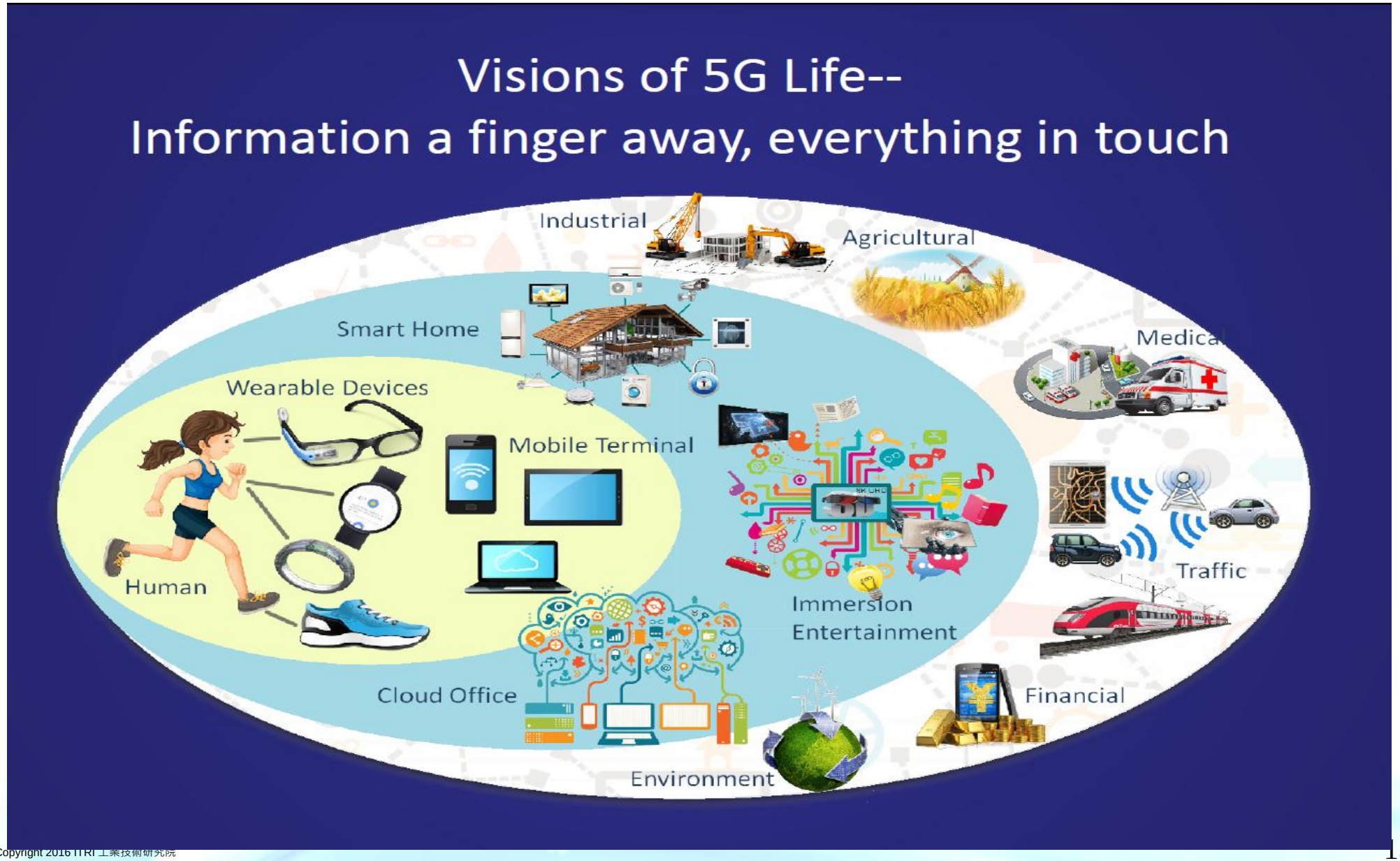
5G Forum (Korea)

Source: RWS-150055



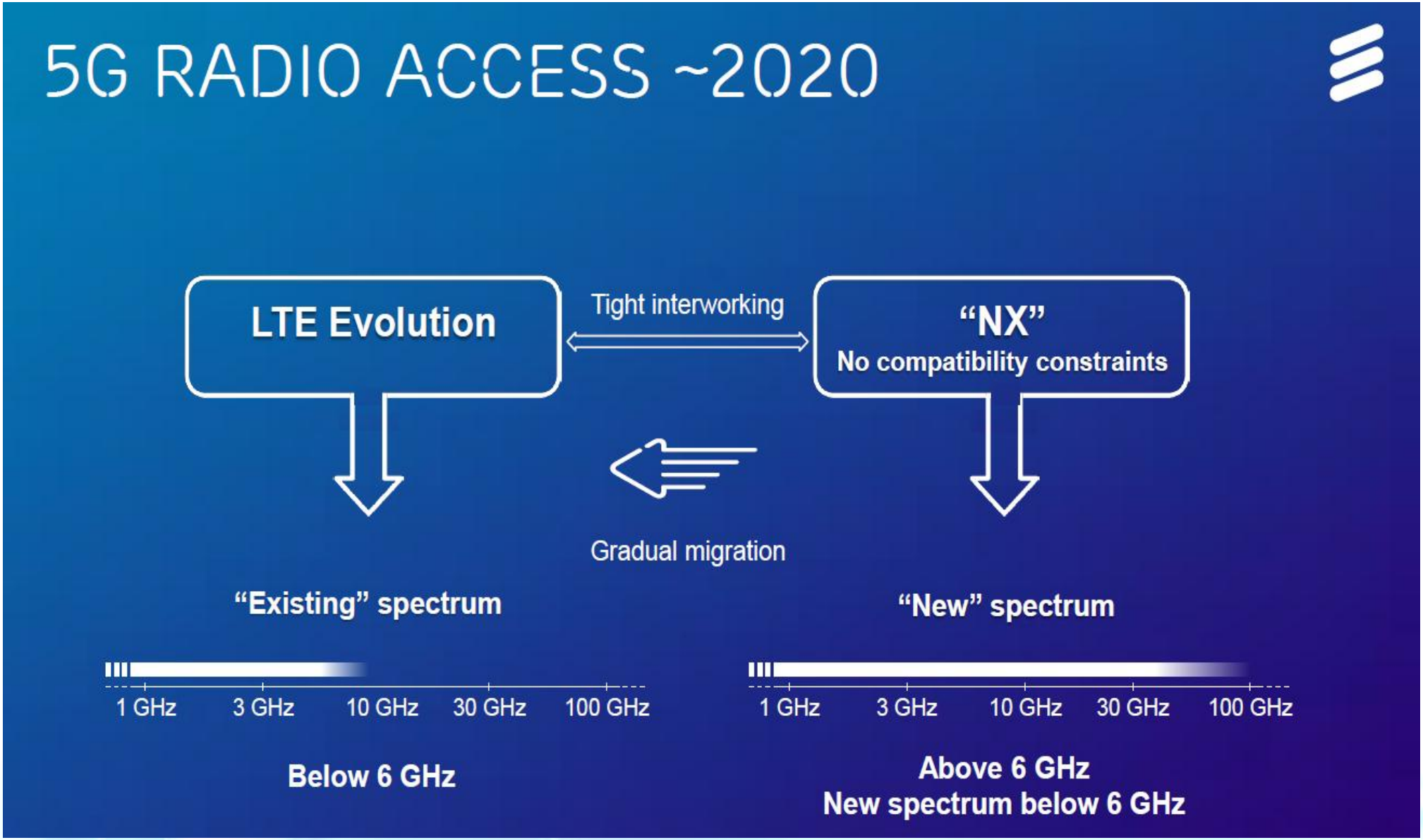
IMT-2020 (Mainland China)

