# Recommendations

- Huawei Learning Website
  - http://learning.huawei.com/en
- Huawei e-Learning
  - https://ilearningx.huawei.com/portal/#/portal/ebg/51
- Huawei Certification
  - http://support.huawei.com/learning/NavigationAction!createNavi?navId=_31&lang=en
- Find Training
  - http://support.huawei.com/learning/NavigationAction!createNavi?navId=_trainingsearch&lang=en

# More Information

- Huawei learning APP

# 5G Motivation and Industry Progress

# Objectives

- Upon completion of this course, you will be able to:
  - Describe 5G application scenarios
  - Describe 5G protocol standardization
  - Describe the evolution and deployment plan of the 5G network

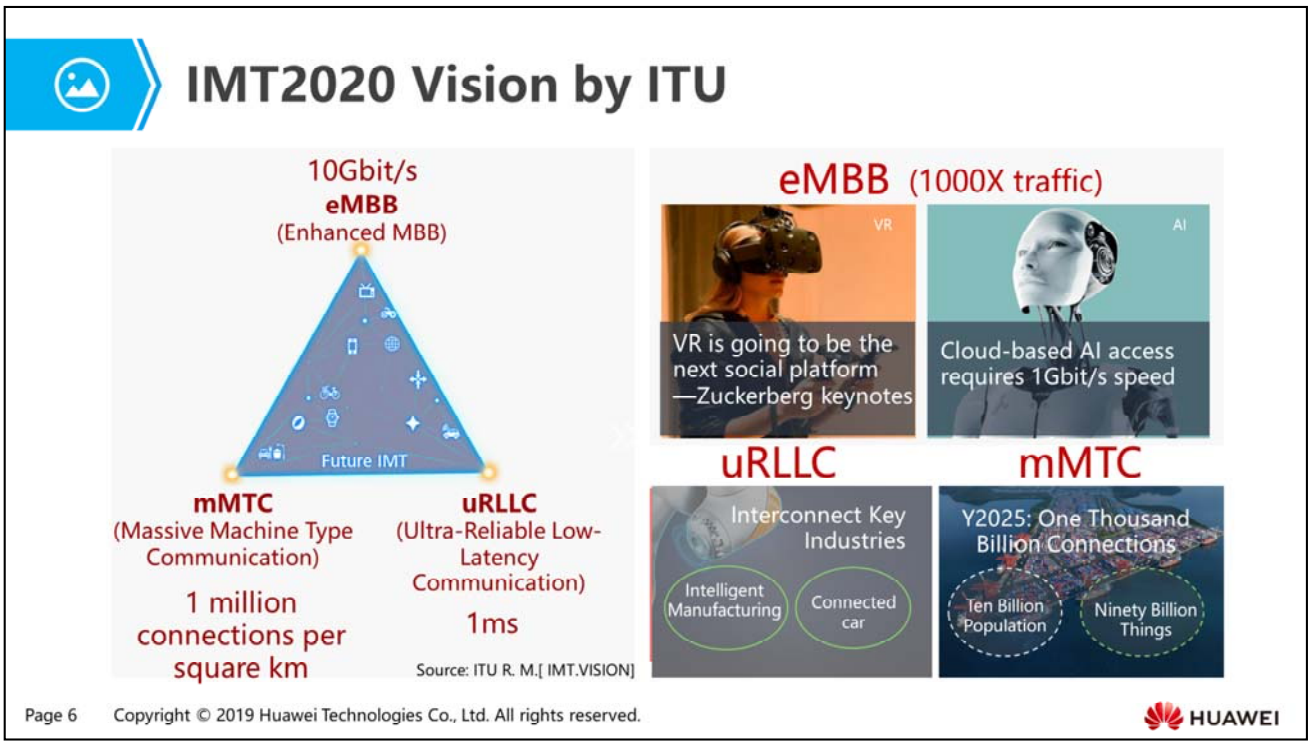
# Contents

# What is 5G?
# Why is 5G required?
# What can 5G do?

# IMT2020

- In the World Radio Communication Conference 2015 hold in Geneva, Switzerland, ITU-R officially approved three resolutions to facilitate the future 5G research process and formally determined the name of 5G is "IMT-2020 ".
- With the launch and implementation of the ITU5G plan, China has accelerated its pace of 5G network development. Under the leadership of the government, China's 5G technology R&D test is under the control of the IMT-2020 (5G) promotion team and is being actively implemented.

# Challenges in the 5G Era




- ITU-R has defined three types of 5G application scenarios in June 2015: eMBB (Enhanced Mobile Broadband), mMTC (Massive Machine Type Communication), and uRLLC (Ultra Reliable & Low Latency Communication). In addition, the capability requirements for 5G networks are defined from eight dimensions, such as throughput, delay, connection density, and spectral efficiency improvement.
- Huawei predicts that there will be 100 billion connections around the world in 2025.

# VR/AR/MR have High Requirements on Speed

Industry representative:

VR: Oculus Rift and Touch

Everything you see is virtual

VR: Virtual Reality

AR

You can see the virtual messages over the real image

AR: Augmented Reality

MR: Magic Leap/HoloLens

You can't distinguish between true and virtual image

MR: Mixed Reality

# Typical Requirements for VR Services

| Standard | Pre-VR (current) | Entry-Level VR (in the next two years) | Advanced VR (in the next three to five years) |
|---|---|---|---|
| Resolution | 1080*1200 | 1920*1920 | 3840*3840 |
| Color depth | 8 | 8 | 10 |
| Frame rate | 90 | 90 | 120 |
| Typical Bandwidth Requirements | 50Mbps | **200Mbps** | 1.4Gbps |

