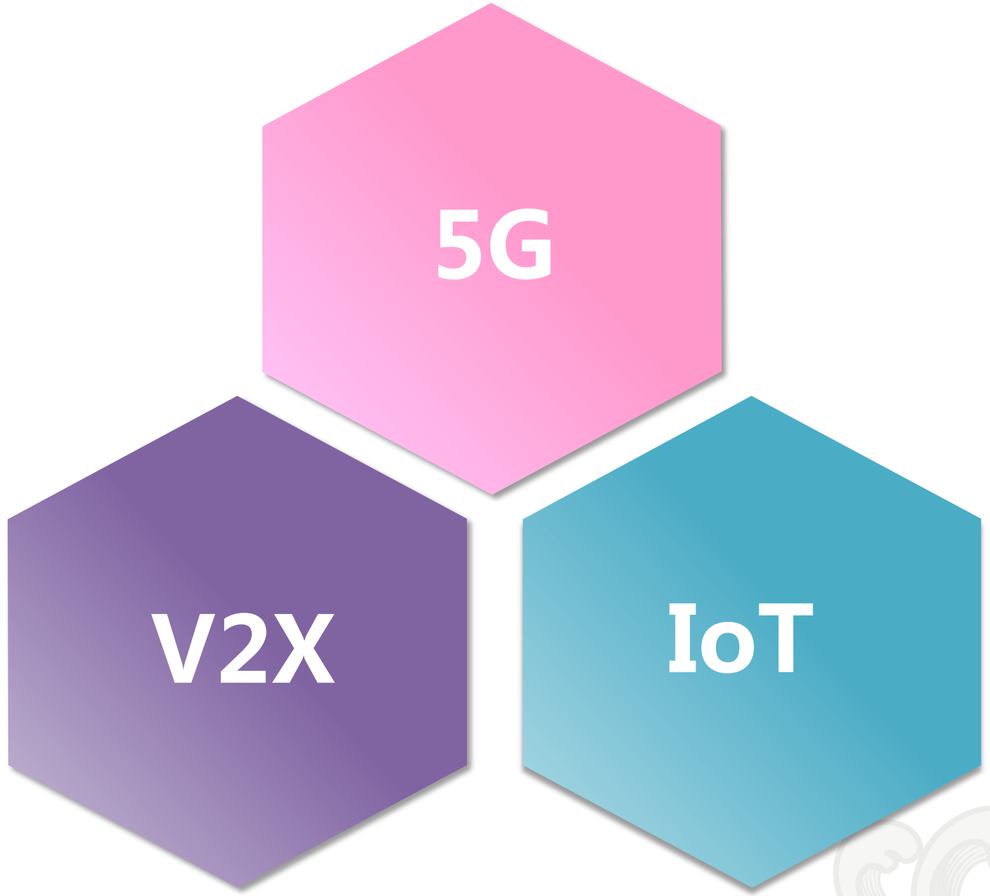
Emerging Radiocommunication Technologies and Applications

Spectrum Engineering Department,
The State Radio Monitoring Center, MIIT,
China

Contents

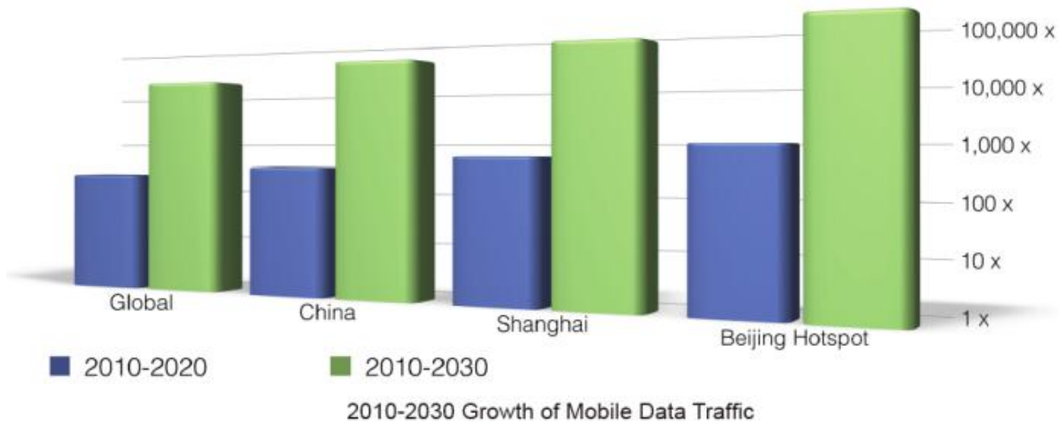
State Radio Monitoring Center of China
Radio Monitoring Department



5G

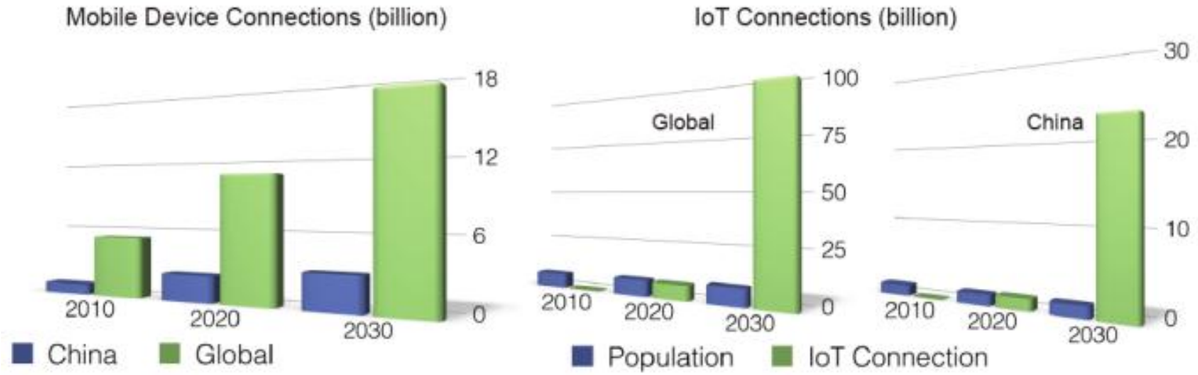
Why 5G ?

Mobile Data Traffic
Thousands of times growth



2010-2030 Growth of Mobile Data Traffic

Mobile Internet & IoT Connections
Up to 100 billion

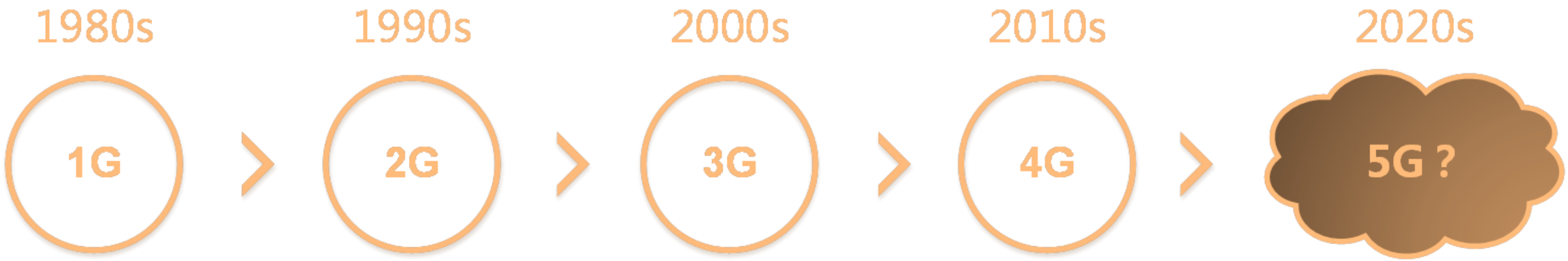


2010-2030 Growth of Mobile Device and IoT Connection

Source: IMT-2020(5G)PG - WHITE PAPER ON 5G CONCEPT

Current and projected dramatic growth of mobile data traffic necessitates the development of 5G mobile communications technology.

What is 5G ?



- FDMA
- Analog voice

- TDMA
- Digital voice
- Low-data-rate services

- CDMA
- 2~Tens of Mbps (peak data rate)
- Multimedia

- OFDMA
- 100M~1Gbps (peak data rate)
- MBB

5G Concept ?

IMT-2020 named by ITU

Requirements——Market & Services

Avalanche of
Traffic Volume

Further expansion of mobile broadband

Additional traffic due to communicating machines

“1000x in ten years”

Massive growth in
Connected Devices

“Communicating machines”

“50 billion devices in 2020”

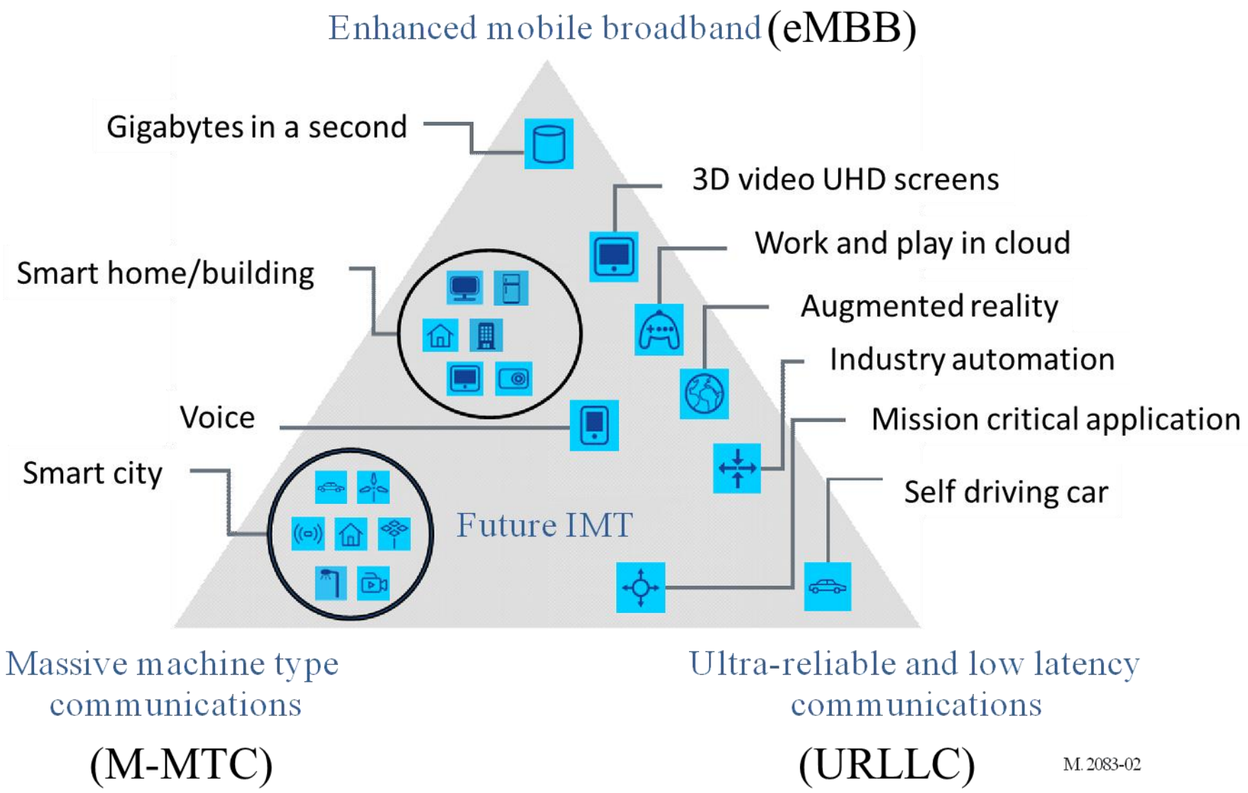
Large diversity of
Use cases & Requirements

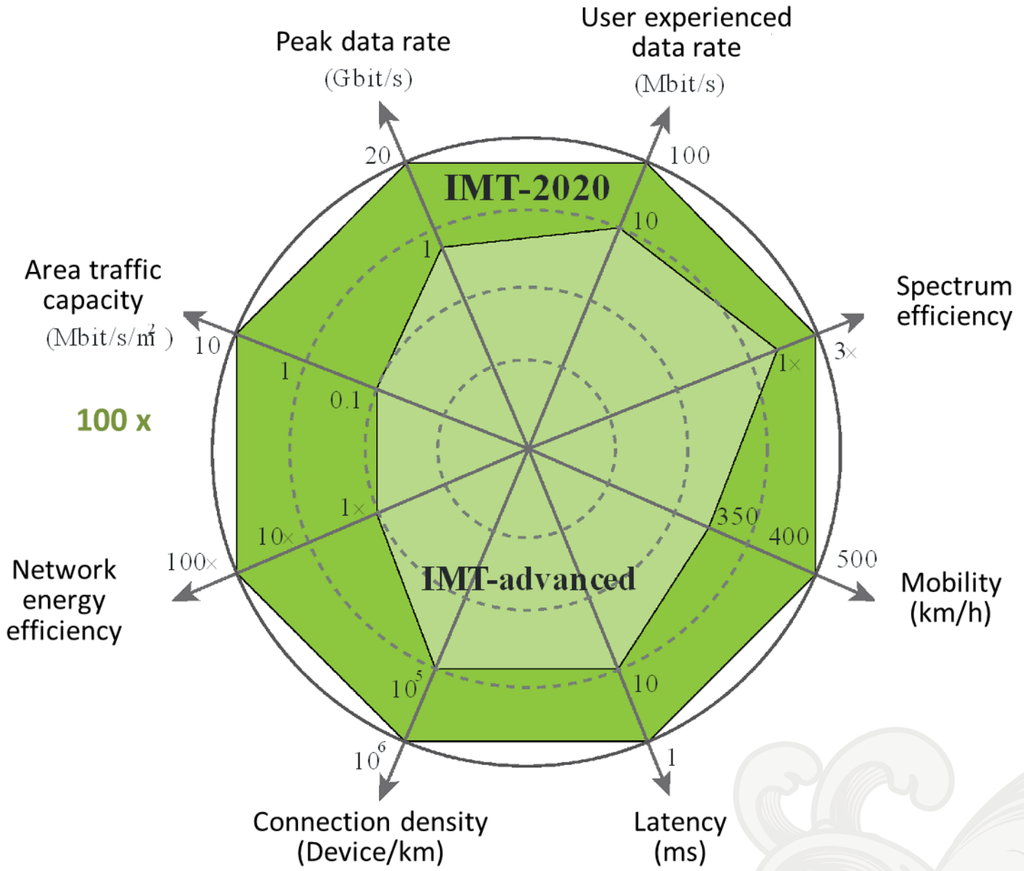
Device-to-Device Communications

Car-to-Car Comm.