Source: RWS-150050

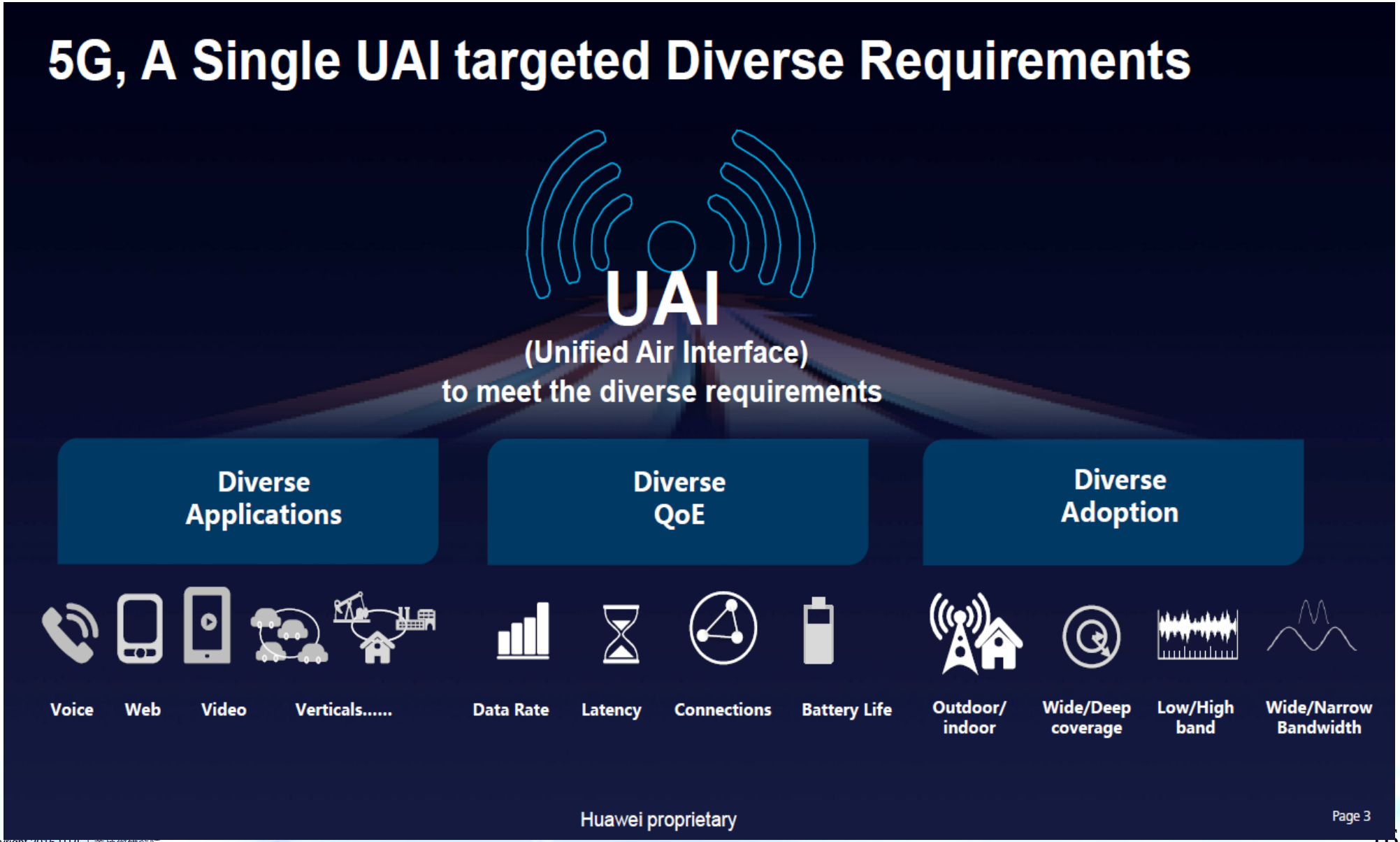


- **5G requirement and use cases**
  - 5G Use Cases/Scenarios
    - From Organization
    - From Industrial

Source: RWS-150009



Source: RWS-150006



Source: RWS-150010

5G multi-service architecture

5G Radio Interf. (RI) Multi-connectivity
5G – LTE Tight integration
Multi-Dual Connectivity require anchor point

Common Core Network

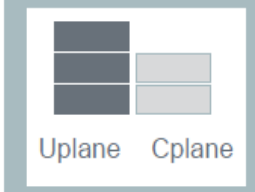
Diverse deployment scenarios depending on available xhaul

Any xhaul

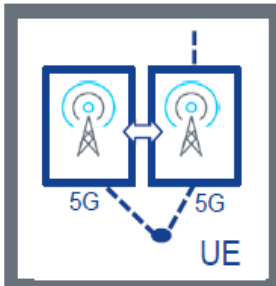
QoE for Traditional, verticals and dynamic application-aware QoE for OTT

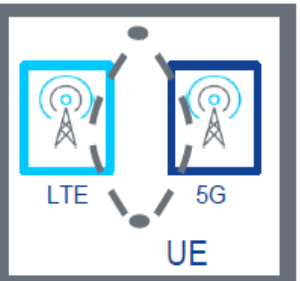
Enhanced QoS-QoE

Flexible scalability of functions:
C/U Plane, Cell/UE related
Load-adaptive scaling



Elasticity





Multi connectivity

Flexible, programmable multi-service architecture

Qualcomm

Source: RWS-150012

5G mobile broadband: scenarios & phasing

From LTE to 5G: multi-connectivity framework for licensed & unlicensed

NTT DoCoMo

Source: RWS-150051

Network/Communication Society in 2020 and Beyond

NTT docomo

Everything connected by wireless

Monitor/collect information & control devices

Multiple personal devices

Interaction across multiple devices

Transportation (Car/Bus/Train)

Entertainment, Navigation
Traffic information

Consumer electronics

Remote operation using personal terminal

Watch/jewelry/cloths

Human interface (HI) and healthcare sensors

House

Remote control of facilities
House security

Sensors

Smart power grid
Agriculture and farming
Factory automation
Weather/Environment

Cloud computing

ドコモクラウド

All kinds of services supported by the mobile personal cloud

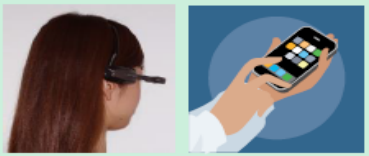
Extension/enrichment of wireless services

Deliver rich content in real-time & ensure safety

Video streaming

4K/8K video resolutions
Video on newspapers
Background video

New types of terminal/HI



Glasses/Touch Internet

Healthcare

Remote health check & counseling

Education

Distance (remote) learning
Any lesson anywhere/anytime

Safety and lifeline system

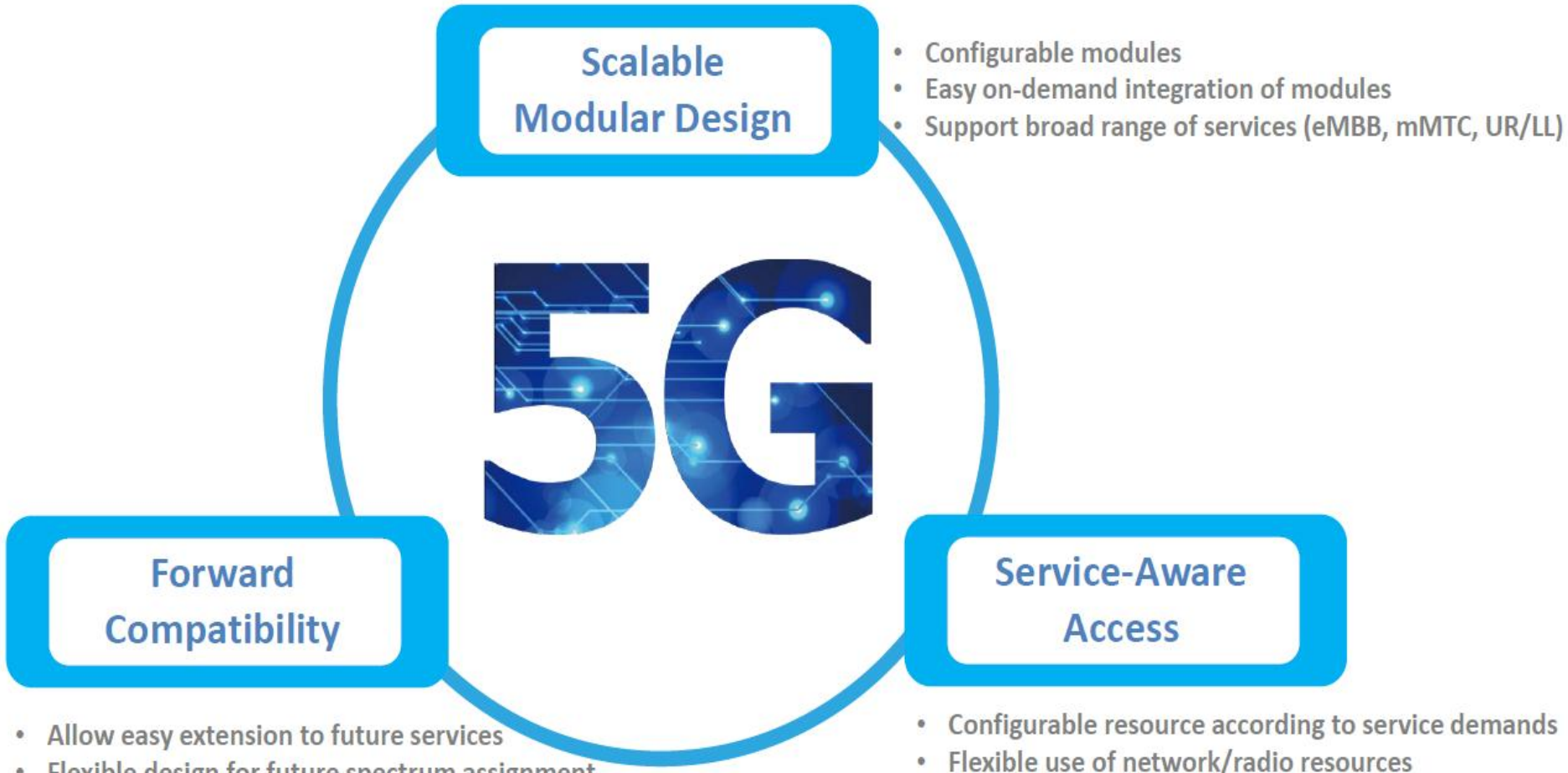
Prevention of accidents
Robustness to disasters

Samsung

Source: RWS-150039

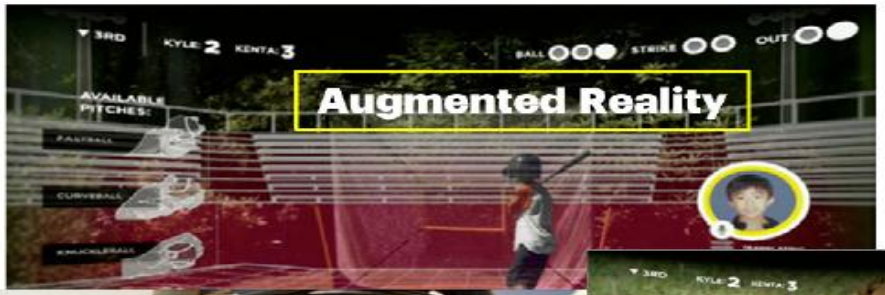
5G Design Principle

SAMSUNG



Source: RWS-150066

5G: Seamless Information Interactions



"It Takes A Network™"

See Sprint Autobahn Connected Lifestyle Video
https://www.youtube.com/watch?v=P5souMYIlhY