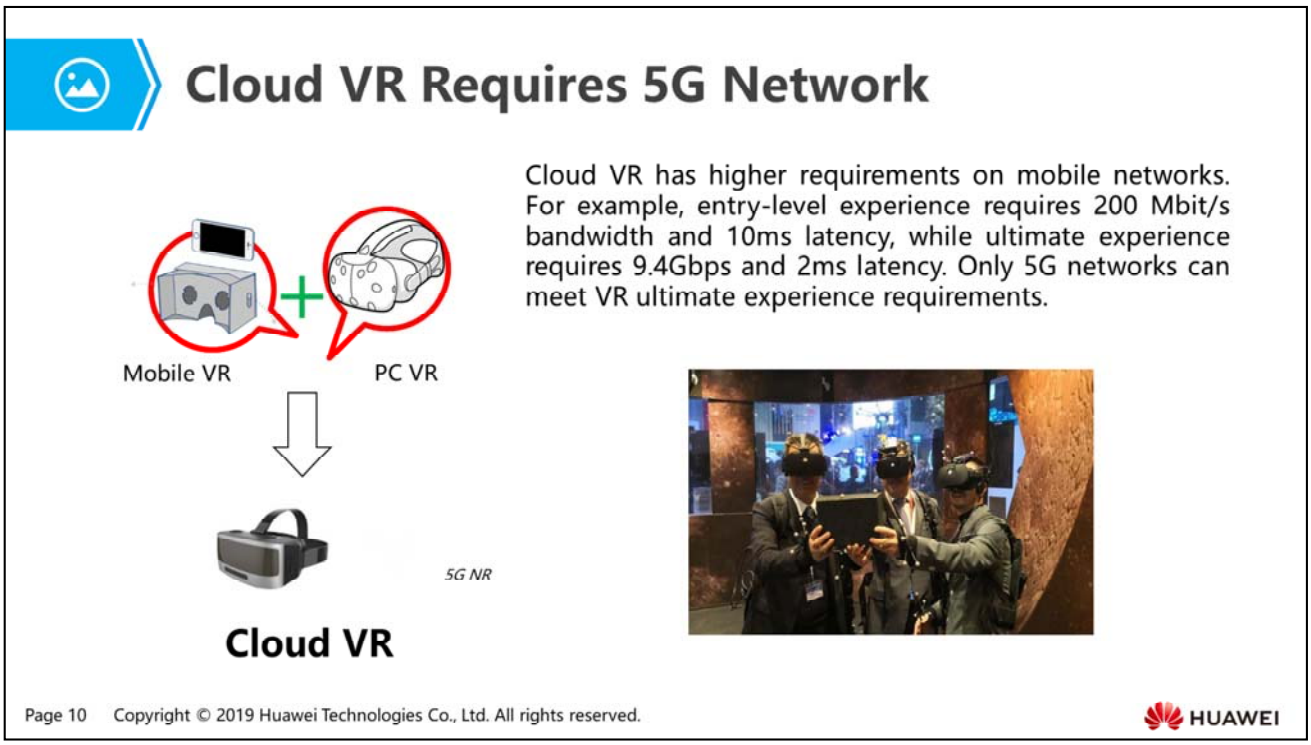
# Evolution of VR

**VR Glasses**

**PC VR**

**Cloud VR**


| | Handset + Glass | Local PC + Fat Terminal | Cloud + Thin Terminal |
|---|---|---|---|
| Experience | Install handset inside the box, Easy to use, but poor experience. | Good video experience. With Cable connected, headset is heavy ,not convenient to use. | Cloud Image rendering with good experience and low requirements to terminal , wireless connection to more types of terminals. |
| Cost | Very Cheap, could be 2USD. | PC+PC VR head display, total cost up to 2000USD. | With the cloud computing service , terminal need to support the decoding and display only , the cost could be lower than 400 USD. |
| Content Copyright | Difficult to control the offline content, and no copyright protection is provided. | Difficult to control the offline content, and no copyright protection is provided. | Easy to control the content, and copyright protection is ensured. |
| Business prospect | Not the mainstream market. | High cost for a single user, content is insufficient, and difficult to promote. | Cheaper cost, easy access, and good ecosystem. |



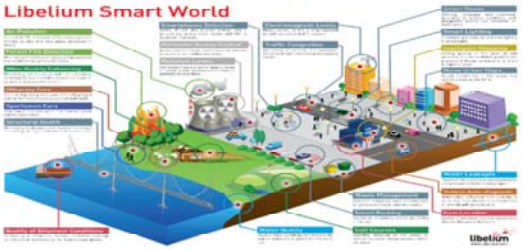

- Huawei Wireless X Labs research shows that Cloud VR, which is rendered by cloud, will be the development trend of VR in the future. In local VR mode, the VR terminal needs to be connected to the local server through cables. The user experience is poor and the cost is high. The Cloud VR implements the wireless function of the terminal and implements image rendering through the cloud server, this greatly reduces terminal costs and improves user experience. Cloud VR poses higher requirements on mobile networks, including bandwidth and latency. For example, entry-level experience requires 100 Mbit/s bandwidth and 10 ms latency, while ultimate experience requires 9.4Gbps and 2 ms latency, only 5G networks can meet VR experience requirements. Currently, the application scenarios of VR are video and Gaming, which will be expanded to more application scenarios in the future.