New requirements and characteristics due to communicating machines

Requirements——Scenarios & KPIs





Requirements—— Evaluation

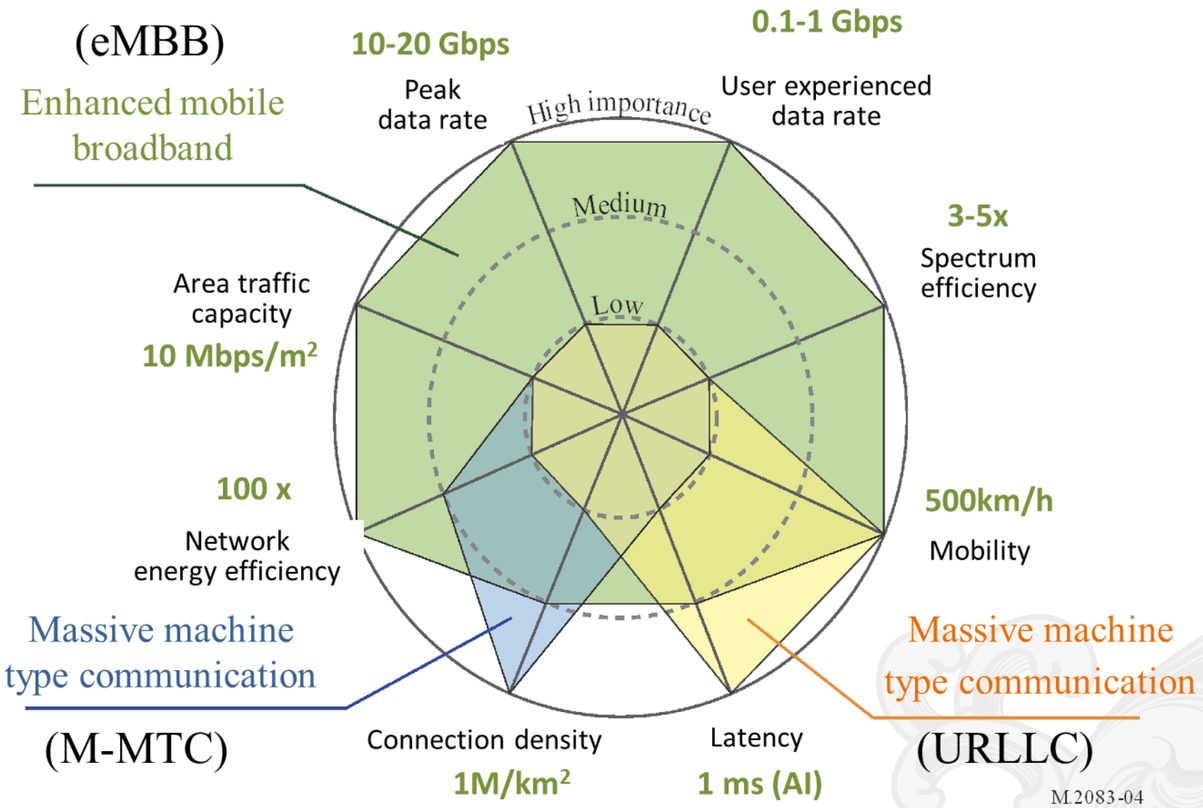
5 Test environments

eMBB		
Indoor hotspot	Dense urban	Rural coverage

M-MTC
Urban coverage

URLLC
Urban coverage

14 KPIs



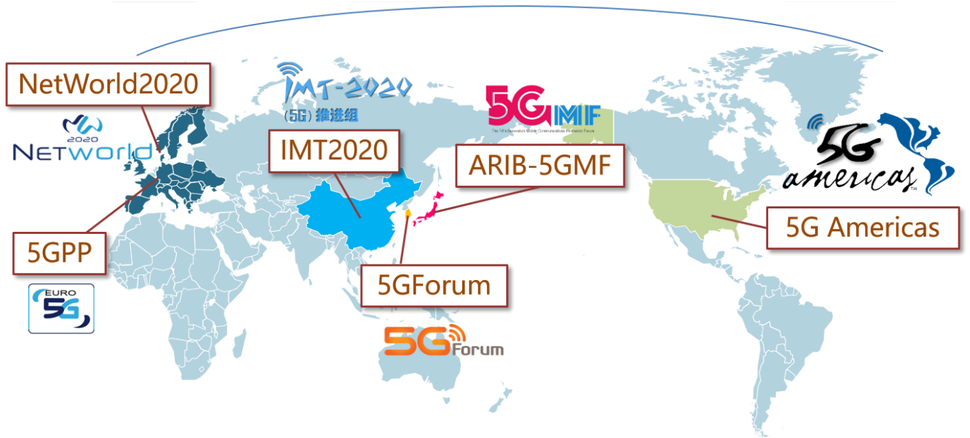
Standards

International Standards Bodies

ITU GSMA 3GPP IEEE NGMN WWRF

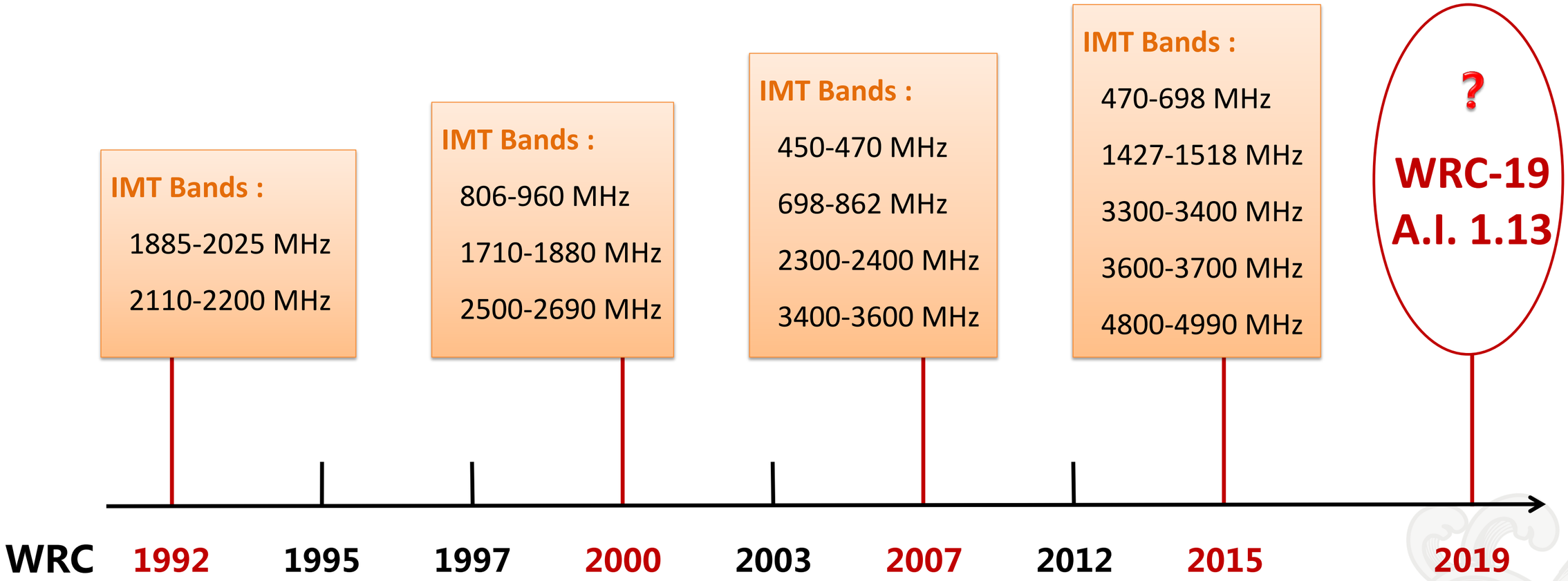
- **ITU:** International Telecommunication Union
- **GSMA:** GSM Association
- **3GPP:** 3rd Generation Partnership Project
- **IEEE:** Institute of Electrical and Electronics Engineers
- **NGMS:** Next Generation Mobile Networks
- **WWRF:** Wireless World Research Forum

Reginal/National Standards Bodies



- **5G Americas:** 5th Generation Americas
- **5GPPP:** 5th Generation Public Private Partnership
- **5GMF:** 5th Generation Mobile Communications Promotion Forum
- **5GForum:** 5th Generation Forum
- **IMT-2020:** International Mobile Telecom System-2020

Spectrum


IMT Bands :
1885-2025 MHz
2110-2200 MHz
IMT Bands :
806-960 MHz
1710-1880 MHz
2500-2690 MHz
IMT Bands :
450-470 MHz
698-862 MHz
2300-2400 MHz
3400-3600 MHz
IMT Bands :
470-698 MHz
1427-1518 MHz
3300-3400 MHz
3600-3700 MHz
4800-4990 MHz
?
WRC-19
A.I. 1.13
WRC
1992
1995
1997
2000
2003
2007
2012
2015
2019

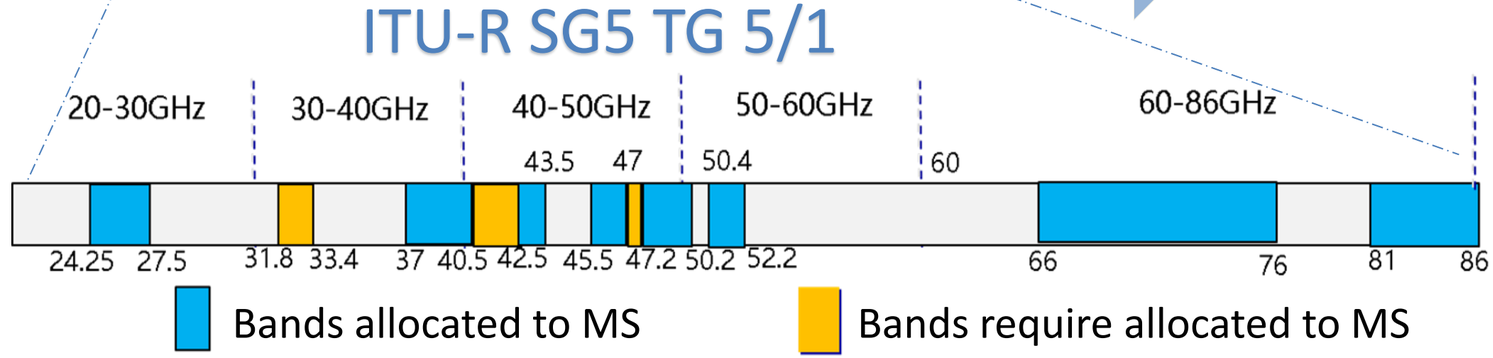
M-MTC

Ultra-Reliable and Low-Latency Communications (ULLC)

Enhanced mobile broadband (eMBB)

450 - 470
698 - 960
1710 - 2025
2110 - 2200
2300 - 2400
2500 - 2690
3400 - 3600
470 – 698 (WRC-15)
1427-1518 (WRC-15)

3300-3400 (WRC-15)
3600-3700 (WRC-15)
4800-4990 (WRC-15)



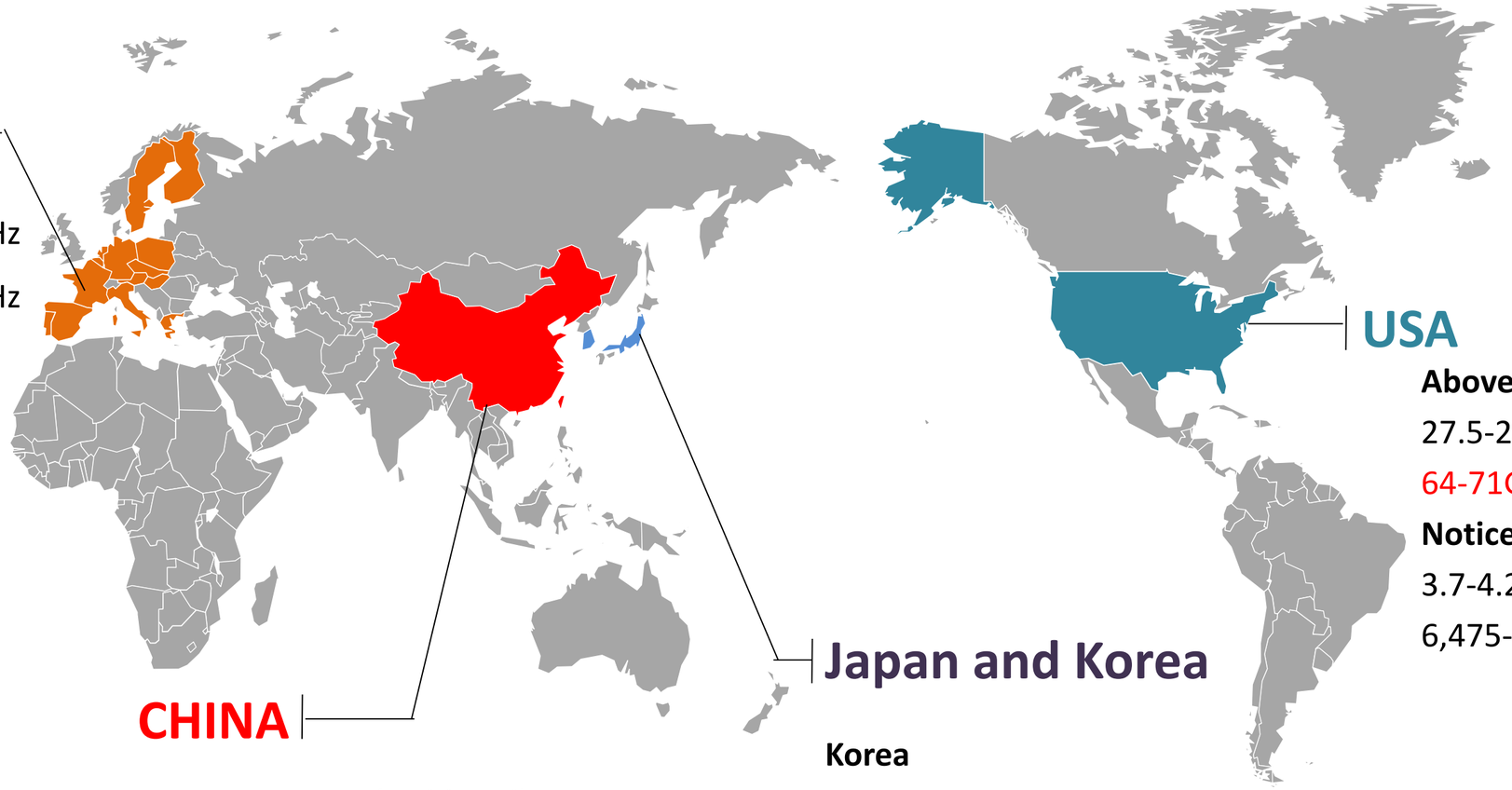
WRC-19 A.I. 1.13

Studies on frequency-related matters for IMT identification including possible additional allocations to the mobile services on a primary basis in portion(s) of the frequency range between 24.25 and 86 GHz for the future development of International Mobile Telecommunications for 2020 and beyond.