Mobile 2-Way Video

Remote Security/ Entry Authorization

Sony

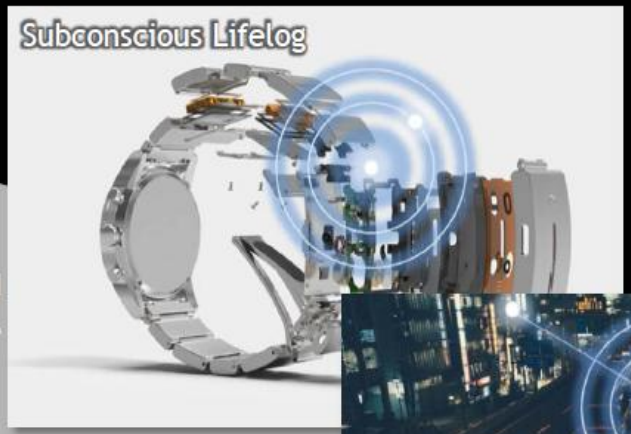
Source: RWS-150068

5G - Key to a BE MOVED Experience

SONY

Sony's mission is to continue delivery of a MOVING experience to our customers

5G is expected to be the cornerstone to achieve our mission



Enhanced Usability

Extreme Quality

Unlimited Connectivity

RWS-150068

NTT DoCoMo奧運5G網路示範規劃

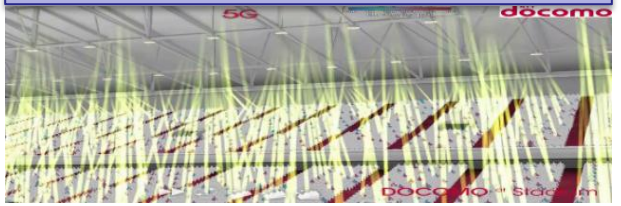
- **展示環境與網路: 巨蛋超高密度網路**
  - 16個 LTE-A小型基站 ，5G UDN 佈建技術
    - 使用技術 LTE-A ➔ 1 GHz Bandwidth (mmWave or LAA ?)
    - 4 Sectors x 2.2 Gbps; 每個小型基站能力: 8.8 Gbps
    - 系統總容量: 16 * 8.8 = 140.8 Gbps
- **展示目標**
  - 巨蛋中每區塊內14,000 人，同時上網的1,400人(使用率10%)
    - 每人平均享有 140.8 Gbps/1,400 = 100 Mbps

資料來源：NTT DoCoMo；工研院IEK(2015/09)

模擬環境：體育場每一區塊(140公尺x70公尺)，可容納14,000人

假設條件
- 假設有10%使用中的用戶基礎 ➔ 同時上網人數: 1,400 人
- 16台small Cells，使用LTE-A, 使用使用1GHz頻寬
- 利用密集的天線陣列，提升小基站每個 sector 通訊能力至2.2 Gbps
- 每個小基站配至四個sectors增加密度、每個小基站能力提升至8.8 Gbps

利用Massive-MIMO和天線陣列內的128偏振元件，加上窄波束傳輸給每個用戶



任何人皆可以4K視頻點播，收看奧運場館的現場畫面

Outline

- 5G requirement and use cases
- 3GPP Progress Toward 5G: Technology Trends
  - Technology Trends
    - PHY aspects
    - RAN aspects
    - Network aspects
  - 3GPP's 5G Timeline
- Summary

New Marker: LTE-Advanced Pro

- **3GPP has approved a new LTE marker that will be used for the appropriate specifications from Release 13 onwards. (*October 28, 2015*)**
- **The major advances achieved with the completion of Release 13 include: MTC enhancements, public safety features – such as D2D and ProSe - small cell dual-connectivity and architecture, carrier aggregation enhancements, interworking with Wi-Fi, licensed assisted access (at 5 GHz), 3D/FD-MIMO, indoor positioning, single cell-point to multi-point and work on latency reduction.**

Source: http://www.3gpp.org/news-events/3gpp-news/1745-lte-advanced_pro

5G PHY

Air Interface

- Flexible Duplex
- Coding
- New Frame Structure
- Modulation
- Novel Multiple Access
- Lean Carrier
- In-band full duplex

mmWave

- New RAT
- Dual Connectivity/CA
- Channel model

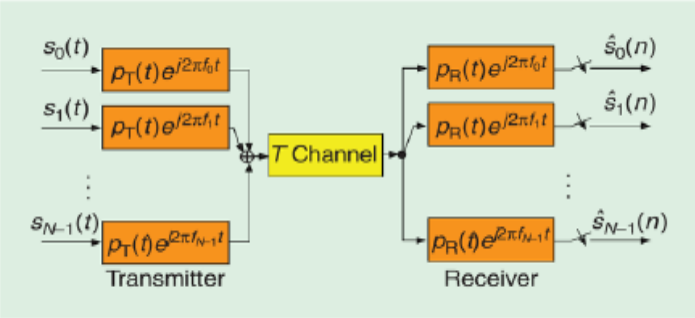
Massive MIMO

- Beam-forming/Beam-tracking
- Distributed antennas

New Waveform

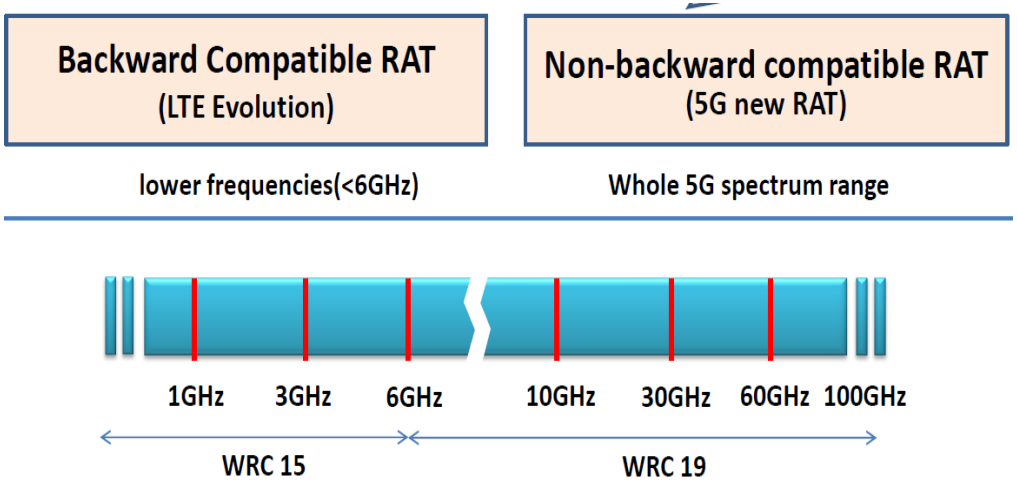
- OFDM-based with new numerology
- Filtered multi-carrier
- Single-carrier (high band)
- OTFS