# Large-Scale IoT Connections

**Shared Bicycle**

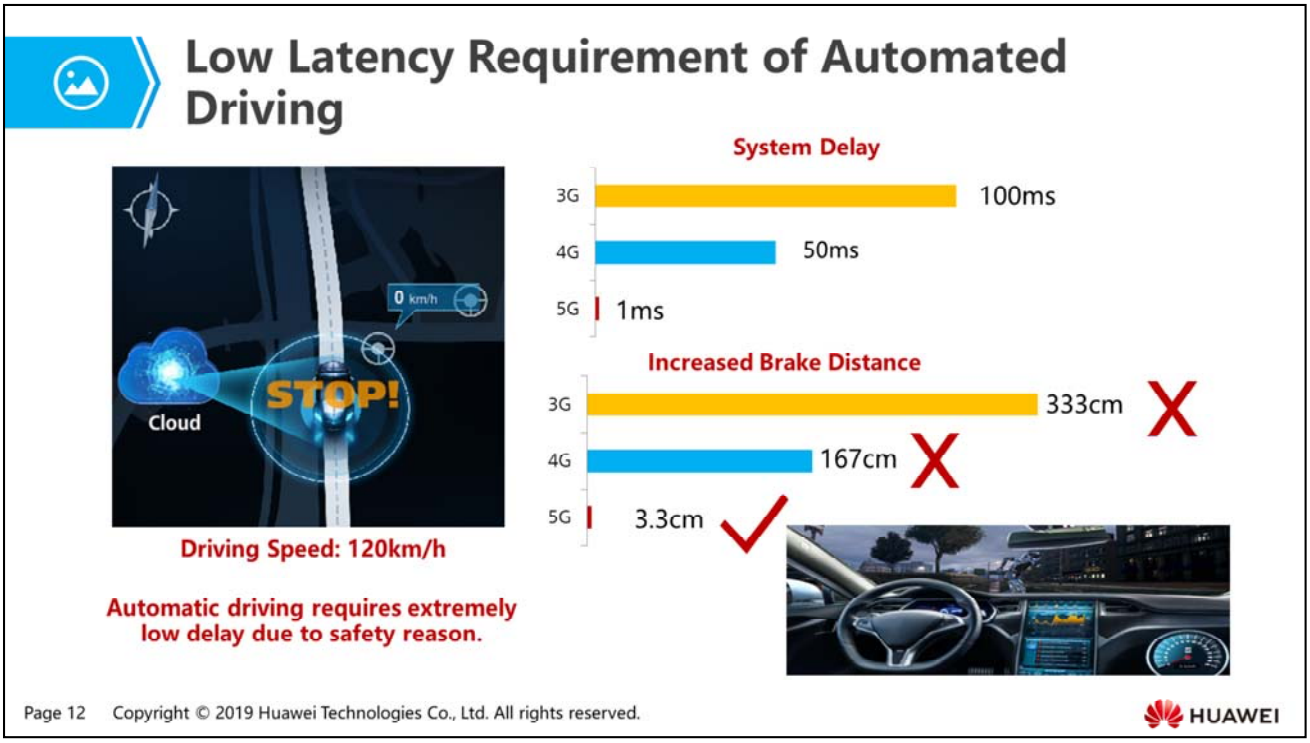
**IoT Builds a Better Connected Society**

**Smart City**




**Smart Meter**

**Smart Parking**




- Delay: The delay of the 4G network is less than 50 ms, which is equivalent to half of the 3G network. However, applications such as automatic driving require a much lower latency than 4G networks.
  - Take automatic driving as an example. Under the existing 4G network delay conditions, car with a speed of 100 km/h requires 1.6 meters to stop down start from discovering obstacle until startup braking system. This is the distance between life and death.
  - Under the 5 G network condition, the distance between the vehicle with the same speed can be reduced to 3.3 cm, which is expected to reach the ABS level.
  - 5G can achieve a ultra-low latency of 1 ms, which will increase the response speed of 5G networks by 50 times than the 4G networks.

# 5G Breakthrough Point

**Key control points: The reliability of automatic driving is greatly improved.**


- Currently, automatic driving is mainly using devices such as video cameras, radar sensors, and laser rangefinder to operate.
- The 5G Internet of Vehicles (IoV) greatly enhances the awareness of the surrounding vehicles. (The system based on the radar sensor camera cannot achieve the non-line-of-sight.)
- HD maps, data exchange between vehicles and vehicle sensors require a large capacity and low latency.

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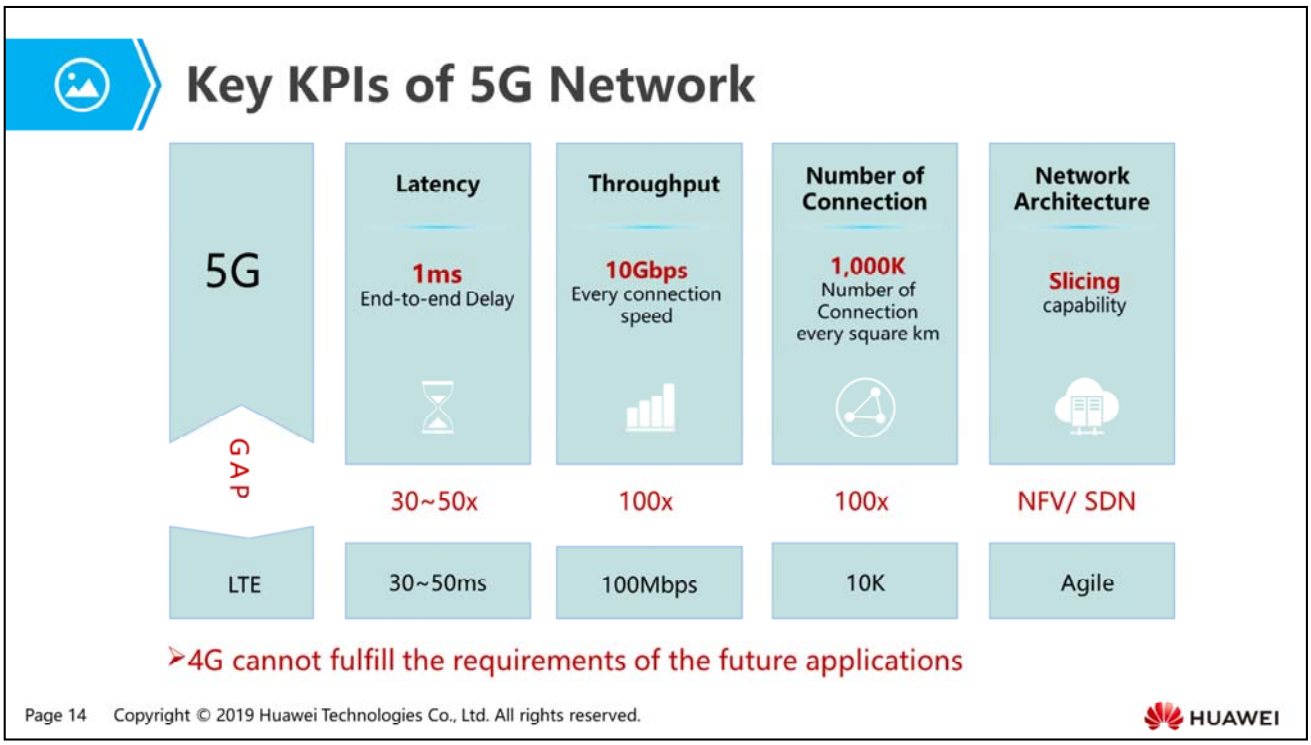
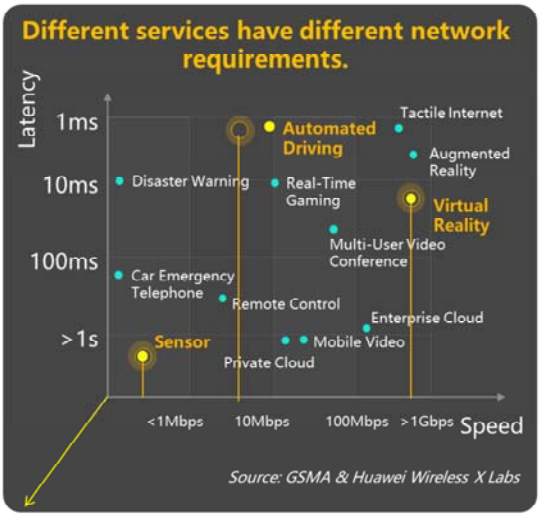
- Currently, automatic driving mainly uses devices such as video cameras, radar sensors, and laser rangefinder to operate.
  - Level 0: Manual driving, no driving assistance system, only reminder
  - Level 1: Assisted manual driving, a single speed or steering control automation (such as fixed speed cruise, ACC).
  - Level 2: In some automatic driving scenarios, the vehicle speed and steering control can be implemented automatically. But the driver must always keep monitoring (for example, maintain at the middle of the lane).
  - Level 3: Conditional automatic driving, can be hands off, driver monitoring system and intervene if necessary.
  - Level 4: Advanced automatic driving, can be eyes off. In some predefined scenarios, drivers do not need to be involved.
  - Level 5: Full automatic driving, full automation, no need for driver (driverless)