Development Status

State Radio Monitoring Center of China
Radio Monitoring Department

国家无线电监测中心
The State Radio Monitoring Center



EU

Below 6GHz：700MHz, 3.4-3.8GHz

Above 6GHz：24.5-27.5GHz

USA

Above 6GHz:

27.5-28.35GHz, 37-40GHz,

64-71GHz（Unlicensed）

Notice of inquiry:

3.7-4.2GHz, 5.925-6.425GHz,

6,475-7.125GHz, etc

CHINA

Below 6GHz: 3.4-3.6GHz,4.8-5.0GHz (Field trial),

3.3-3.4GHz, 4.4-4.5GHz, 4.8-5GHz (under consideration)

Above 6GHz: mainly focus on 26GHz, 40GHz frequency band

24.75-27.5GHz, 37-42.5GHz (Field trial)

Japan and Korea

Korea

3.4-3.7GHz, 26.5-29.5GHz

Japan

3.6-4.2GHz, 4.4-4.9GHz, 27.5-29.5GHz

Spectrum——Remarks

- 5G system need to support aggregation of frequency bands:
  - ✓ frequency bands below 6GHz for 5G coverage,
  - ✓ frequency bands above 6GHz for 5G capacity and backhaul.
- Frequency band below 1GHz is applicable for M-MTC scenario
- Cooperation in ITU is important to ensure global/ regional harmonization

Technologies

Unified Air interface framework

- Flexible System Design
- NR Technologies
- Massive MIMO

Novel Network Architecture

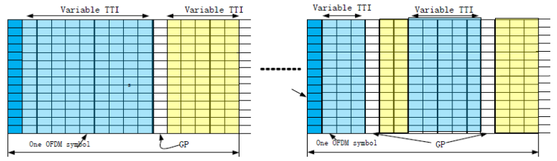
- Service Based Architecture
- Network Slicing
- Edge Computing
- Security Algorithm

From Vision to Standard Innovation

Technologies make KPIs achievable

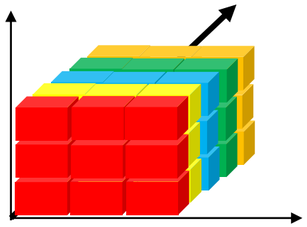
Flexible System Design

- **Flexible Frame Structure** to support Self-contained and variable length TTI
- **Flexible Waveform** to provide forward compatibility
- **Flexible Duplex with Symmetric TX/RX Design** to realize cross link unified design and interference mitigation



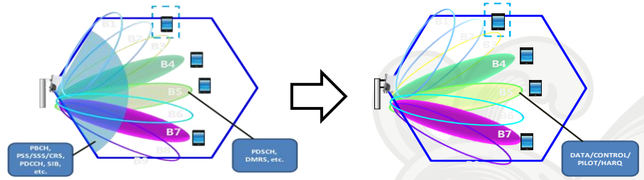
Technologies for NR

- **Non-Orthogonal Multiple Access (NOMA)**
  - SCMA
  - PDMA
  - MUSA
  - ……
- **New coding schemes**
  - Polar code
  - LDPC



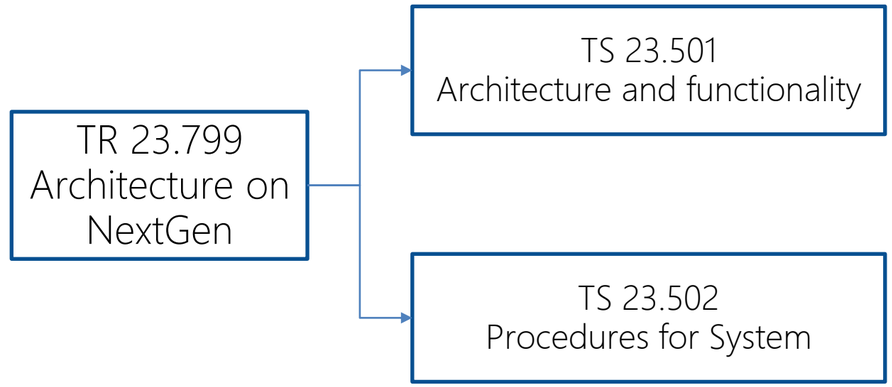
Massive MIMO

- **Unified MIMO framework** for control and data
- Control signaling and feedback enhancement for MU-MIMO
- More accurate CSI reporting
- More robust open-loop schemes
- **Beamforming enhancement**
  - Self contained beam
  - Hybrid beamforming in baseband and analog domain



3GPP Release 15

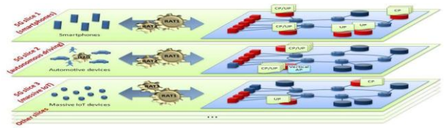
5G system Standardization comprehensively considers the aspects of **architecture, network function and infrastructure**.



Service based Architecture

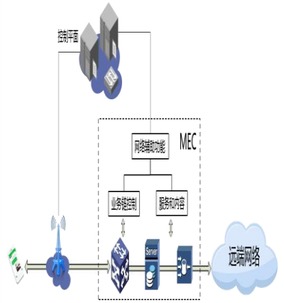
- Service based control plane
- Support flexible Network Functions Reconstruction
- Facilitate network functions reuse and capabilities exposure

Network Slicing



- One network, Multiple scenarios
- On demand Mobility
- Programmable User Plane

Edge Computing



- Distributed User-Plan with efficient routing
- Session and Service Continuity

5G studies in China

Spectrum needs of IMT-2020 by technical performance-based approach in WP5D

Deployment scenario	Macro	Micro	Indoor
Below 6GHz	**802-1090MHz**	—	—
24.25-43.5GHz	—	5.3-7.58MHz*	5.3-7.58MHz
45.5-86GHz	—	—	9.7-12.42GHz
Between 24.25 and 86GHz	—	**15-20GHz**	

*24.25-43.5 GHz for Micro scenario can also be reused in indoor hotspot.

Consultations on frequency usage of 3300-3600MHz and 4800-5000MHz for 5G communication system (IMT-2020)

3300-3600MHz and 4800-5000MHz are allocated as IMT-2020 operation bands

1. For **3300-3400MHz**, IMT-2020 system should, in principle, be limited for indoor use only. Without any interference to in-used station of radiolocation service, it can be used for outdoor.
2. For **3400-3600MHz**, IMT-2020 should not generate interference to earth stations of FSS with valid license on this band. Meanwhile, IMT-2020 should provide protection to satellite telemetry system in this band and in adjacent band. Details protection method should be negotiated btw MNOs and Satellite operator.
3. For **4990-5000MHz**, IMT-2020 shall not generate interference to radio astronomy stations listed in footnote of CHN 12 in “People’s Republic of China regulations on the radio frequency allocation”.

The above bands are used as IMT-2020 operating frequency bands and are managed by the national radio regulation authority. Specific regulations of **frequency allocation**, **RF technical indices** and **radio station management** will be developed and released in future.

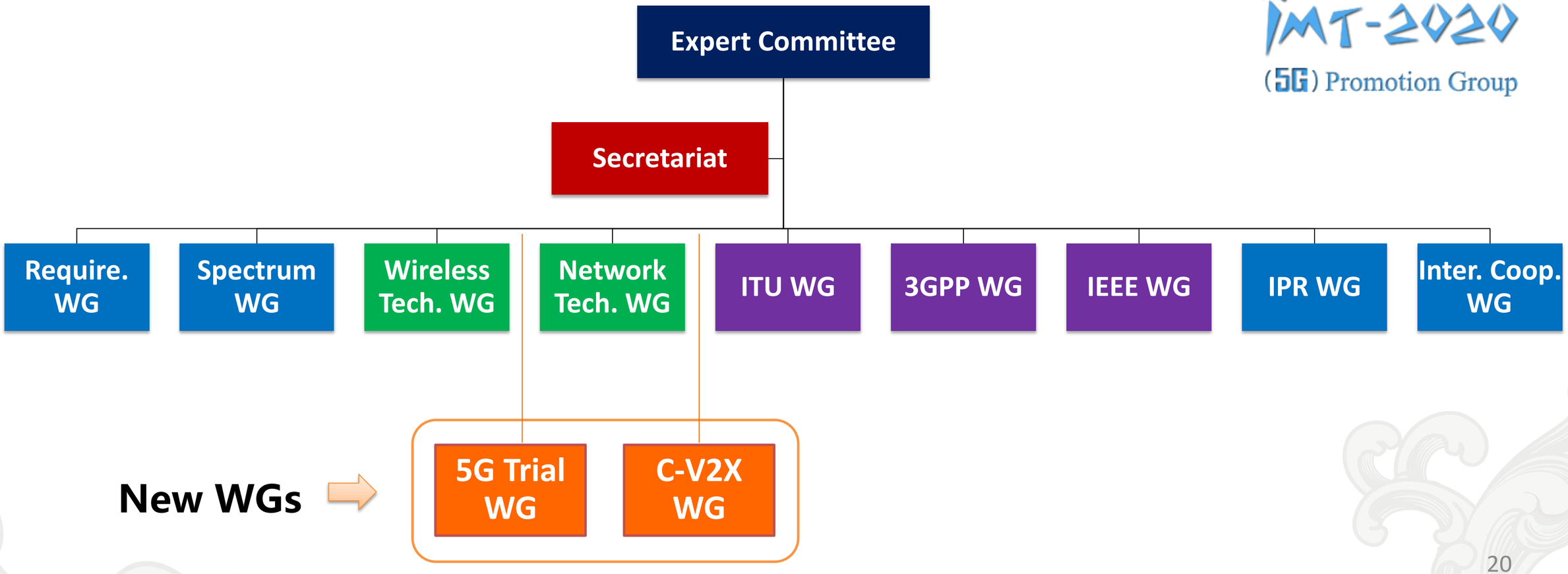
Consultations on mmWave Frequency Band Allocation for 5G system

MIIT is soliciting public comments on identifying 24.75-27.5GHz, 37-42.5GHz and other mmWave bands for 5G IMT system. Feedback may include but are not limited to following items.

1. Companies/organizations which are using or plan to use these bands, could list out the current usage/intended usage of these bands, deployment plan & key time point and provide opinions upon how to use these band for 5G.
2. Illustrate technical problems (including RF components, chipset, instruments & etc.) to deploy 5G system in these bands, as well as feasible solutions and schedule.
3. Coexistence & sharing study reports could be attached in which detailed system parameters, obit/position of stations, study method and results should be included.
4. Suggestions on how to coordinate 5G system with other systems operating in the same or adjacent bands, as well as possible technical/administrative methods to achieve the coexistence of 5G and other systems.
5. Other issues need to be addressed.

IMT-2020(5G) promotion group was established in 2013 by 3 ministries in China

IMT-2020 (5G) Promotion Group



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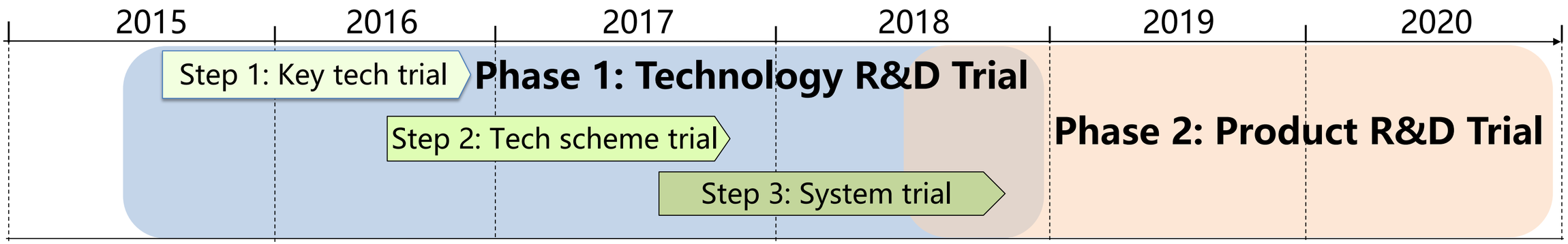
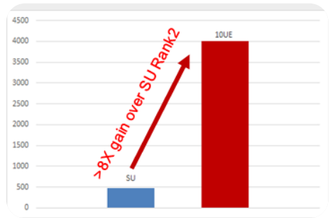


Trail Status	Frequency bands	Remarks
Step 1	• N/A	Vendor dependent
Step 2	• 3400-3600 MHz	Step 2 focuses on below 6GHz frequency bands
Step 3	• 3400-3600 MHz • Other below 6GHz frequency bands (TBD) • High-frequency bands in 6-100 GHz (TBD)	Step 3 covers below 6GHz bands and above 6GHz bands

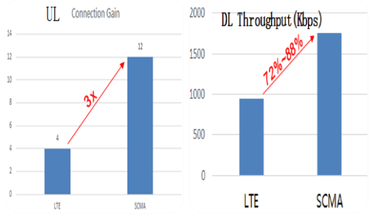
Trial Results of Step 1

Massive MIMO



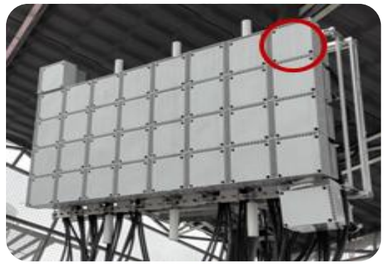
Maximum cell throughput of MU-MIMO is more than **8 times** to SU-MIMO with two streams

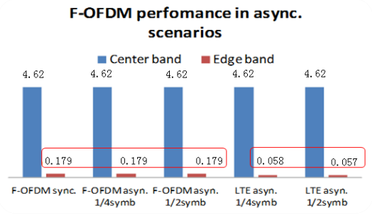
Novel Multiple Access



Novel multiple access can obtain **3 times** connection gain and **72% - 88%** average throughput gain

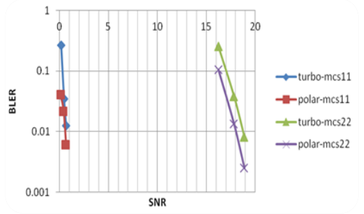
New Multi-Carrier





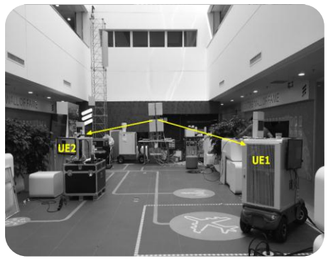
New Multi-Carrier is **more robust** than OFDM waveform in asynchronous transmission

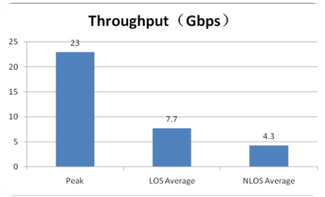
Advanced Codes



Performance gain of polar coding could achieve **0.45-0.9 dB**

High-Freq Comm.