mmWave

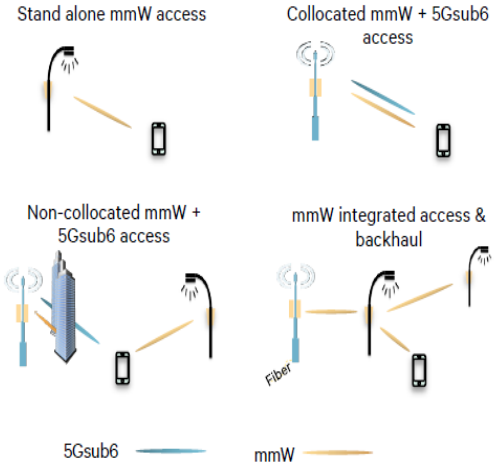


Behrouz Farhang-Boroujeny , "OFDM vs. Filter Bank Multicarrier" IEEE 2011

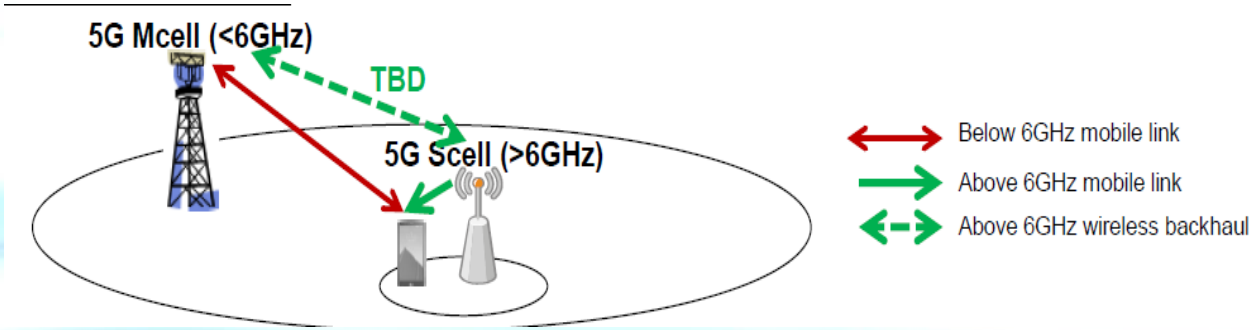
Source: RWS-150002



Source: RWS-150003

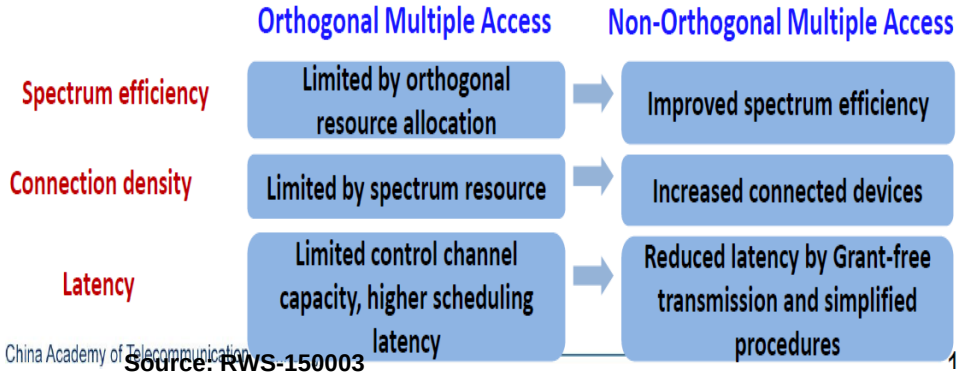


Source: RWS-150012

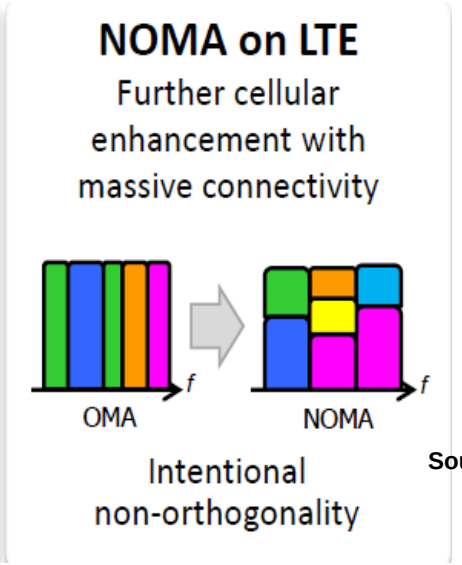


Source: RWS-150052

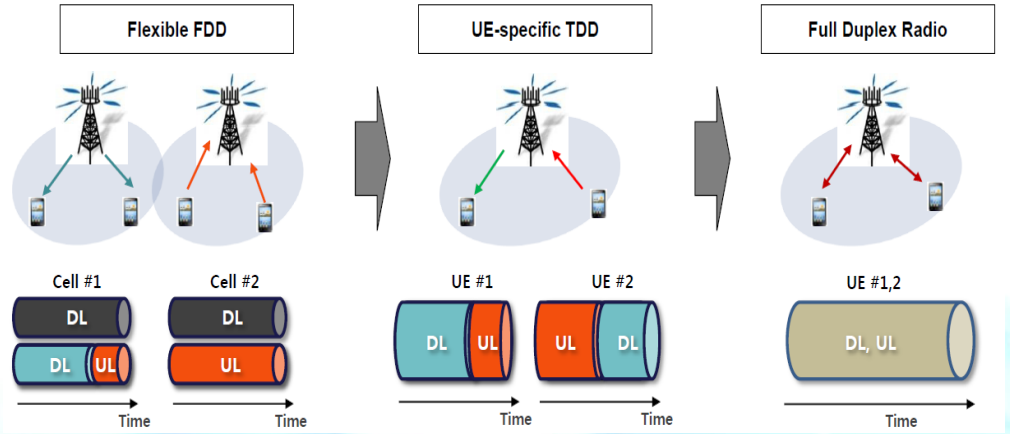
Air Interface



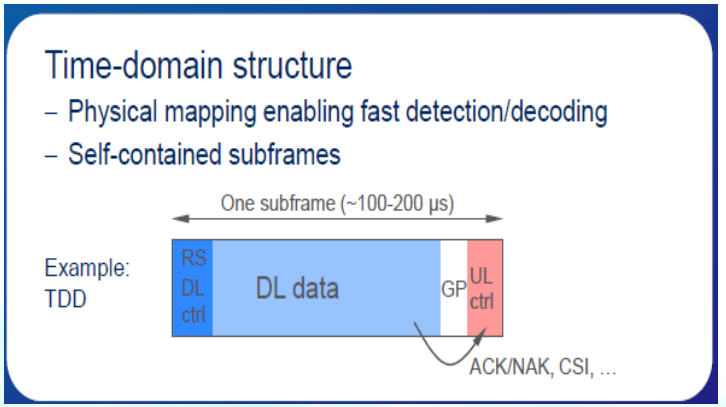
Source: RWS-150003



Source: RWS-150051



Source: RWS-150052

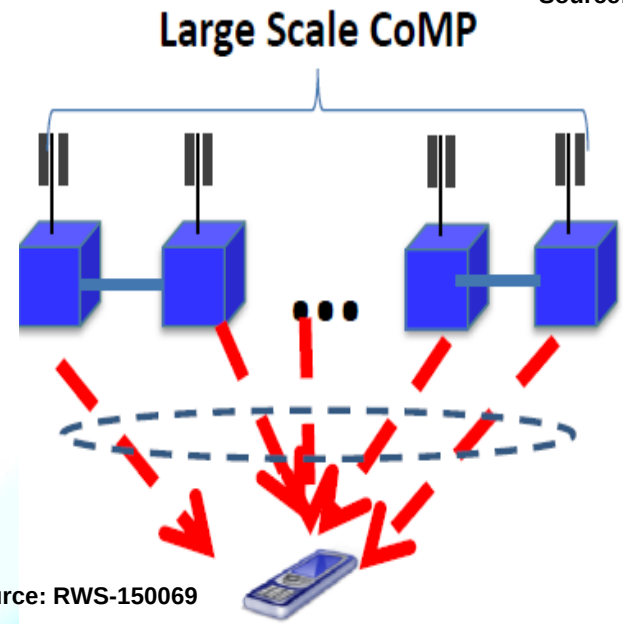


Source: RWS-150009

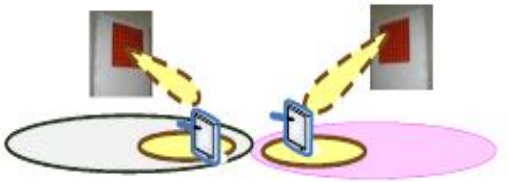
Massive MIMO

Beamforming

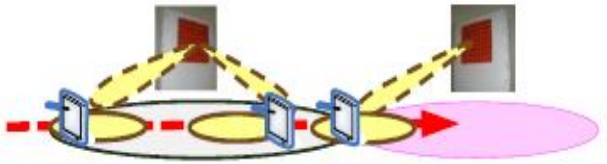
Source: RWS-150009



Source: RWS-150069



Inter-cell interference coordination,
Intra eNB CoMP

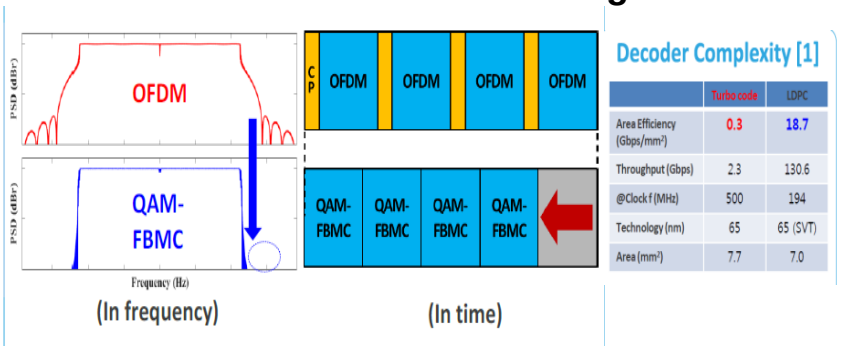


Mobility Control with beamforming, CoMP

Source: RWS-150018

New Waveform

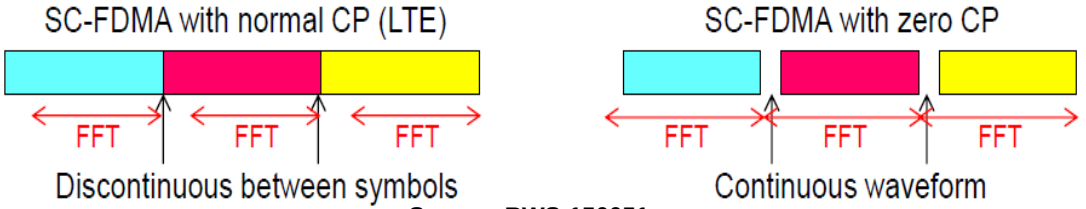
Modulation and Coding



Decoder Complexity [1]

	Turbo code	LDPC
Area Efficiency (Gbps/mm²)	0.3	18.7
Throughput (Gbps)	2.3	130.6
@Clock f (MHz)	500	194
Technology (nm)	65	65 (SVT)
Area (mm²)	7.7	7.0

Source: RWS-150039



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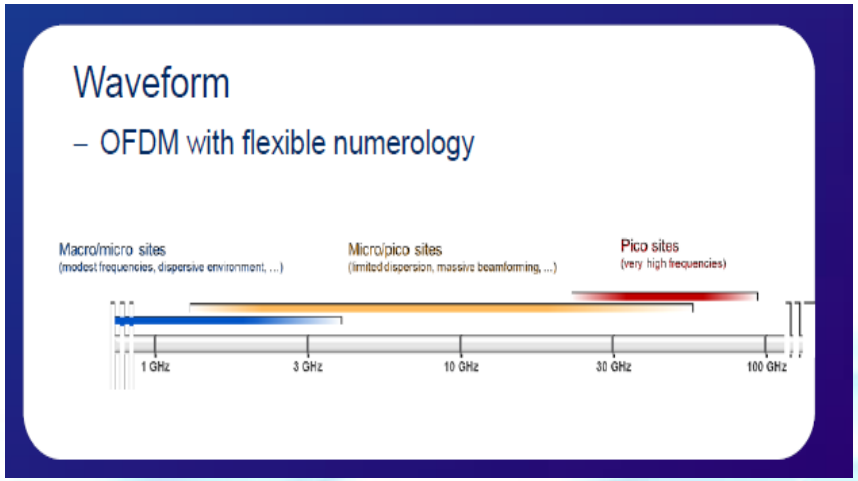
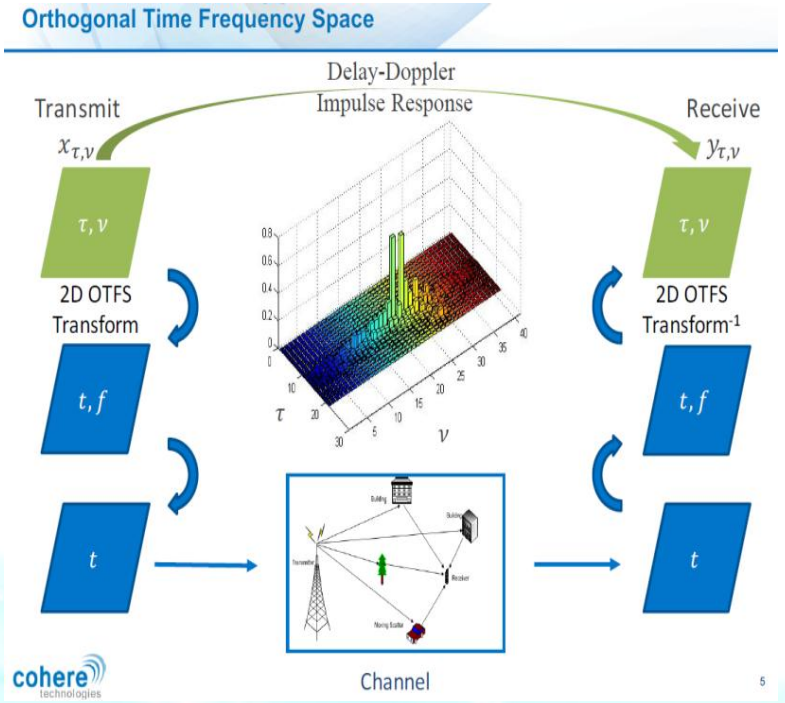