- 4G cannot meet future applications requirements, regardless of the delay, throughput, and the number of connections.

# Requirements for 5G Network Capabilities




- Future services have different network requirements. Therefore, the future network must be flexible.
- This figure shows the 5G network capability model defined by 5GPPP.





- Based on the above example, the future services have different requirements on the network. Therefore, the future network must be flexible.

# 5G = Platform


**Consumer**

Universal network service
Personalized and consistent user experience

**Vertical industry**

Easy sharing of 5G architecture
Network slices allocated based on demand

**Carrier**

Easy deployment and O&M
Flexible service, enabling new business

**5G is a platform for new applications, new business models, and new industries.**

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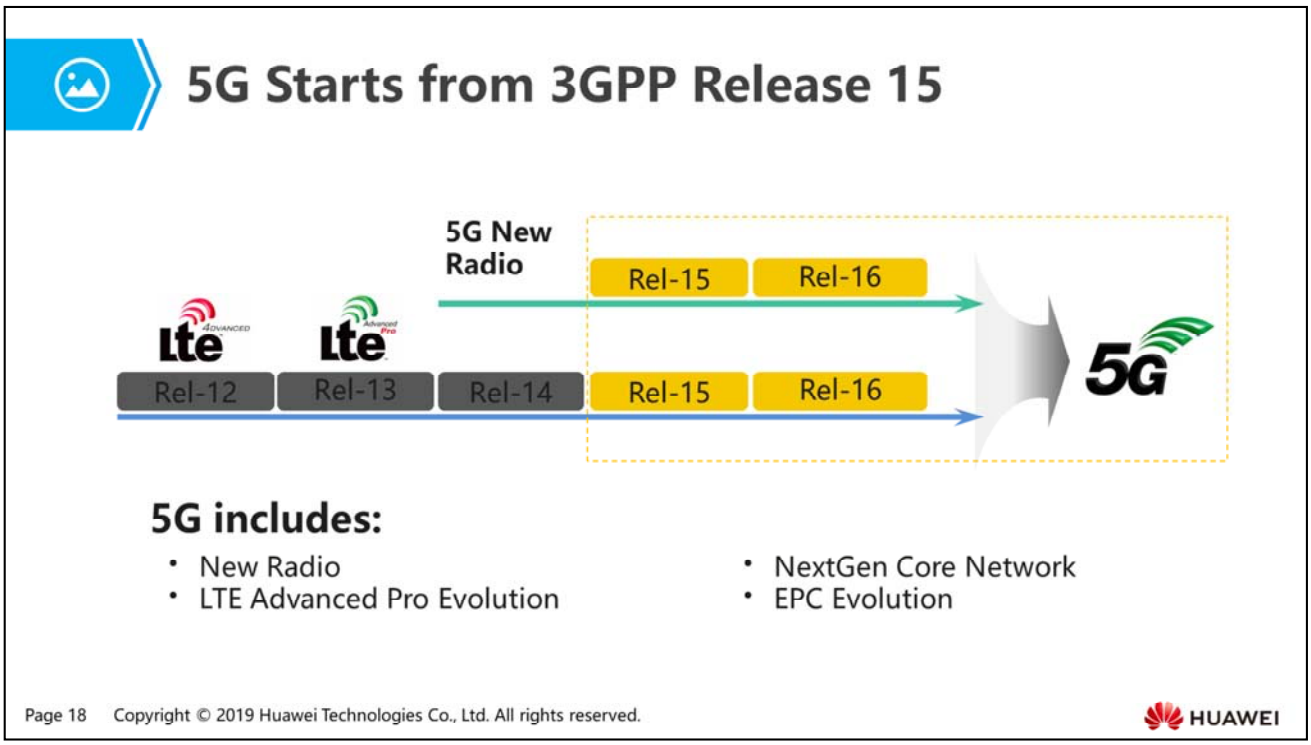