23Gbps of max throughput @800MHz, 2UEs. **7.7 /4.3 Gbps** of average throughput in LOS/NLOS(Indoor).

Summary

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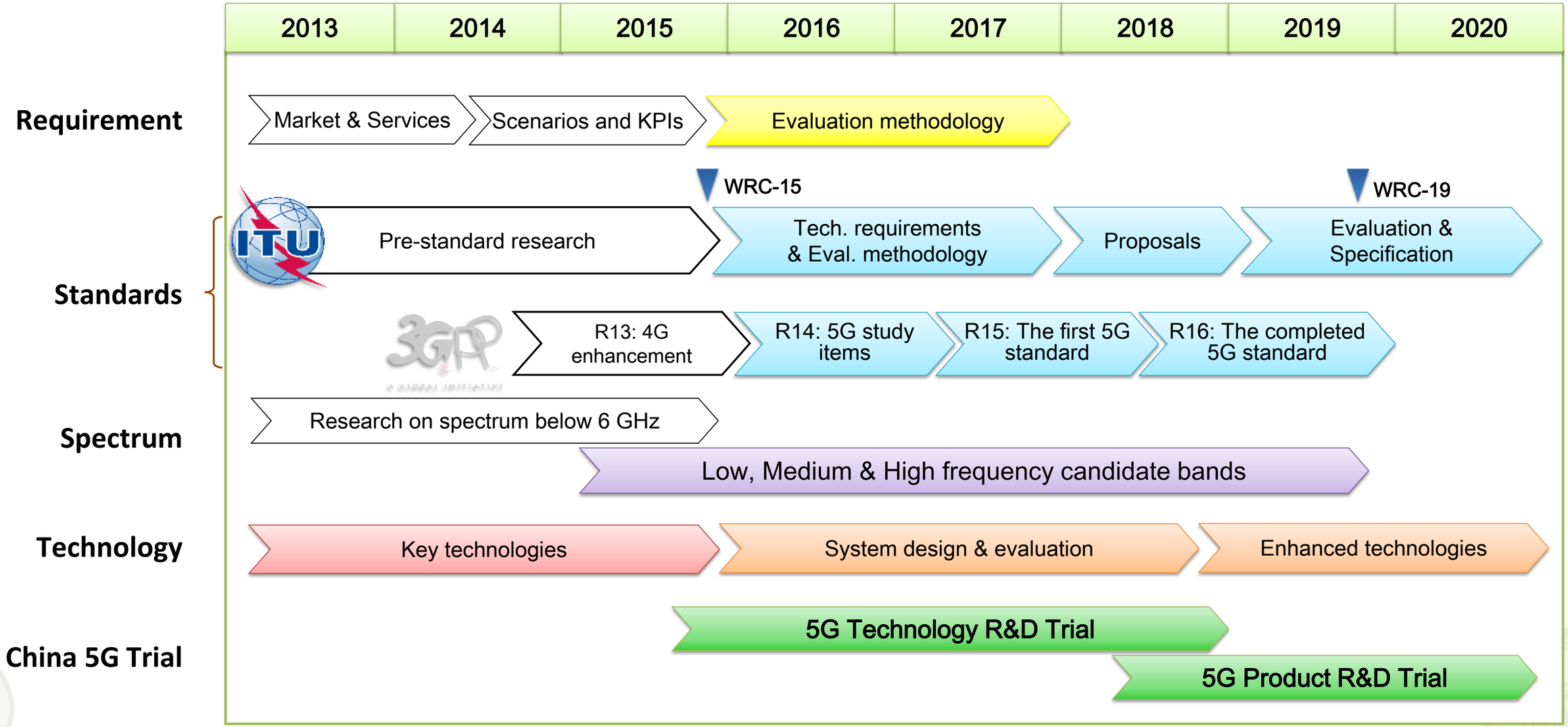
The State Radio Monitoring Center



IoT

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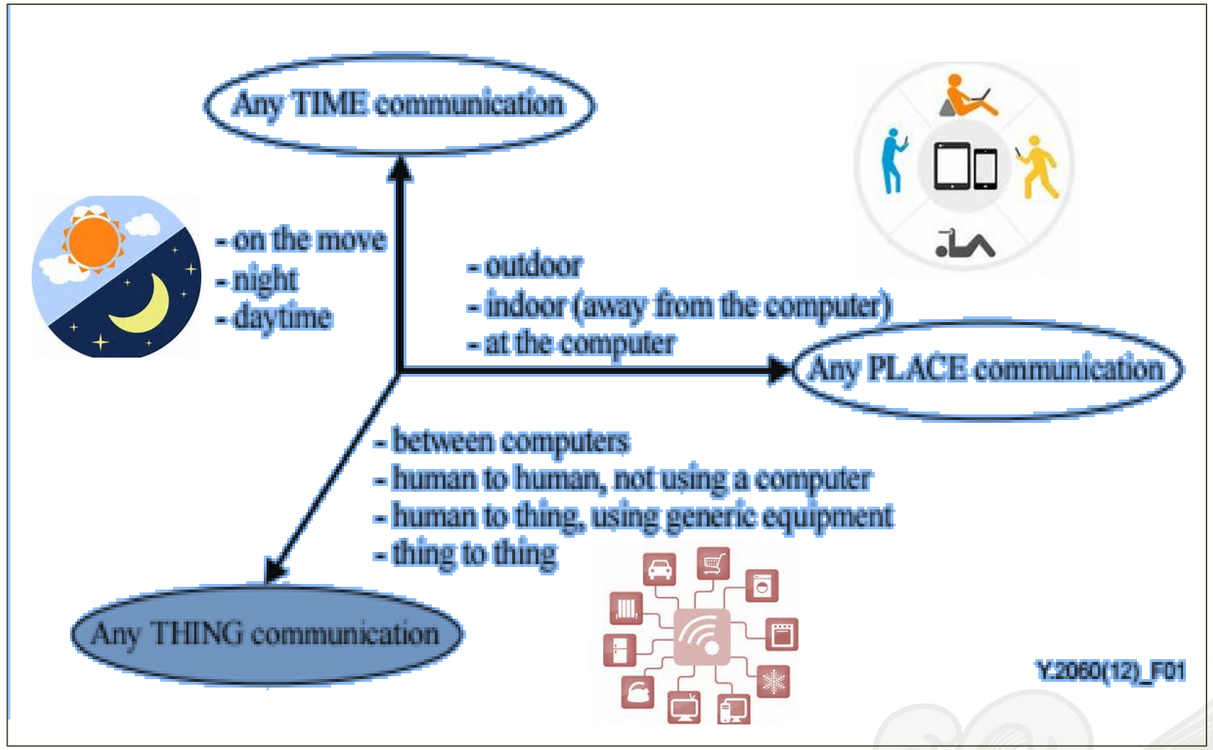
Why IoT ?

Meet the communication needs at

Any **Time**, Any **Where** with Any **Device** !



Added the dimension Any THING Communication to ICTs !

What is IoT ?

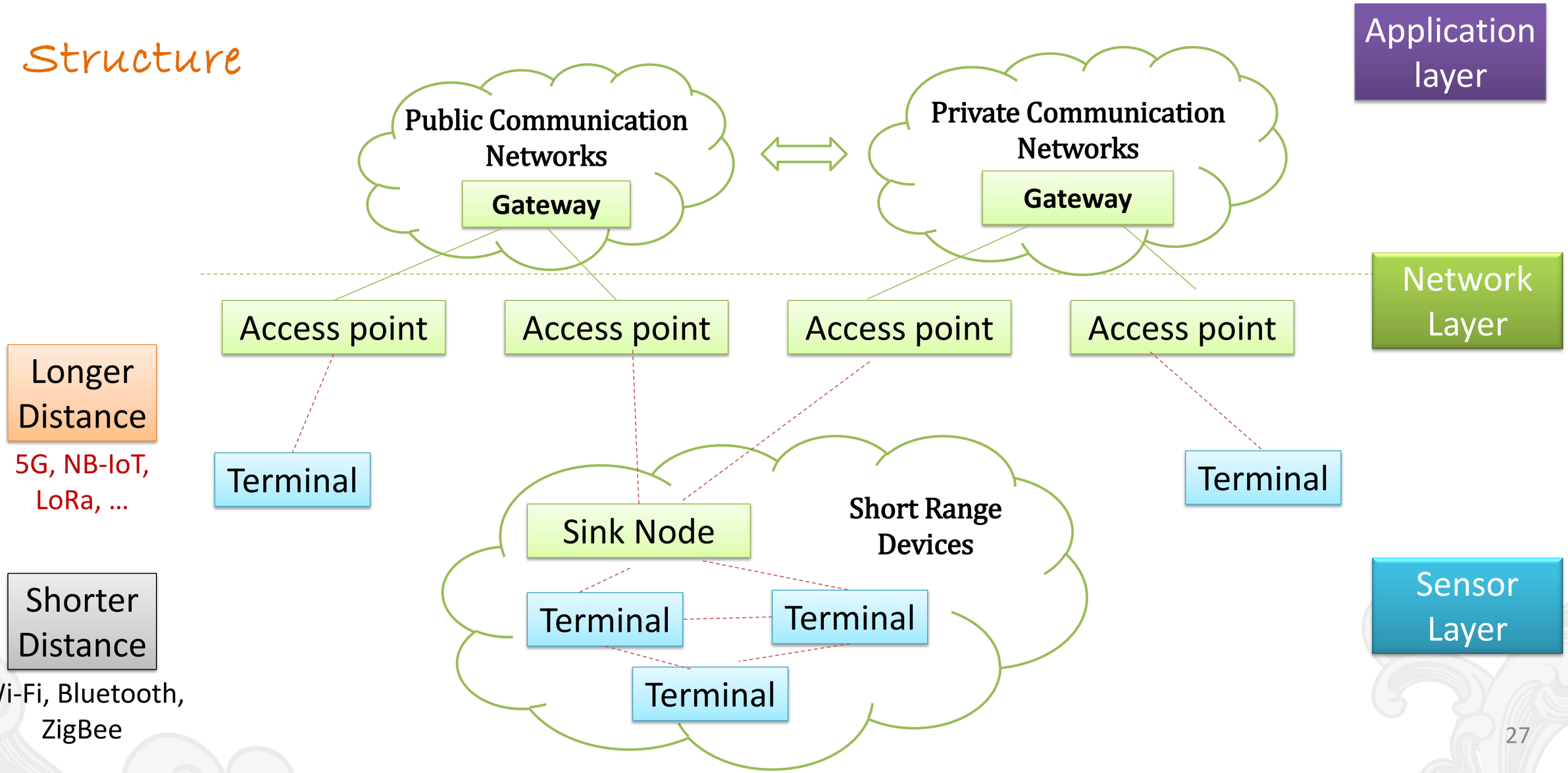
Definition of Internet of things (IoT) in Recommendation ITU-T Y.2060 (06/2012)

A **global infrastructure for the information society,** enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.

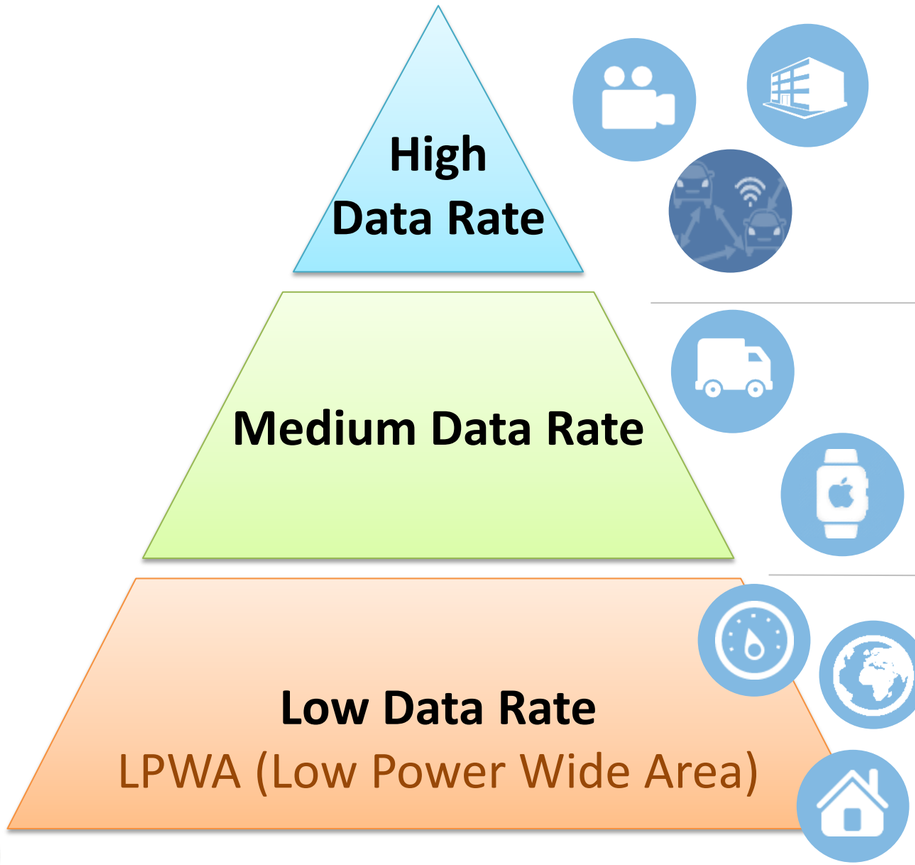
NOTE 1 – Through the exploitation of **identification**, **data capture**, **processing** and **communication** capabilities, the IoT makes full use of things to offer services to all kinds of applications, whilst ensuring that **security and privacy requirements** are fulfilled.