Source: RWS-150009



Source: RWS-150034

5G RAN

Latency Reduction

- Flexible TTI length
- Configurable TDD UL/DL switching
- Dynamic UL/DL subframe
- Configurable HARQ timing
- Fast access

Ultra-Dense Network

- UDN
- Cloud RAN
- Wireless Mesh Network

Multiple Connectivity

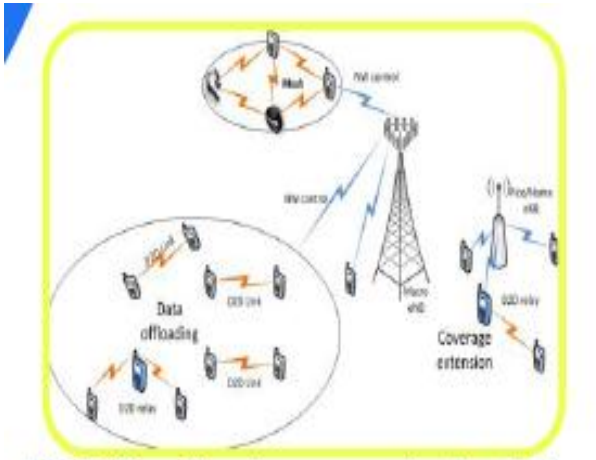
- Multiple-site/Node/RAT connectivity
- Unlicensed band/Shared band
- Device centric

LTE Enhancement

- New TDD configuration
- New Frame structure
- Flexible Duplex
- IoT
- Power/battery efficiency

LTE Enhancement

- **New TDD configuration**
  - 9:1:0; 10:0:0
- **New Frame structure**
  - DL/UL control in a single subframe
- **Flexible Duplex**
  - TDD cell in UL spectrum
  - Supplementary DL in UL spectrum
- **Power/battery efficiency**
  - Efficient sleep
- **IoT**
  - D2D aided MTC/IoT
  - In band IoT (reuse the same spectrum resource)

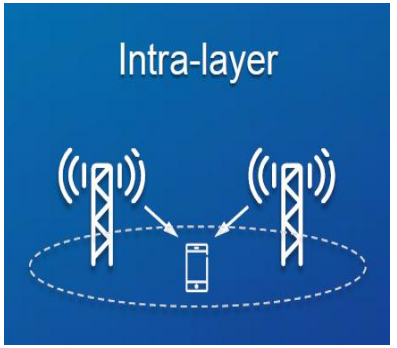


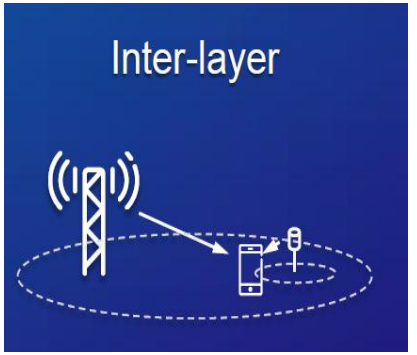
eD2D for 'Best connected' - Ultra dense multi-layer networks

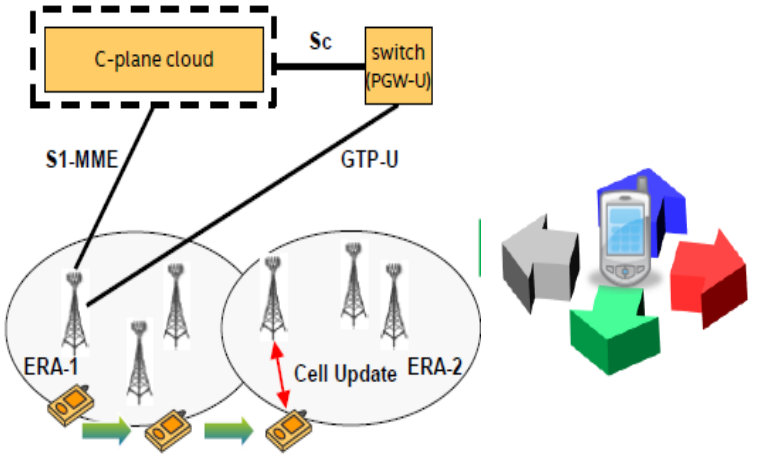
Source: RWS-150023

Multiple Connectivity

- **Multiple-site/Node/RAT connectivity**
  - Macro and small cell
  - Carrier Aggregation
  - Dual Connectivity
  - Control plane/User plane split
  - LTE and WiFi and new RAT
  - Mobility management
- **Unlicensed band/Shared band**
  - LAA like
  - WiFi coexistence
- **Device centric**
  - Dynamic connectivity/access selecti
  - UE based mobility



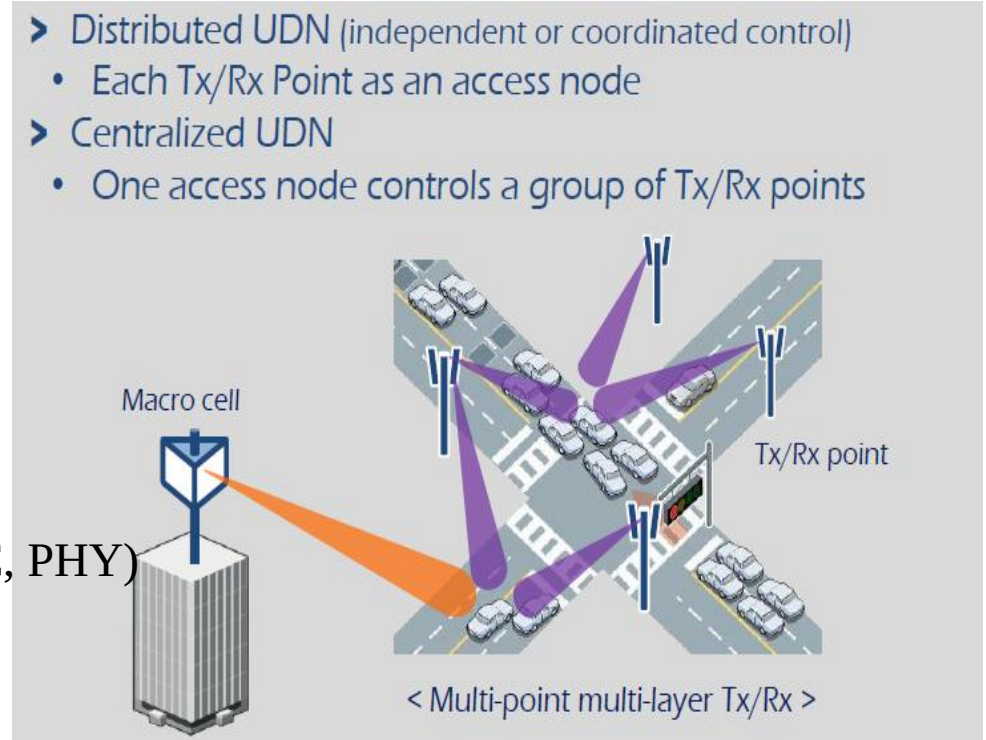




Modified from RWS-150009, RWS-150023, RWS-150044

Ultra-Dense Network

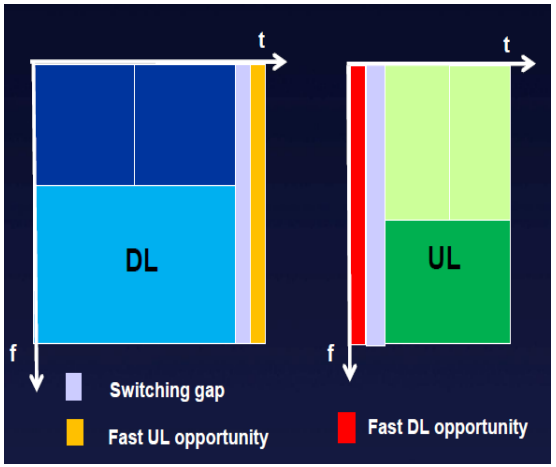
- **UDN Inter cell interference coordination**
  - Joint access
  - Smoothed virtual cell
  - Multiple nodes connectivity
  - CA
  - Self configuration and deployment
  - CoMP
  - Fast control
  - Fast coordination
  - Backhaul for smalls
- **Cloud RAN**
  - RAN function split (PDCP, RLC, MAC, PHY)
  - SDN for RAN
  - Enhanced Fronthaul (BBU and RRH)
- **Wireless Mesh Network**
  - Between base station
  - Wireless backhaul for small cells