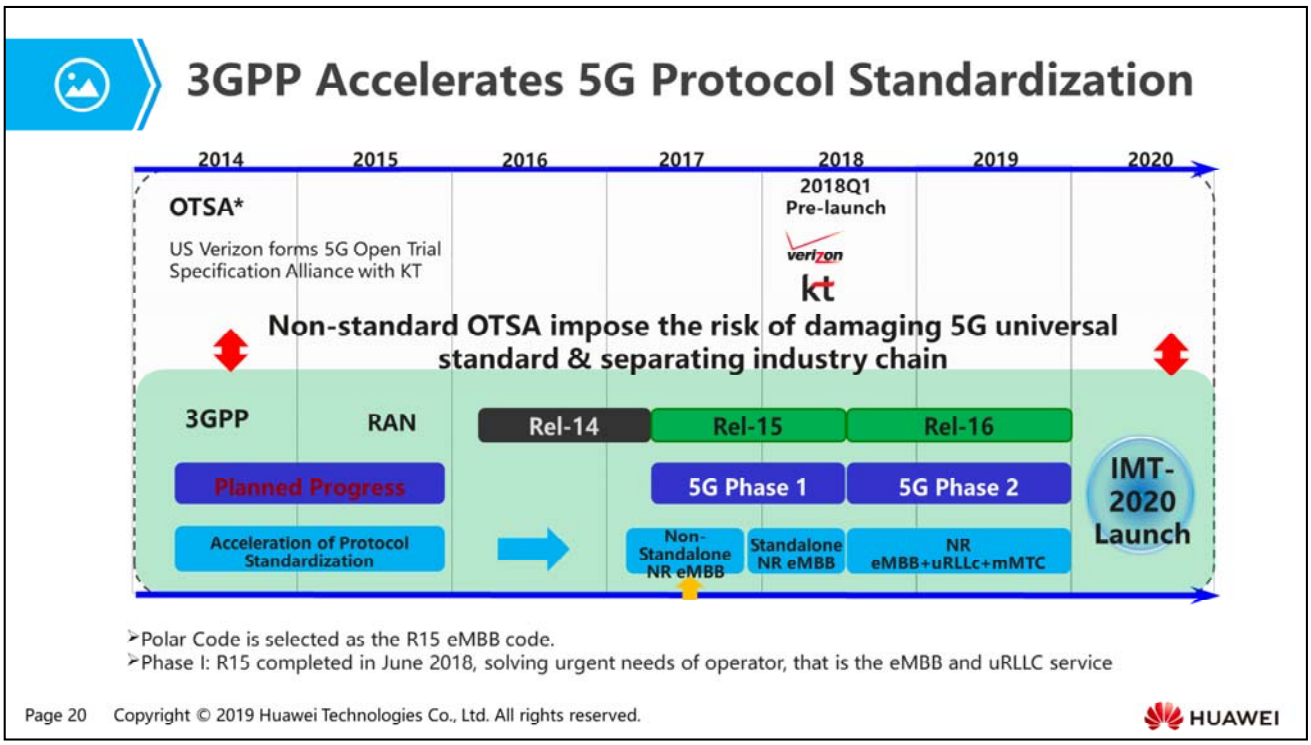

- 5G is including LTE evolution and 5G new technologies, which are defined in R15 and R16.
- This course focuses on 5G new technologies including NR and NextGen core network.
- LTE is from R8, LTE-A is from R10, 4.5G (LTE-A Pro) is from R12, and 5G is from R15.

# Operators of Japan, Korea and Verizon Formed an Alliance

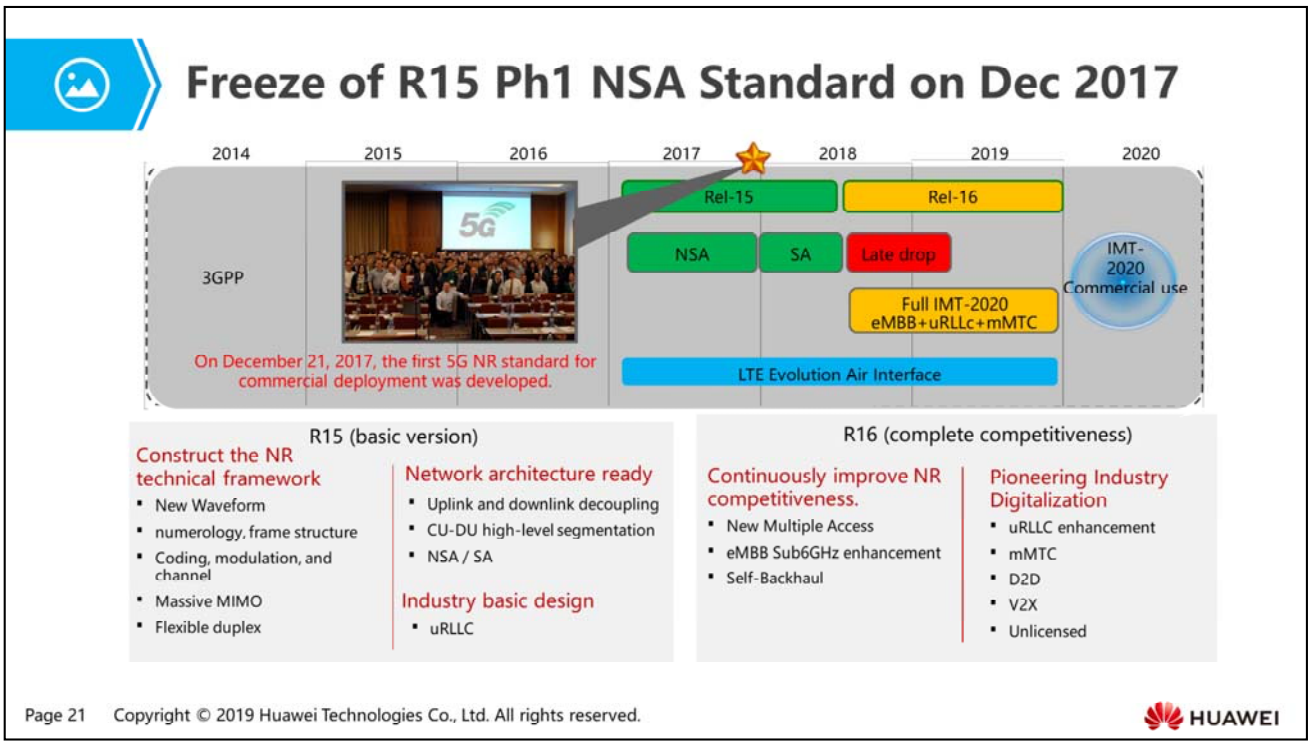
**Four operators forming OTSA, aiming to accelerate 5G standardization and commercial deployment process**