NOTE 2 – From a broader perspective, the IoT can be perceived as a vision with **technological and societal implications.**

Structure

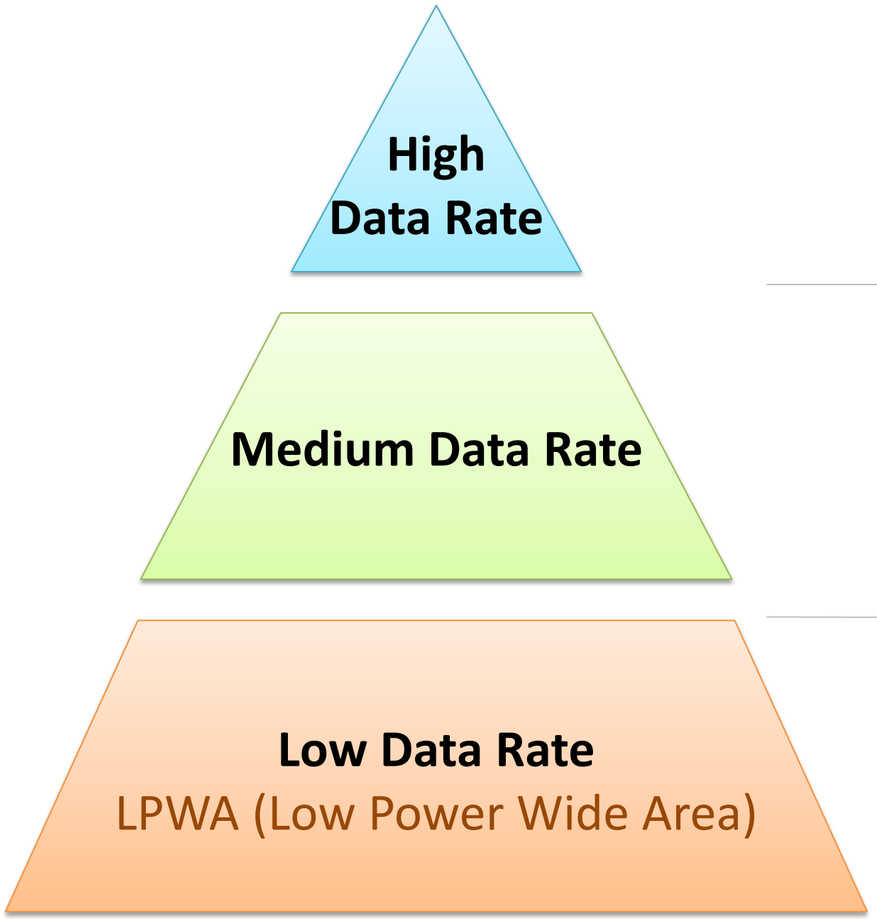

Application layer
Public Communication Networks
Gateway
Private Communication Networks
Gateway
Network Layer
Access point
Access point
Access point
Access point
Longer Distance
5G, NB-IoT, LoRa, …
Terminal
Terminal
Sink Node
Short Range Devices
Terminal
Terminal
Terminal
Shorter Distance
Wi-Fi, Bluetooth, ZigBee
Sensor Layer

Use case and Requirements



	Use Cases	Requirements
High Data Rate	• Surveillance cameras, • Internet of Vehicles • eHealth •	• Data Rate>1Mbps , • High Traffic capacity • Insensitive to power consumption • Ultra-Reliable and Low-Latency
Medium Data Rate	• Intelligent wearing • Road Traffic control • Smart Logistics •	• Data Rate： 100kbps~1Mbps • Voice Service • Mobility
Low Data Rate LPWA (Low Power Wide Area)	• Smart Metering • Environmental monitoring • Smart Home •	• Data Rate < 100kbps Mainly text data • Low traffic capacity • Sensitive to power consumption • Depth of coverage

Technologies



LTE-V, 5G

- Ultra-Reliable and Low-Latency
- Driving assistance, emphasizing safety

Licensed Network: eMTC

- Consider both medium data rate service and LPWA service
- Besides deep penetration, also support mobility functions and higher data rate

Unlicensed Networks

LORA, SIGFOX

- Mainly focus on LPWA service

Licensed Network: NB-IOT

- Mainly focus on LPWA service
- Ultra-deep penetration, low power, low cost aspects

Technologies——NB-IoT

Main simplification

- Reduced data rate/bandwidth, mobility support and further protocol optimizations.

Billions of connections

100K per Cell

Low data rate

< 62.5Kbps

20 dB better link budget

Deep penetration

indoors & underground

Low cost devices

Integrates into cellular system

Easy deployment

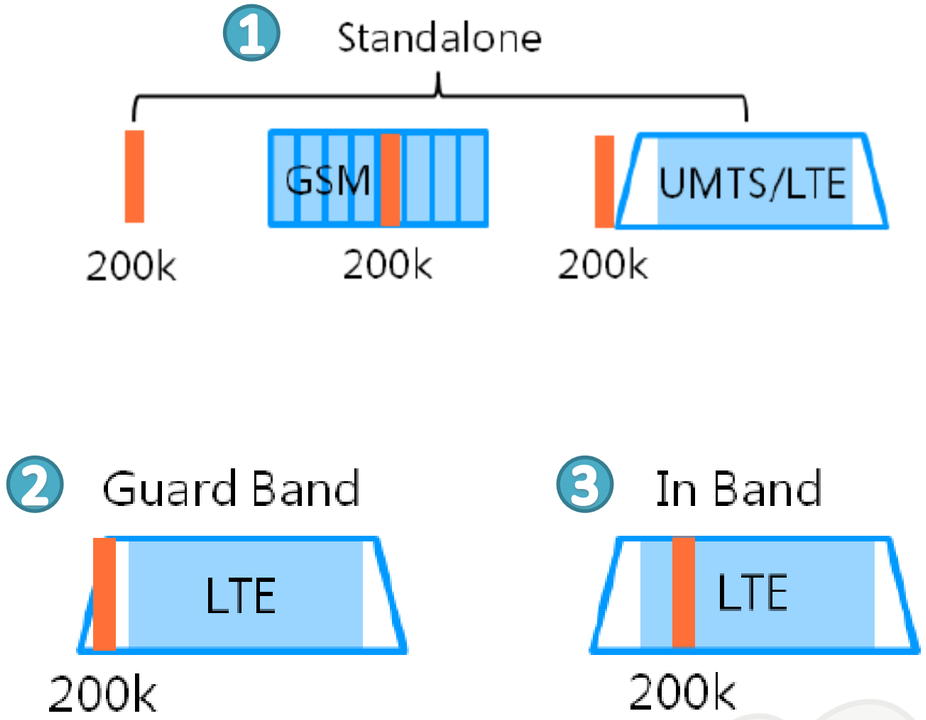
Low power operation

10+ years

Battery life

Operation Characteristics

- **3 operation modes**
  - **Standalone** deployment mainly utilizes new bandwidth
  - **Guard band** deployment is done using the bandwidth reserved in the guard band of the existing LTE network
  - **In Band** makes use of the same resource block in the LTE carrier of the existing LTE network.
- **Single Bandwidth: 180kHz**
- **FDD, half duplex(HD) modes**



Technologies——NB-IoT

Use cases

IoT Appliance

- Smart metering
- Alarms & Event Detectors
- Smart garbage bins

IoT Public

Use Cases

IoT Personal

- Wearable devices
- Smart bicycle
- Kids monitoring

IoT Industry

- Logistics tracking
- Asset tracking
- Smart agriculture

Technologies——eMTC

Billions of connections

100K per Cell

11 dB better link budget

Deep penetration

indoors & underground

Integrates into cellular system

Easy deployment

Medium to low data rate

FDD **< 1Mbps**

TDD **< 200Kbps**

Low cost devices

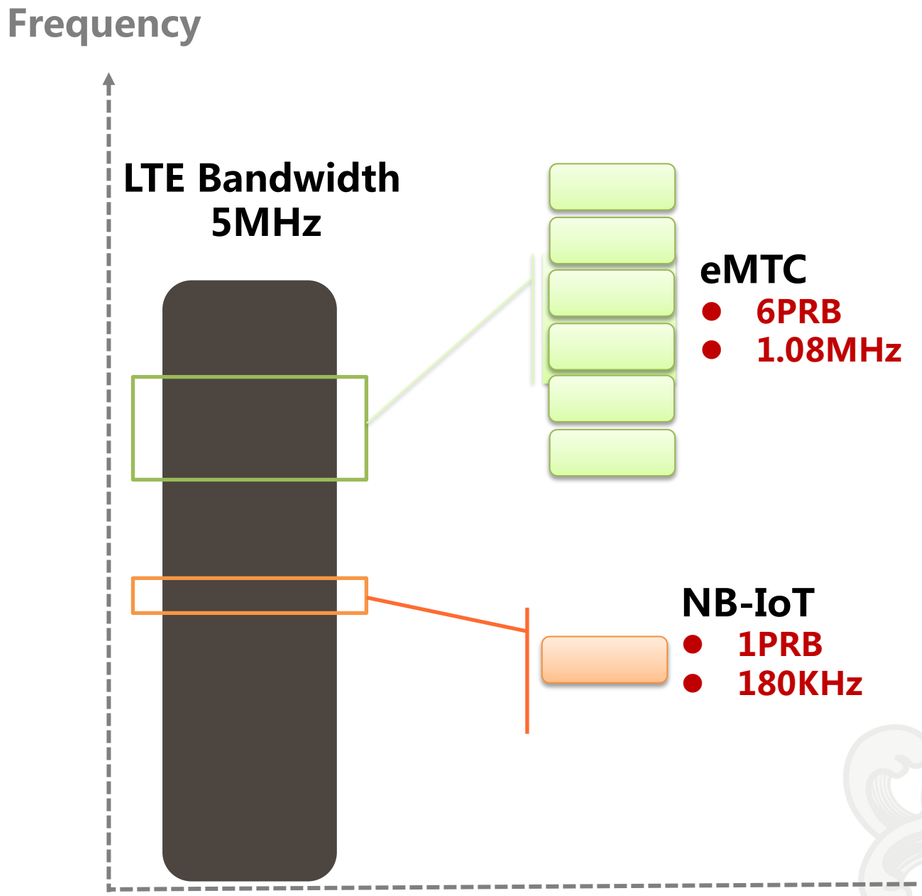
Low power operation

5-10 years

Battery life

Operation Characteristics

- **1 mode only: In-Band LTE**
  - Can be deployed in any LTE spectrum.
  - Coexist with other LTE services within the same bandwidth.
  - Reuse exiting LTE base stations with software update.
- **Support FDD, TDD and half duplex(HD)**
- **Bandwidth 1.08 MHz**
- **Frequency hopping** with narrowband retuning for frequency diversity.



Technologies——eMTC

Use cases

1. deep penetration
2. mobility functions
3. higher data rate

Use Cases

Logistics tracking

- Shipping status
- Real-time monitoring

IoT Industry

Wearable devices

- Emergency call
- Real-time Locating

- Location tracking
- Driving status

IoT Public

Elevator guard

- Emergency call
- Real-time monitoring

Comparison between NB-IoT and eMTC

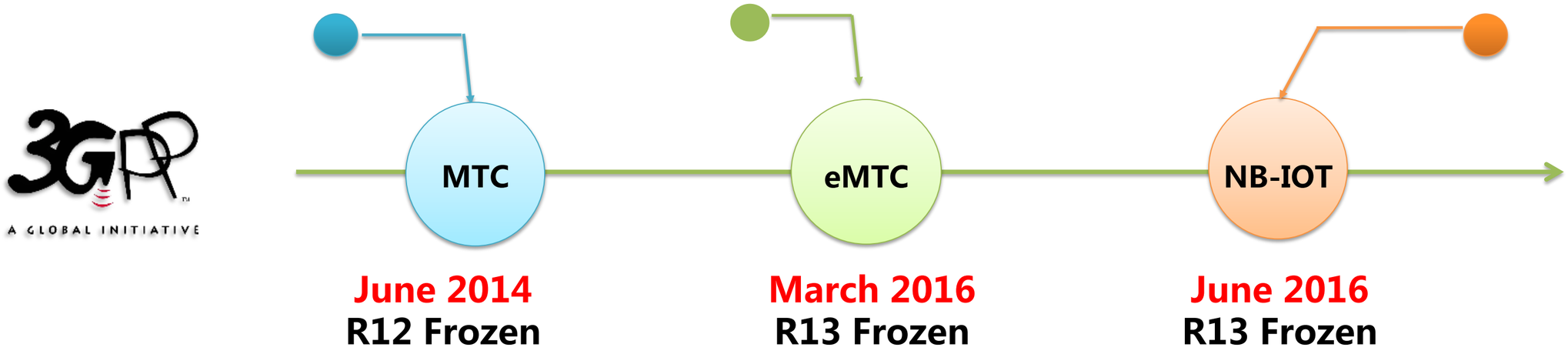





	Coverage	Power Consumption	Low Cost	Data Rate	Mobility	Real Time Interactivity
eMTC	11dB+ (than GSM)	5~10 Years	$5~10	FDD<1Mbps TDD<200Kbps	Support Handover	Support Voice
NB-IoT	20dB+ (than GSM)	~10 Years	<$5	<62.5Kbps	Unable to Handover	Unable

Similar in numbers of connections, deployment convenience, better in peak data rate, mobility and real time interactivity !

Comparison between NB-IoT and eMTC



3GPP NB-IoT and eMTC standardization now complete!