Source: RWS-150029

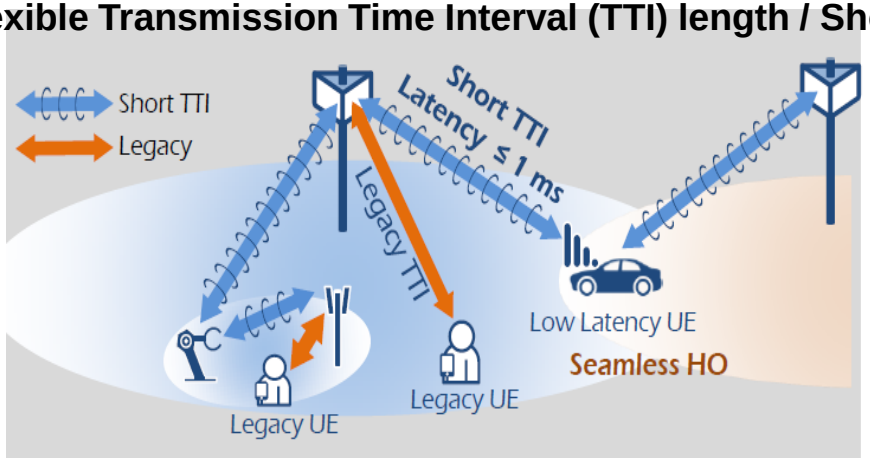
Latency Reduction

Configurable TDD UL/DL switchin



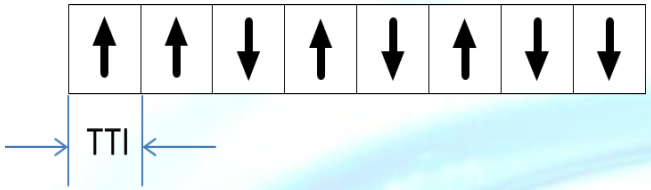
Source: RWS-150006

Flexible Transmission Time Interval (TTI) length / Short TTI



Source: RWS-150029

Dynamic UL/DL subframe

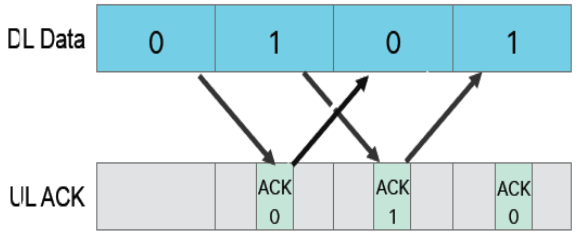


Source: RWS-150047

Fast access

- Grant free access
- Contention based, pre-schedule
- Connection less
- TA free
- ACK/NACK less Retransmission

Configurable HARQ Timing



Source: RWS-150012

Flexible Network

- Cloud RAN
- Network Function Virtualization
- Network Slicing
- xHaul

Throughput Enhancement

- Spectrum Sharing
- Unlicensed Spectrum Access

5G NW

Network Architecture

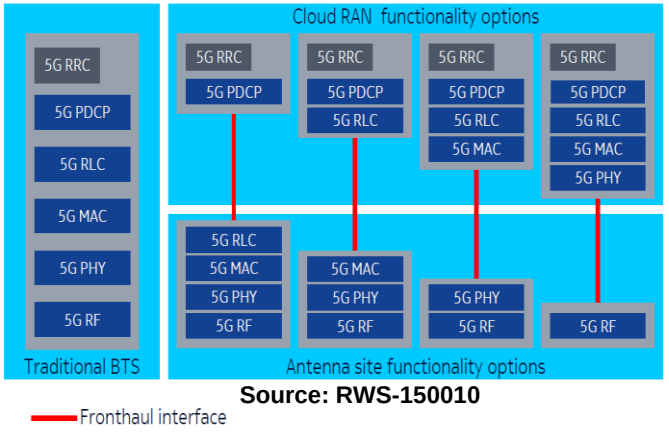
- Networking
- LTE/2G/3G/WLAN/New RAT Integration
- Interface

User Experience Improvement

- Latency Reduction
- User/Application QoE
- Smart RAN - Security

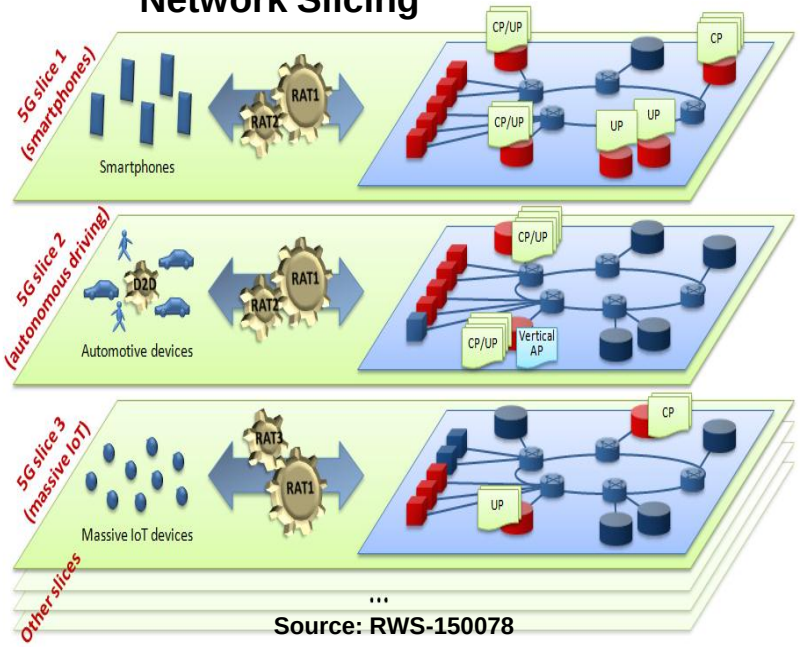
Flexible Network

Cloud RAN



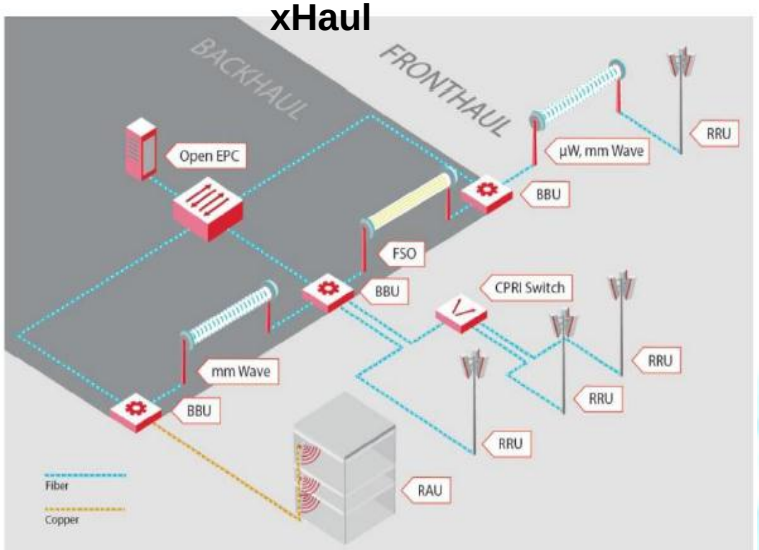
Source: RWS-150010

Network Slicing



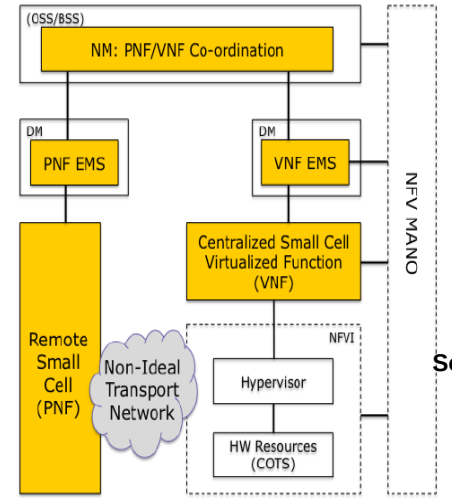
Source: RWS-150078

xHaul



Source: http://xhaul.eu/wp-content/uploads/2015/10/ITRI-Dr.-Fang-Chu-Chen-20150922-5G-summit-final.pdf