**OTSA:** 5G Open Trial Specification Alliance


- Standardize 5G trial specification together, advancing 5G development efficiently
- Other than operators, the alliance will be joined by network vendor, chipset, terminal and instrument manufacturer
- Promote 28GHz spectrum grant
- Accelerate commercial service solution, advancing 5G development
- Jointly develop and discuss 5G use cases



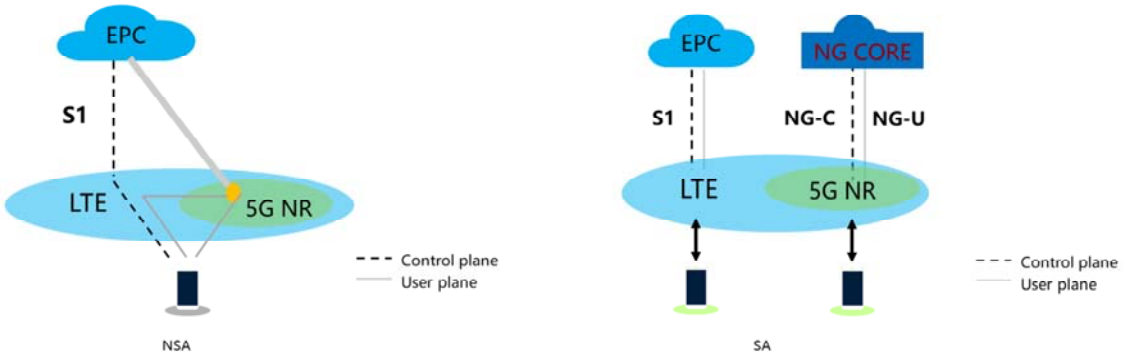

- United States: Verizon is currently undergoing the 28GHz Fixed Wireless Access key technology verification based on OTSA testing standardization (*); Verizon is joining 3GPP afterwards, and the supplier stated they are no longer providing OTSA-based product.
- (* OTSA: 5G Open Trial Specification Alliance was announced during Mobile World Congress 2016 in Barcelona, with the collaboration of Verizon, KT, SKT and DMC, will be focused on technical fundamentals of 5G radio interface trial activities, with the goal of promoting a more inclusive, open, and collaborative approach to developing 5G trial. OTSA formation introduces the risk of standard split. During Mobile World Congress 2017, several of operator and vendor including DCM, KT, SKT, Vodafone, AT&T, BT, DT, Qualcomm, Intel, Nokia, Ericsson, Huawei and etc, declared their support on 3GPP 5G standardization. OTSA was then dissolved.




- New waveform: The F-OFDM technology is used.
- numerology: refers to the change of the timeslot length and frame structure caused by different subcarrier spacing.
- mMIMO: Massive MIMO can support up to 64T64R.
- Flexible duplex: The uplink and downlink configurations are flexible. In addition, the uplink and downlink can be included in the same timeslot.
- New multiple access: such as SCMA
- D2D: Device communicates with the device without a network. Devices can communicate with each other.
- V2X：Vehicle to Everything

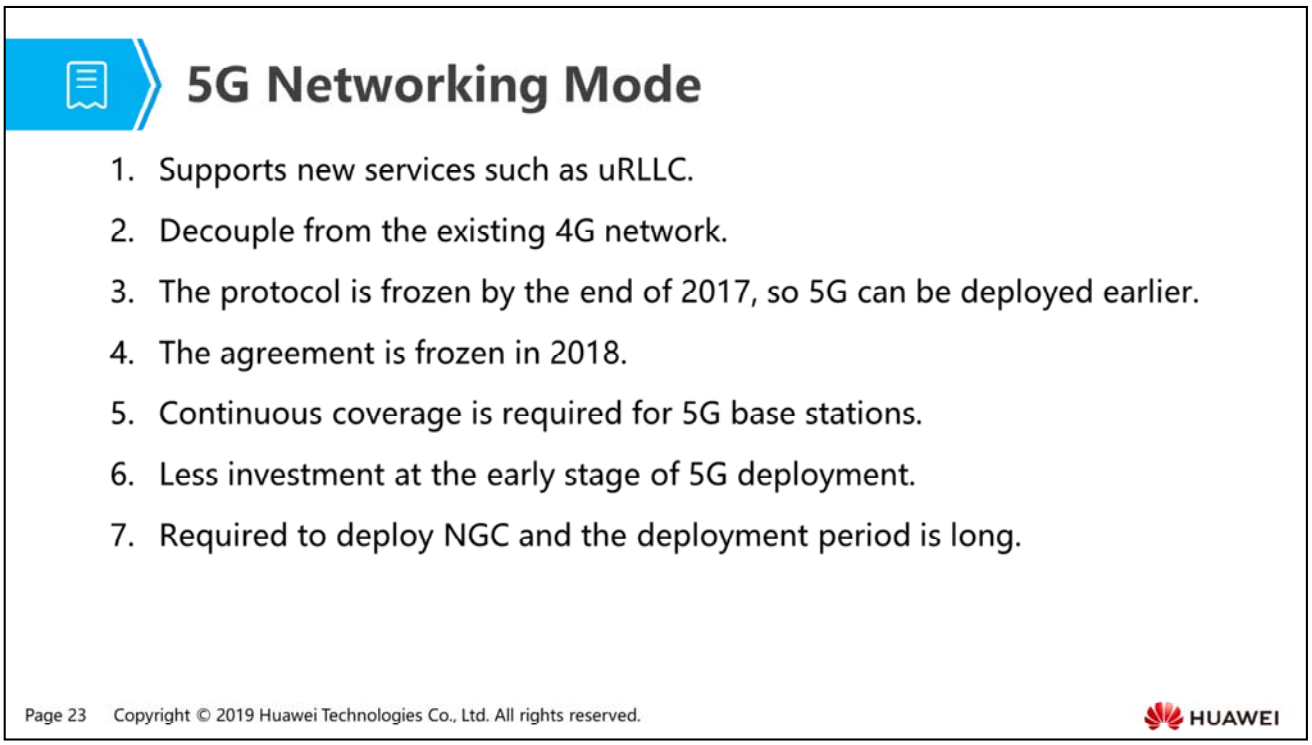
# 5G Networking Mode

- Phase1.1 launches the 5G non-standalone networking architecture (NSA, NR+EPC) and uses the MSA technology to implement collaboration between the two modes.
- Phase1.2 launched the 5G independent network architecture (SA, NR+NGC).