Comparison between NB-IoT and eMTC

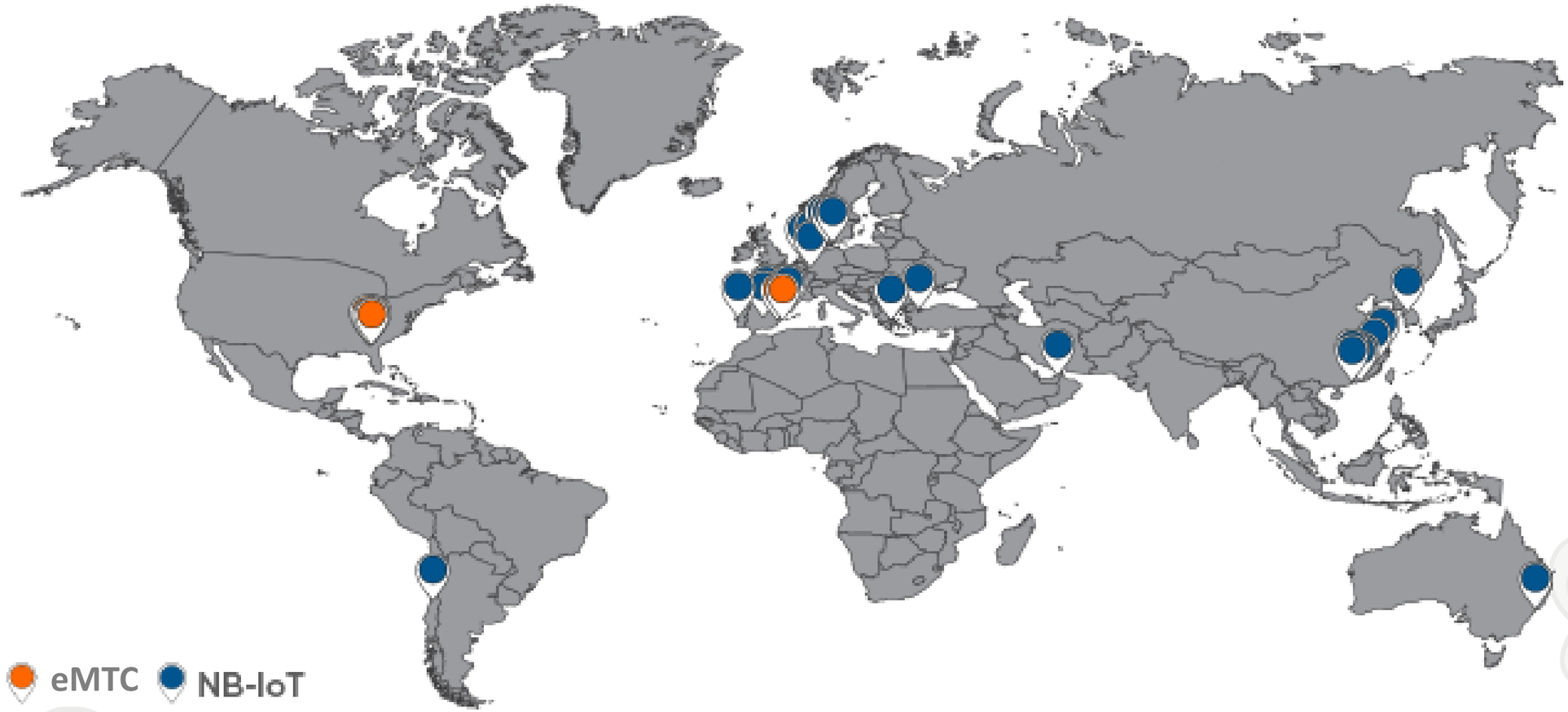
		Network equipment	Terminal/Chipset	Operator
eMTC	FDD	• Mainstream manufacturers worldwide • Q4 2016	• Chip manufacturers • Q4 2016 ~ Q2 2017	• America and Japan
	TDD			
NB-IoT		• Mainstream manufacturers worldwide • Q3 2016	• Chip manufacturers • Q3 2016	• Europe and Asia

Not yet a mature industry chain

Comparison between NB-IoT and eMTC

国家无线电监测中心
The State Radio Monitoring Center

Mobile IoT pilots: 11 eMTC Networks and 28 NB-IoT Networks



Technologies——LoRaWAN

Bigger Coverage

Deep indoor coverage

- Greater than cellular
- Star topology

Low cost

- Minimal infrastructure
- Low cost end node
- Open SW

Multi Usage

- High capacity
- Multi-tenant
- Public network

Low power operation

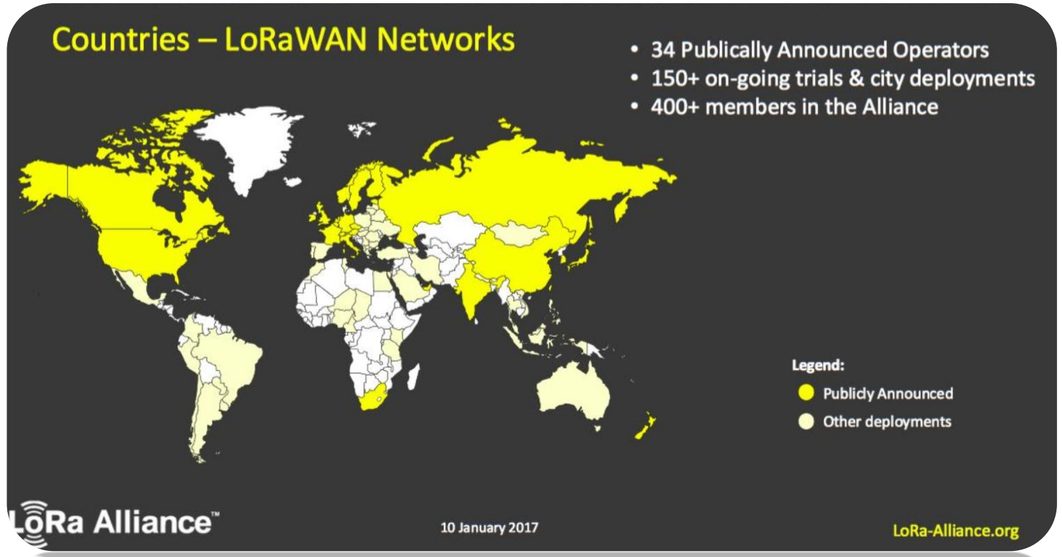
10-20 years

- >10x vs cellular M2M

Technologies——LoRaWAN

LoRa Alliance™
Wide Area Networks for IoT

- The LoRa Alliance is an open, non-profit association of members.
- Alliance members collaborate to drive the global success of the LoRaWAN protocol.
- Mission: to standardize low Power Wide Area Networks.
- “Enable things to have a global voice”



Technologies——Sigfox

Operates on sub-GHz, ISM bands

- 868MHz in Europe/ETSI
- 902MHz in the US/FCC.

Ultra Narrow Band radio modulation：

- 200kHz bandwidth.
- Each message is 100Hz wide

Enables long range communications：

- With a 162dB link budget, longer than GSM.

Light weight protocol

- Tailored protocol to handle small messages.

Small payload：

- Uplink messages is 12-bytes.
- Downlink messages is 8 bytes.

Star network architecture：

- A device is not attached to a specific base station.
- Message received by any base station in the range.

Technologies——Sigfox

- An operated telecommunication network, **dedicated to IoT.**
- Launched in **2012**, First in **France**.
- Expansion in **Europe, America, Middle East Africa, Asia-Pacific**.
- Now presence in **60+ countries**.

- **Bidirectional** communication. Initiated by the device.
- Designed for **small messages**.
- Energy efficiency.

Spectrum

Unlicensed spectrum

Characteristics

- Low cost /no license fees
- Regulatory limits (EIRP restrictions)
- Non-guaranteed QoS

Disadvantages

- All devices can have access to spectrum, subject to compliance with specified technical conditions
- Short range and delay-tolerant applications are typical use cases

Licensed spectrum

Advantages

- Better Inference management
- Network Security
- Reliability

Categories

- **Mobile operator Network**

  Reuse cellular infrastructure and device eco-system for M2M/ IoT apps

- **Dedicated Network**

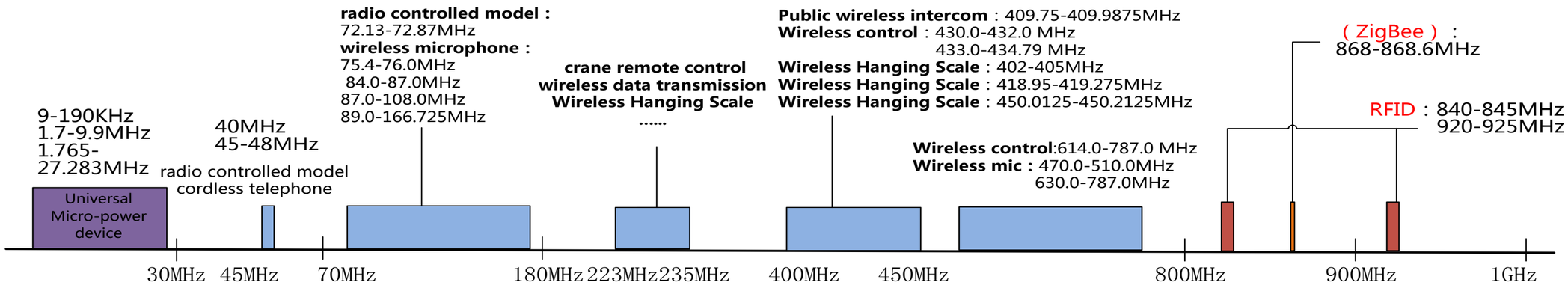
  Private network customized for specific M2M/IoT apps.

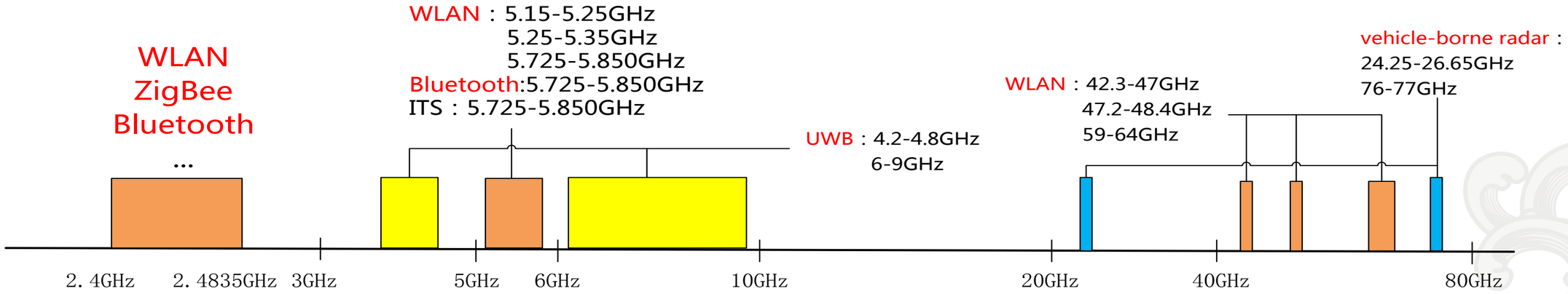
Technology	Standard	Spectrum bands
NB-IoT	3GPP	Band 1, 3, 5, 8, 12, 13, 17, 19, 20, 26, 28 (FDD mode only for R13)
eMTC	3GPP	Band 1, 2, 3, 4, 5, 7, 8, 11, 12, 13, 18, 19, 20, 21, 26, 27, 28, 31, 39, 41
LoRa	LoRa Alliance	EU: 863-870MHz, 433MHz, USA: 902-928MHz
Sigfox	Proposed by France	EU: 868MHz, USA: 902MHz
Bluetooth	IEEE 802.15.1	2400-2483.5MHz; 5725-5850MHz
ZigBee	IEEE 802.15.4	USA: 902-928MHz; EU & China: 868-868.6MHz
RFID, WLAN…		
5G	3GPP	--

Spectrum——Remarks

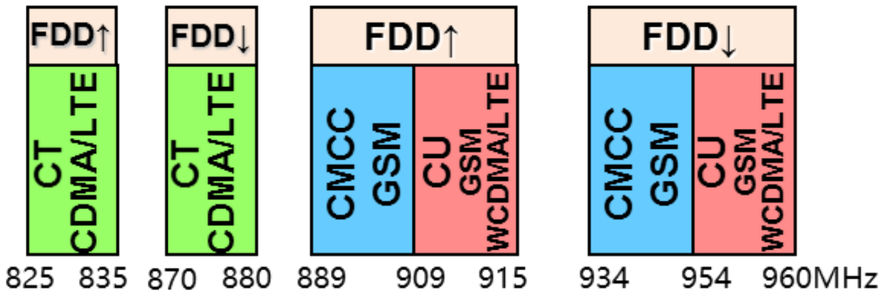
- Frequency bands for IoT are nearly the same:
  - ✓ Licensed Networks: based on 3GPP frequency bands, but various from country to country;
  - ✓ Unlicensed LPWA: Studies mainly in European countries and USA;
  - ✓ SRD: 433MHz, 868MHz, 915MHz, 2.4&5GHz, different in channel assignment for ZigBee and bandwidth for WLAN .