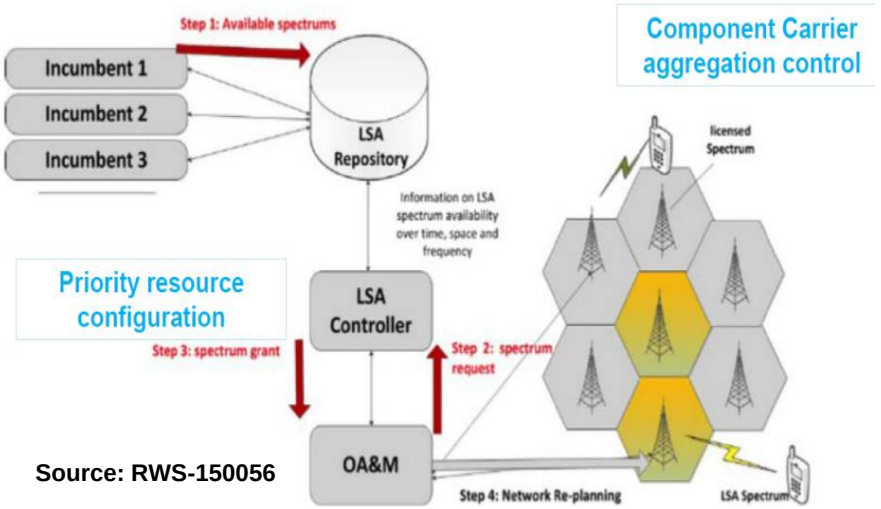
Network Function Virtualization



Source: RWS-150071

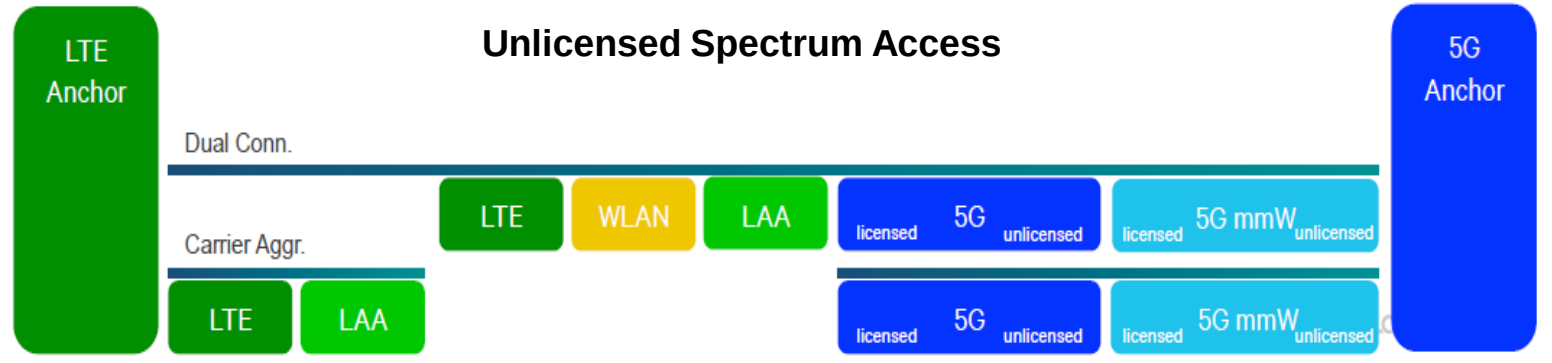
Throughput Enhancement

Spectrum Sharing



Source: RWS-150056

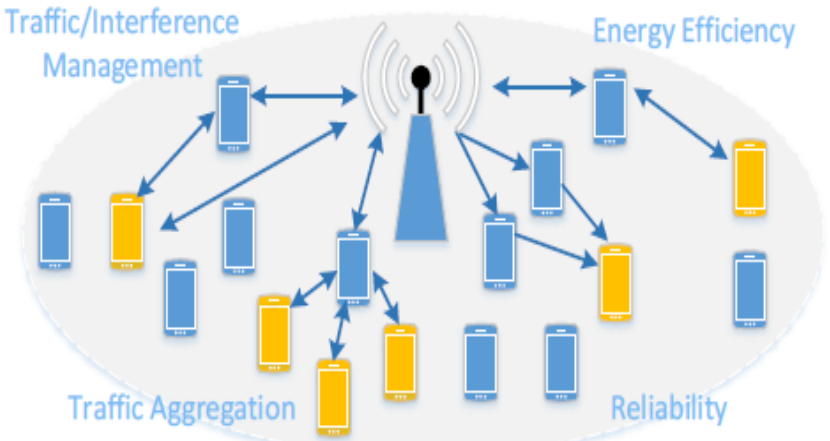
Unlicensed Spectrum Access



Source: RWS-150012

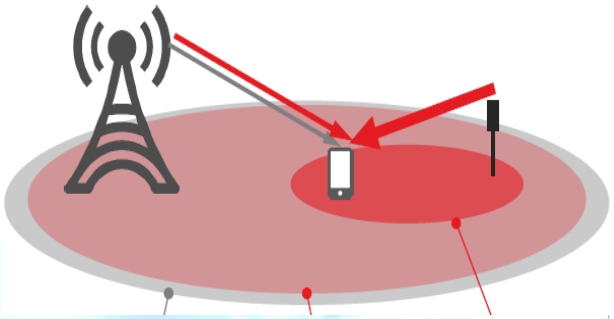
Network Architecture

D2D/V2X/Wireless Mesh/Ultra Dense Network

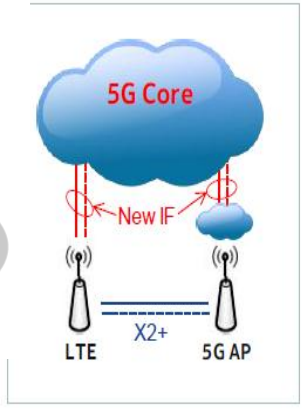


Source: RWS-150023

LTE/WLAN/New RAT Integration

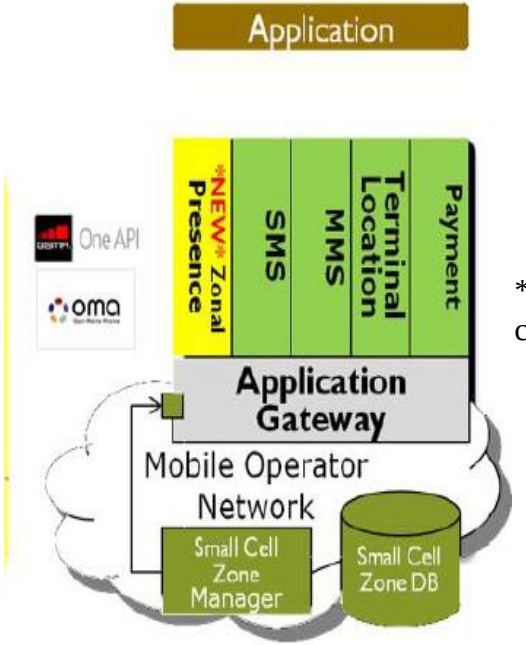


Modified from RWS-150040



Source: RWS-150010

Common API

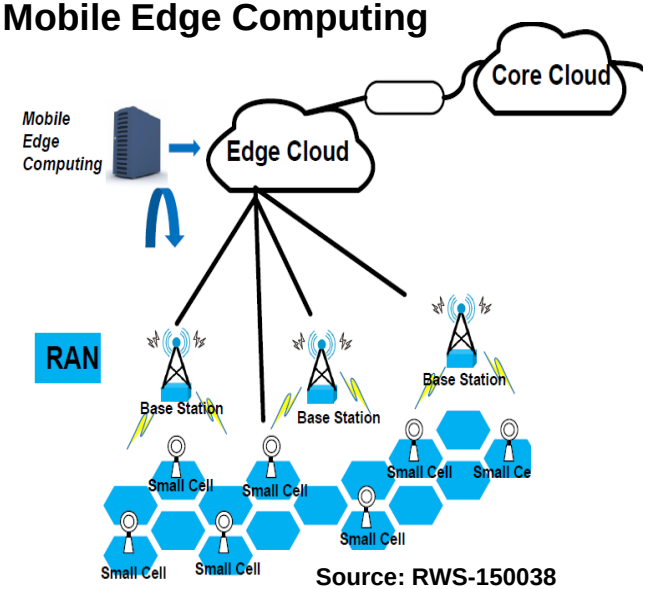


Source: RWS-150071

*To accelerate the commercialization

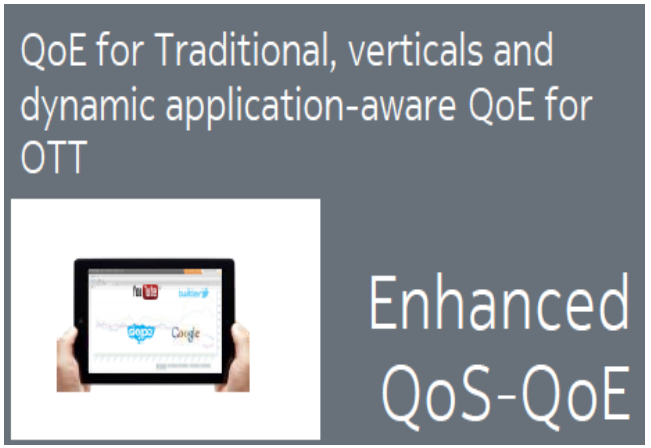
User Experience Improvement

Mobile Edge Computing



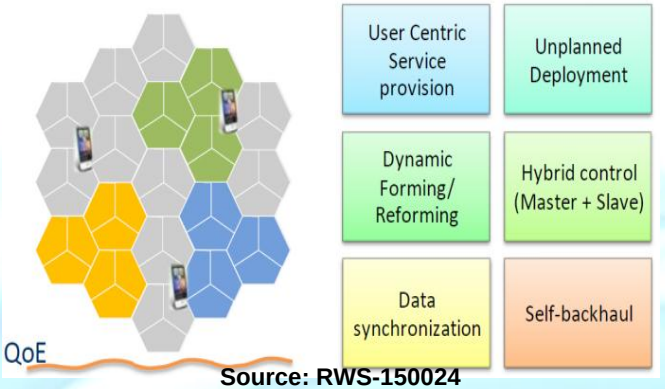
Source: RWS-150038

User\Application QoE



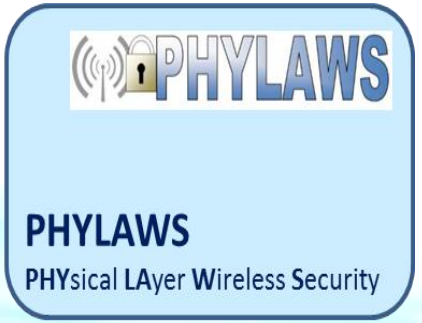
Source: RWS-150010

Smart RAN/Smooth Virtual Cell



Source: RWS-150024

Security



Source: RWS-150007

Source: RWS-150044

Outline

- 5G requirement and use cases
- 3GPP Progress Toward 5G: Technology Trends
  - Technology Trends
  - 3GPP's 5G Timeline
    - From Industrial
    - From Operators
- Summary

From Industrial (1)

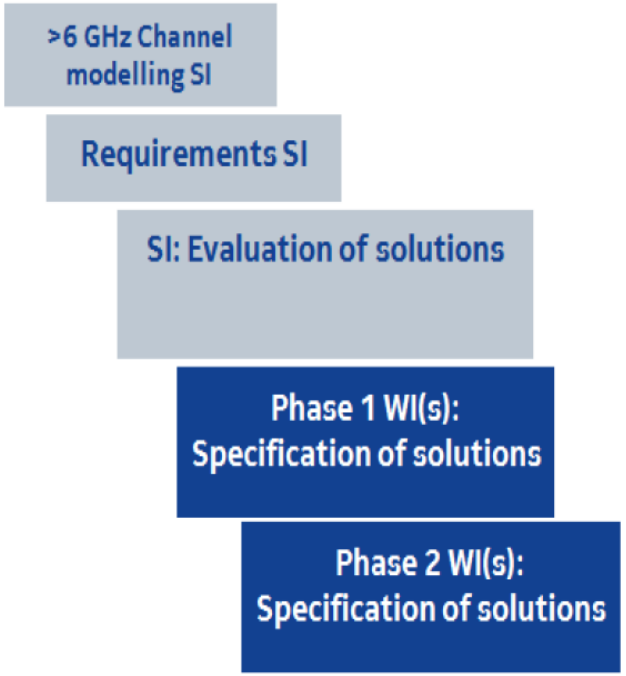
Source: RWS-150036

5G overall picture

5G system to be designed to meet the needs of 2020 and beyond

2020 deployment needs are a subset of the full IMT-2020 capabilities

'5G' to be standardized in phases



Industry Vision and Schedule for the New Radio Part of the Next Generation Radio Technology