- NSA: NR has no independent control plane but only the user plane.
- MSA (Multiple Stream Aggregation): The terminal can use multiple base stations of the same or different standards for data transmission.

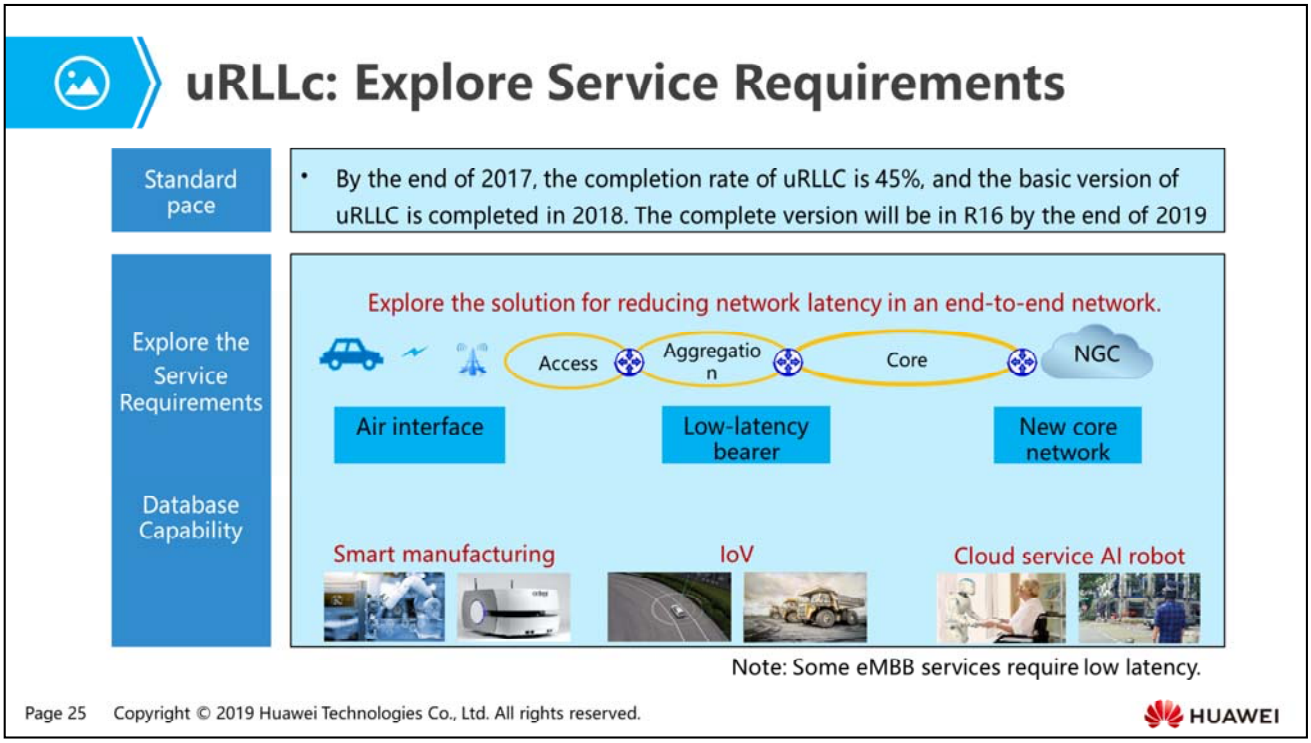



- NSA is number 3 and 6
- Others are SA.

# 5G Networking Mode

Categorize the descriptions into different categories

| | |
|---|---|
| **NSA** | |
| **SA** | |



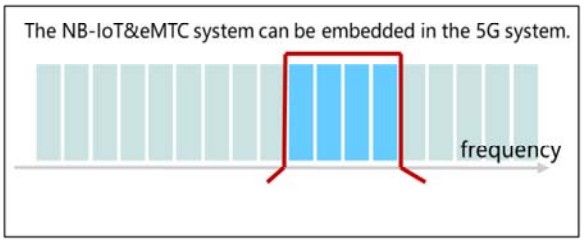

- Rel16 will further improve the Rel15 functions and provides a complete uRLLC low latency and high reliable capabilities.
- uRLLc service explores the industry's network requirements and further improves standards, technologies, and deployment specifications.

# mMTC: Coexist with NB / eMTC

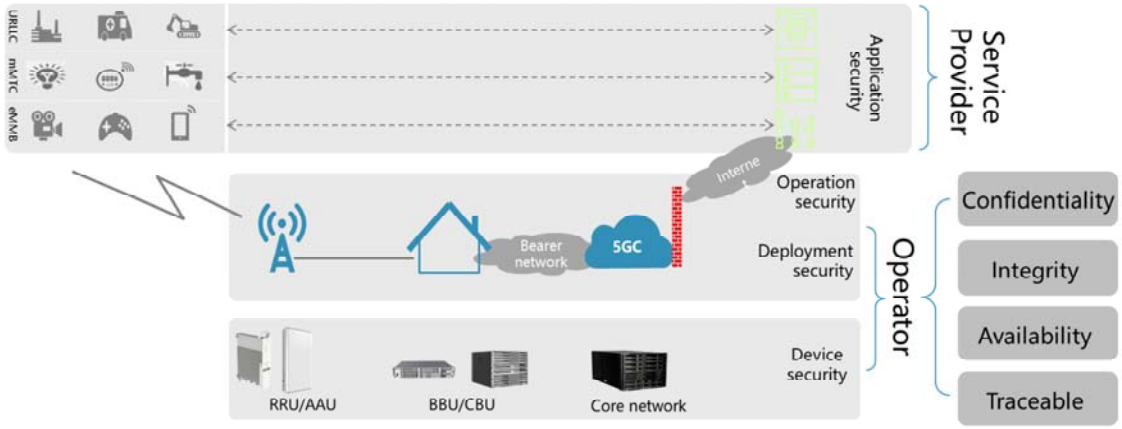
**NB/eMTC can be evolved to the NR system in the future.**