Spectrum for SRD in China

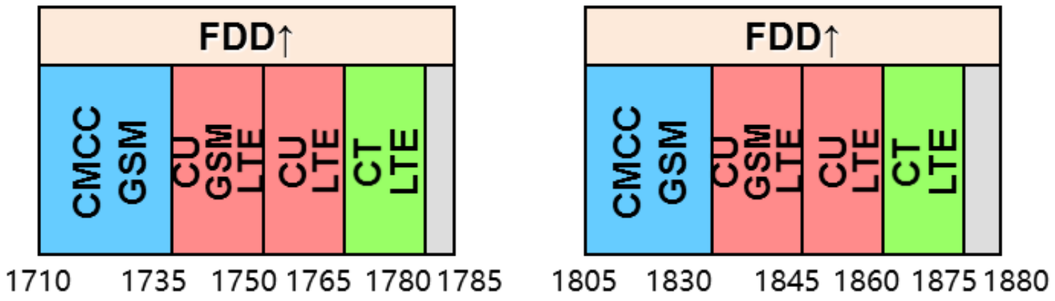


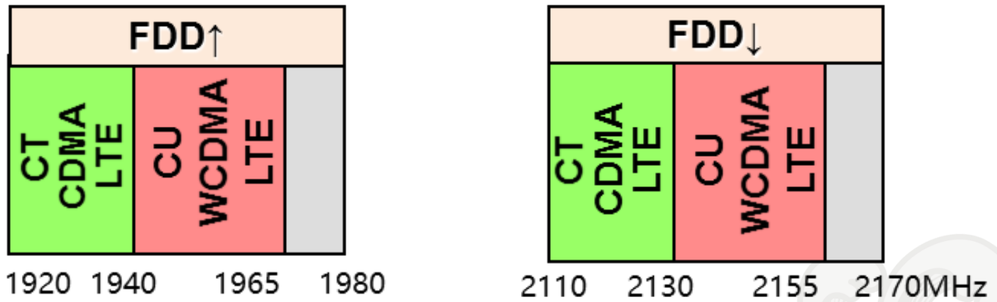


Candidate Spectrum for NB-IoT (FDD) in China



CT	China Telecom
CMCC	China Mobile
CU	China Unicom
Planned, unassigned	





NB-IoT field trial and pre-commercial in China

- **Open laboratory:**
  - ✓ Promote and incubation all kinds of NB-IoT applications
  - ✓ Delivered more than 20 commercial applications

- **Field trials:**
  - ✓ demand-driven
  - ✓ Experimental network deployed in more than 10 cities
  - ✓ Some of the networks consists of hundreds of stations

V2X

traffic information collection and communication

Traffic information collection, monitoring and publishing

Stage1

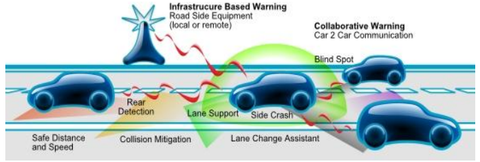
Wired / wireless for RSU communication

Telematics

Cellular communication, providing infotainment, online navigation and remote fault diagnosis

Stage 2

2G/3G/4G Cellular



ITS – Driving assistance

V2V,V2I short-range communication, realize safe assistant driving and danger forewarning

Stage3

LTE-V

VS. IEEE802.11p

V2X driving assistance will decrease traffic accidents by 80%， reduce traffic jam and pollution, greatly improve traffic efficiency

ITS – Autonomous Driving

Realize autonomous, unmanned and safe driving

Stage4

Future technology

5G

1990s' 2000s' 2010s' 2020s' 2030s'

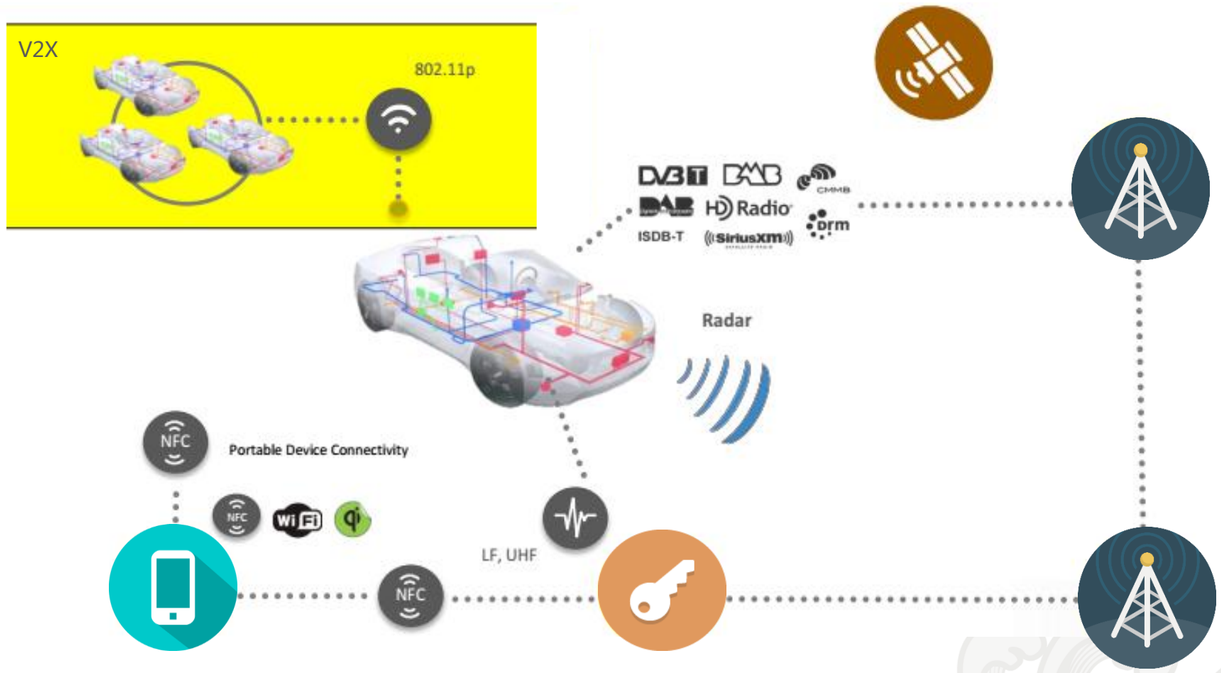
Why V2X?

Objectives

Enable the exchange of information between vehicles and other parties like road network infrastructure, road users, etc.

- Improve road safety
- Increase traffic flow efficiency
- Reduce the environmental impact of traffic
- Provide better traveler information services

Wireless in automotive

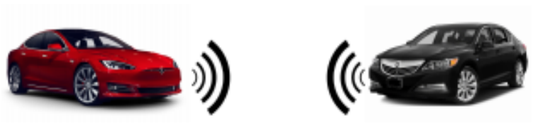


NOT SATISFIED BY simple voice communication or broadcast radio receiver installed in cars

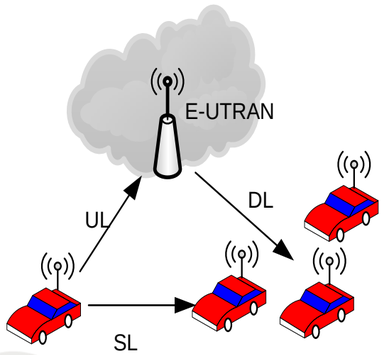
What is V2X?


Vehicle-to-infrastructure (V2I)
e.g. traffic signal timing / priority
Vehicle-to-network (V2N)
e.g. real-time traffic / routing, cloud services
Vehicle-to-vehicle (V2V)
e.g. collision avoidance safety systems
Vehicle-to-pedestrian (V2P)
e.g. safety alerts to pedestrians, bicyclists
Picture courtesy of Qualcomm

V2V (Vehicle-to-Vehicle)

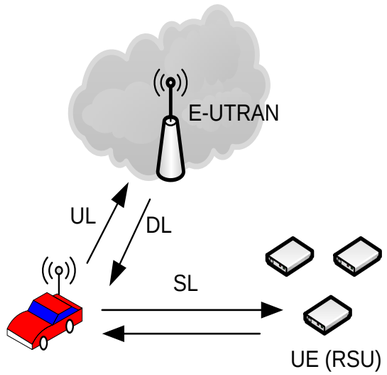


- Covering wireless communication between vehicles.
- Driverless vehicles, advanced driver assistance, collision avoidance.



V2I/V2N (Vehicle-to-Infrastructure)

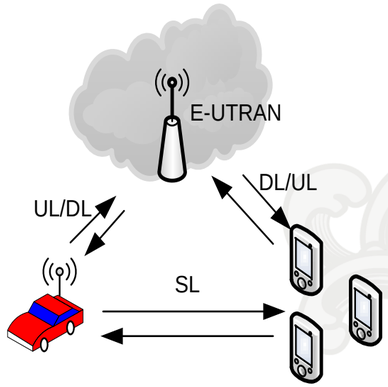
- Covering wireless communication between vehicle and a roadside unit/network.
- Traffic management, speed regulation, safety notification.



V2P (Vehicle-to-Pedestrian)

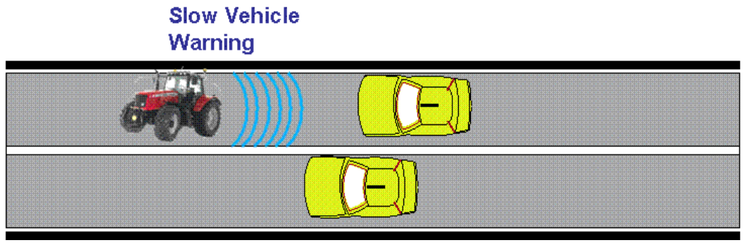
- Covering wireless communication between a vehicle and a device carried by an individual.

(e.g. handheld terminal carried by a pedestrian, cyclist, driver or passenger).



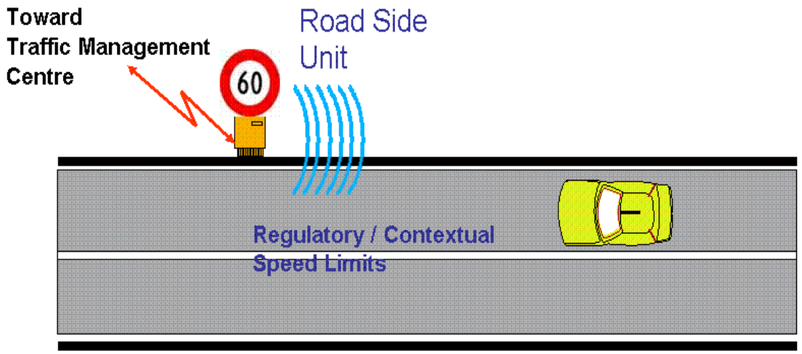
Applications

Road safety



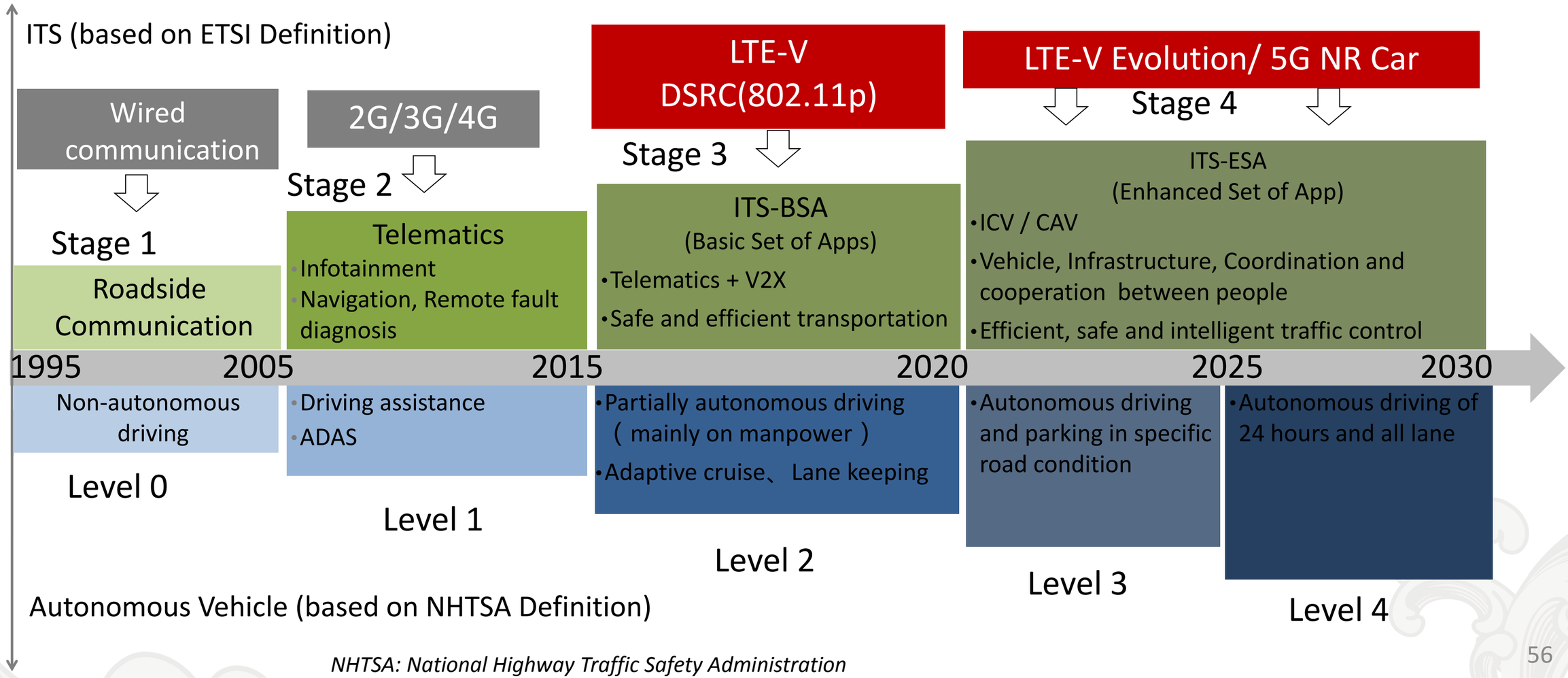
- Forward collision warning
- Emergency vehicle warning
- Emergency stop
- Road safety services
- Pedestrian road safety awareness

Traffic efficiency



- Cooperative adaptive cruise control
- Queue warning
- Automated parking system
- Wrong way driving warning

Technologies



NHTSA: National Highway Traffic Safety Administration

LTE V2X	802.11P
Builds upon existing, ubiquitous LTE infrastructure	**DSRC (based on 802.11p)**
• 5G will standardize post 2020, but LTE V2X here today	• Multiple field trials / 10 years testing, auto industry support, DOT cert.
• MNOs play critical leading roles	• Vehicle OEMs / Transport Agencies playing leading role
• Enhanced range over 802.11p, from 300m to several km	• No evolution path for PHY/MAC layer range, robustness, reliability
• High throughput suitable for connected car applications (entertainment, navigation, etc.)	• Limited high-speed mobility support
• Could leverage DSRC PKI standards for security & privacy, service and application layers	• Lack of standards activity for more advanced use cases such as fully automated vehicles
• Support V2V/V2I/V2P/V2N	• Some apps need ubiquitous RSEs support V2V/V2I
• Velocity :500km/h .250km/h	• Velocity :

Requirements

1. Speed requirement

Support dynamic mobility and high relative velocities between transmitter and receiver

- Appreciable Doppler shift
- Use case at superhighway need to support high speed
- Support for High vehicular speeds
  (absolute velocity 250km/h, relative velocity 500km/h)

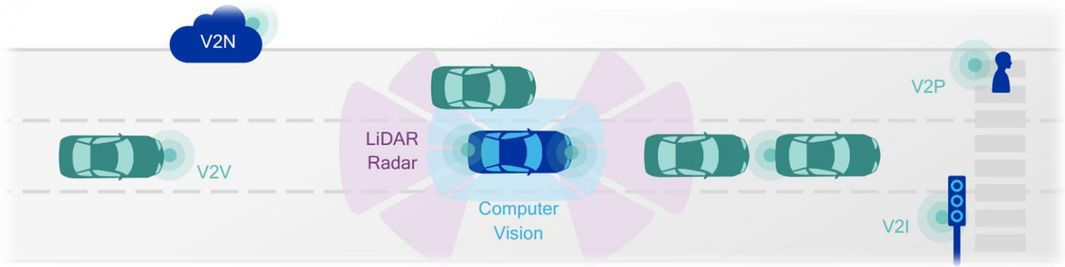
Up to 280 km/h relative speeds - Included LTE Rel.14
(160 km/h absolute vehicle speeds)

Up to 500 km/h relative speeds - 5G target

2. Latency/Reliability requirement

(High reliability and availability**)**

- Extremely low-latency
- ADAS, situational awareness, safety apps
  → require extremely low latency
- Messaging across different MNOs presents a challenge



3. Security Requirements

Bulletproof security and privacy

- Support high reliability without requiring application-layer message retransmissions.
- Support integrity protection of the transmission for a V2X application.