Nokia Networks, Ericsson, Qualcomm, NTT DOCOMO, Samsung, SK-Telecom, Sony, Intel, KT, Panasonic, Verizon, Softbank, Kyocera, Mitsubishi, Sumitomo Electric, Hitachi, NEC, Fujitsu, Sharp, ETRI, Straight Path Communications, KDDI, InterDigital

'5G' standards – Phase I of the New RAT

Phase I introduces the New RAT (not backwards compatible to LTE)

Phase I optimized for eMBB use case, but can be used for other uses cases as well

Tight LTE integration

Frequency & Bandwidth

L1 support for a wide spectrum range, up to at least 30...40 GHz

TDD, FDD and unlicensed

Optimize L1 for 100 MHz or higher carrier bandwidth

Energy efficiency

Minimized overhead channels

Deployments

Urban Macro

Urban Micro

Indoor Hotspot

Waveform

Flexible numerology

OFDM-based, potentially with non-orthogonal waveform and multiple access

20 Gbps peak rate

1 ms latency

Scalable (Variable) TTI

Minimum TTI of 100 µs order

Phase I of the New RAT must be forward compatible with Phase II and beyond, and is not backwards compatible to LTE

Phase I is a stepping-stone on the path to the IMT-2020 system of Phase II

'5G' standards – Phase II of the New RAT

Phase II optimized for all '5G' use cases

The 3GPP candidate SRIT for ITU-R (potentially together with LTE evolution)

Frequency bands	Deployments	Capabilities
~0.3...~100 GHz TDD, FDD (flexible duplex)	All	Meets all ITU-R requirements and additional ones identified in 3GPP

Future proof design essential for further evolution of '5G' beyond Phase II

Flexible design to allow new service introduction using the same network and same carrier frequency

From Operators

Source: RWS-150090

Group of operators' common vision and priorities for Next Generation Radio Technology

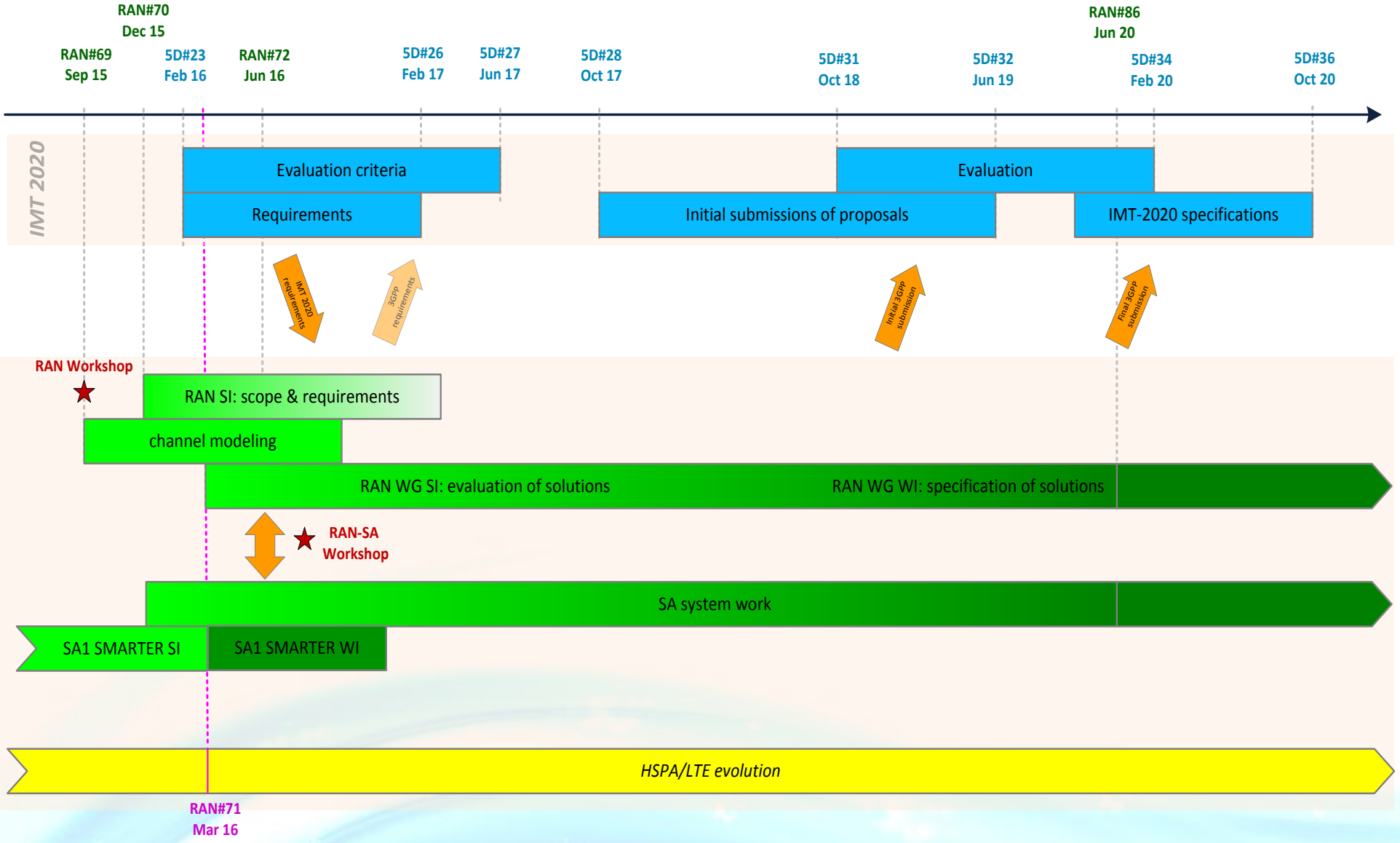
5G design recommendations

Orange, Deutsche Telekom, Telefonica
Telecom Italia, KPN, Telenor, Telia Sonera,
Telus, Swisscom, Dish Network

5G key design principles include:

- Forward compatibility with radio protocol L1/2/3 structures and functionalities required for future services (including phase 2 and beyond)
- Energy efficiency should be a fundamental design principle
- Enhanced security and privacy design
- Cost efficiency
- Tight interworking with LTE (including e.g. bandwidth aggregation, seamless mobility)
- Fixed Mobile Convergence with seamless user experience

3GPP's 5G Timeline



3 Releases / 2 Phases

- **Emerging consensus that there should be two phases for the normative work**
  - Phase 1 to be completed by H2 2018 to address a more urgent subset of the commercial needs (to be agreed)
  - Phase 2 to be completed by Dec 2019 for the IMT 2020 submission and to address all identified use cases & requirements
- **The above implies the following, tentative, release timing**

- **Consensus that there will be a new, non-backward compatible, radio as part of Next Generation Radio Technology**
  - Strong LTE evolution continued ***in parallel***

Latest News: 3GPP 5G Scenarios

*Summarized based on 3GPP RAN Plenary#71 result (2016, March)

- **Skeleton TR (TR 38.913) – Scenarios**
  - Indoor hotspot (~30 GHz or ~70GHz)
  - Dense urban (~4 GHz + ~30 GHz)
  - Rural (~700MHz or ~4GHz)
  - Urban macro (~2/4 GHz and/or 30GHz)
  - High speed (email discussion)
  - mMTC and URLLC (email discussion)
- **Note: A new scenario come up in this meeting**
  - Long coverage

Attributes	Values or assumptions
Carrier Frequency	Below 3 GHz
System Bandwidth	[40] MHz (DL+UL)
Layout	Single layer: Isolated Macro cells ad hoc / isolated
Cell Range	[150 km] for bands above 1GHz [250 km] for between 700 MHz and 1 GHz [400 km] or more for bands below 700 MHz
User density and UE speed	[TBD] users/km² Speed up to [160km/h]
Traffic model	[Average data throughput at busy hours/user: [30kbps] Traffic density: [380-500kbps/km²] User Experienced Data Rate: up to [2]Mbps while stationary and [384kbps] while moving]

Way forward (for 5G-NR)

- **3GPP submission to IMT 2020 (aka 5G) will include**
  - "New Radio of 5G", aka 5G-NR
  - LTE
- **It is for later discussion whether this will be done in a single or two RITs (formal submissions) and how the evaluation process will be organized**
  - In case we decide to have two RITs, it may not be necessary that both RITs fulfill all IMT-2020 requirements. This will also depend on the criteria that will be defined by WP5D to be an approved IMT-2020 technology
- **5G-NR shall eventually address all requirements and usecases identified in the RAN SI**
  - 5G-NR forward compatibility will be key to phase-in the different features in different releases in an optimal way. The Technology SI shall study the best way to achieve that!

Note: 5G-NR is a temp term for the "New Radio of 5G"

*Source: On 5G: IMT2020, RAN Plenary#71 Chairman's Slide

Summary

- **5G is coming soon**
  - Extreme Mobile Broadband
  - Massive Machine Type Communication
  - Ultra-reliable low latency Communication
- **3GPP consider 5G technology as "LTE enhancement + New RAT"**
  - Tremendous technologies to be developed
- **Time to join the 5G race**
  - Participate standard meeting and fight on

台灣資通產業標準協會
Taiwan Association of Information and Communication Standards

ITRI
Industrial Technology Research Institute

THANK YOU!

Q&A

ChunYen@itri.org.tw