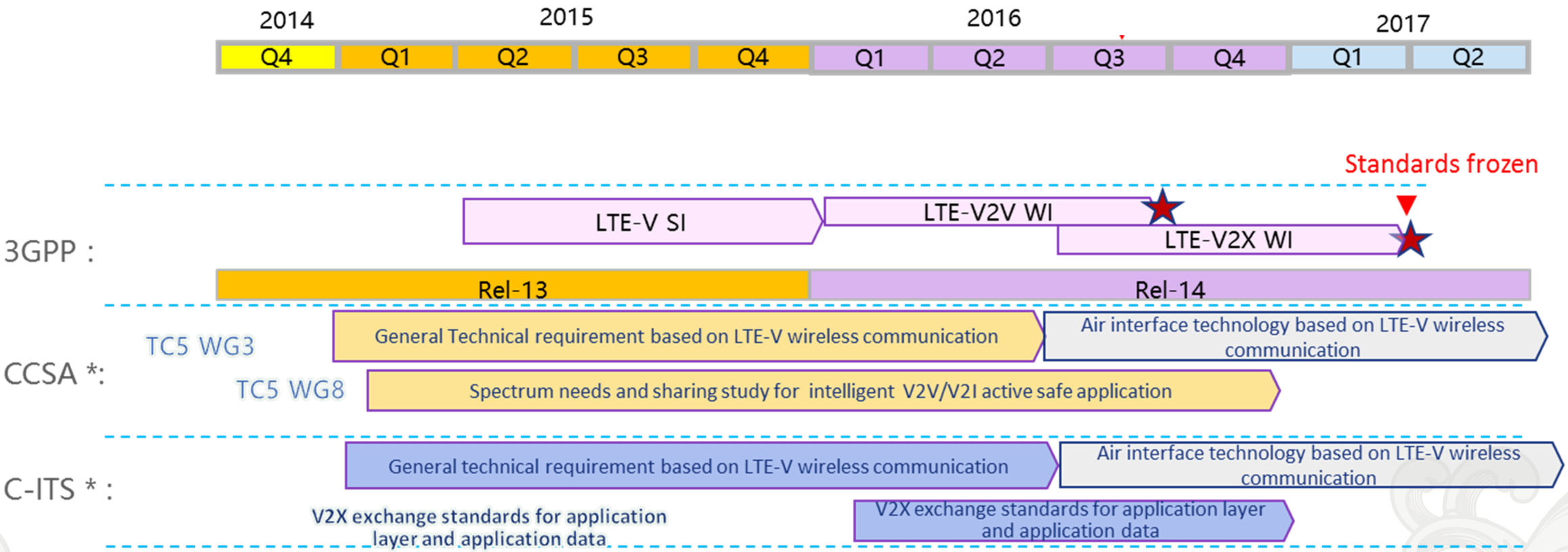
4. Message size requirement

High capacity (multi Gbps) for high message volume

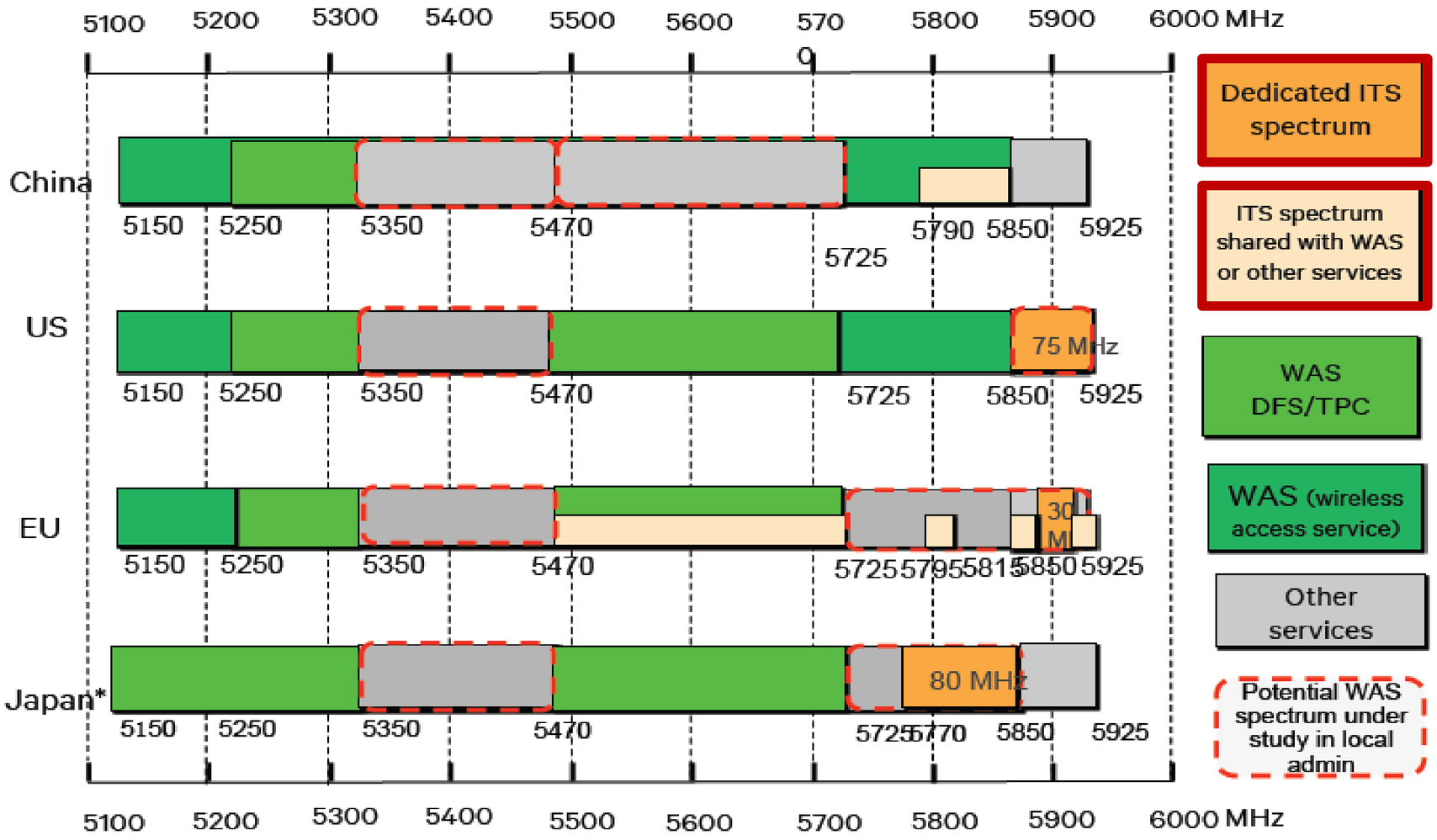
5. Range requirement

Higher link budget(coding gain, transmit power, transmission period) for hundreds of meters.

Standardization



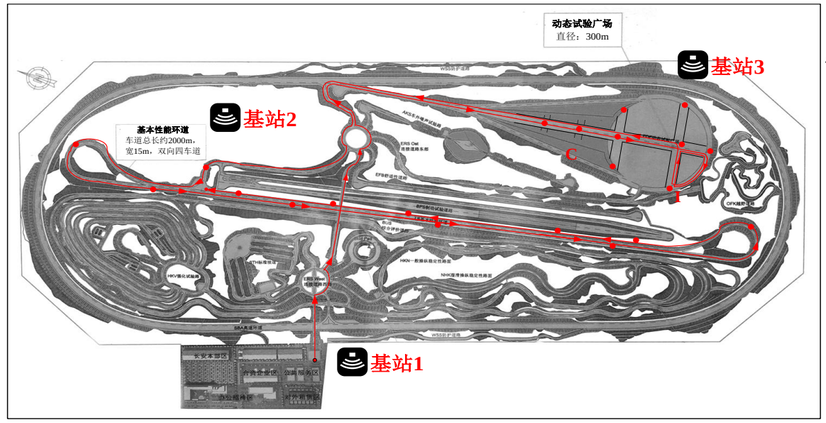
Global V2X key frequency bands: 5.9GHz

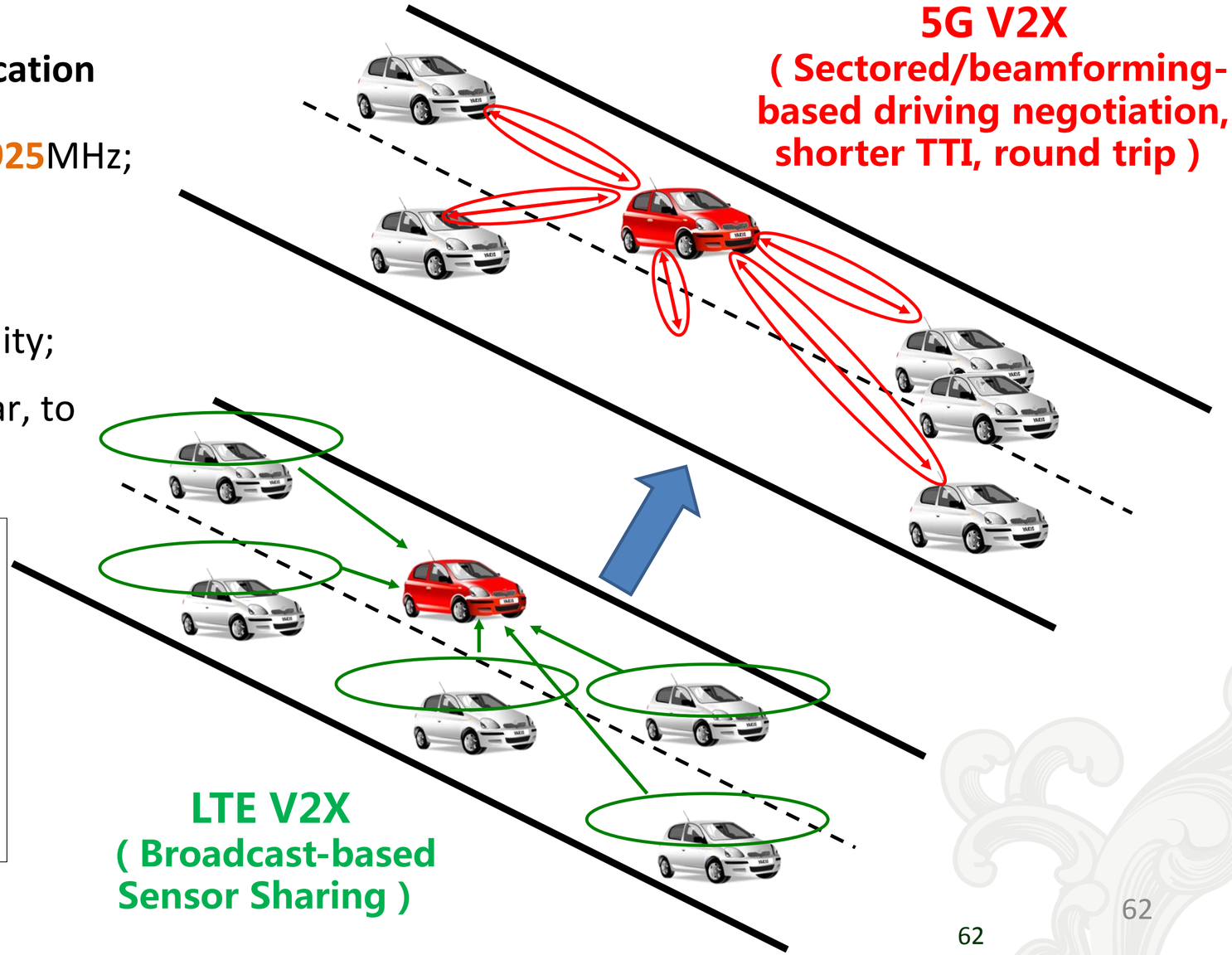


Domestic studies

LTE-V2X/5G V2X is an important URLLC application

- Officially approval of LTE-V trial in **5905-5925**MHz;
- Trial cities: Beijing, Shanghai, Chongqing, Hangzhou, Wuhan, Changchun;
- Trial task: key technologies and compatibility;
- Approval of **77-81GHz** vehicle ranging radar, to promote ITS development.





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- Four stages for ITS
  - ✓ Intelligent transportation system (ITS) is now developing to stage 3, driving assistance, using LTE based V2X and DSRC technologies.
  - ✓ Intelligent transportation system (ITS) will develop to stage 4, Autonomous driving, using LTE-V Evolution/ 5G NR.
- Global V2X key frequency bands: 5.9GHz.
- LTE V2X/5G V2X is an important URLLC application

Thanks