RP-180581 (RAN#79 2018-03-22) is specified in RAN16.0:

- 5G will not be involved in LPWA.
- The NB-IoT/eMTC technology is still evolving.
- 5G will coexist with NB-IoT/eMTC.



# 5G Network Security: Protect User Data and Enable Network Resilience and Business Continuity




- **Confidentiality and integrity:** Protects user privacy information (subscription information and location information), user communication data, and operator' s key data (such as reports and CDRs).
- **Availability:** Identify illegal attacks and reduce the impact of attacks.
- **Traceable:** Record operations for security audit and problem demarcation.

# Enhanced 5G Security

| | Enhanced<br>cryptographic algorithm | Better<br>user privacy protection | Enhanced<br>Interconnection security | Stronger<br>Air Interface Security |
|---|---|---|---|---|
| 5G | 256-bit cryptographic algorithm<br>  | Encryption of users' IMSI<br>  | E2E Protection between PLMNs<br>  | User Plane Integrity Protection<br>  |
| | VS | VS | VS | VS |
| 4G | 128-bit cryptographic algorithm | User IMSI is sent in plaintext. | Similar to SS7 attacks | Attack of user plane |

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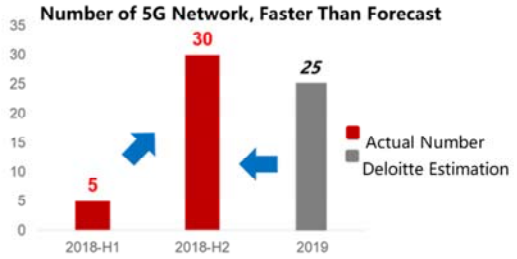
# Market Penetration of 5G will Exceed 3G/ 4G

1. **Users:** It will take only three years for 5G to reach 500 million user scale.
2. **Terminal industry chain:** Only take 1 year to release first 5G terminal. Terminal and network are ready.


**Requirements:** The rapid development of the industry chain drives GSMA to increase the 5G connection forecast from 1.2 billion -> 1.4 billion @2025.

**Deployment**: In 2019, 60+ countries will deploy 5G networks, 50+ spectrum auctions, 40+ terminals and smartphones will be ready.



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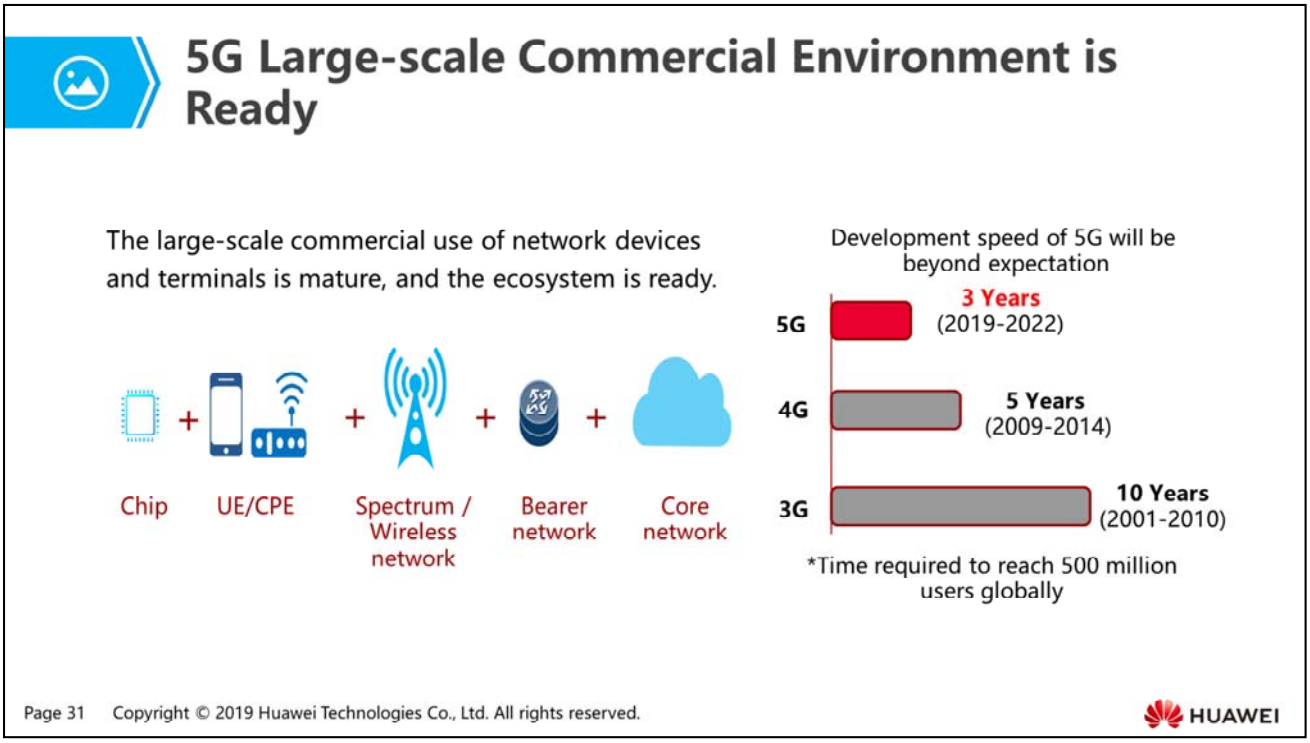
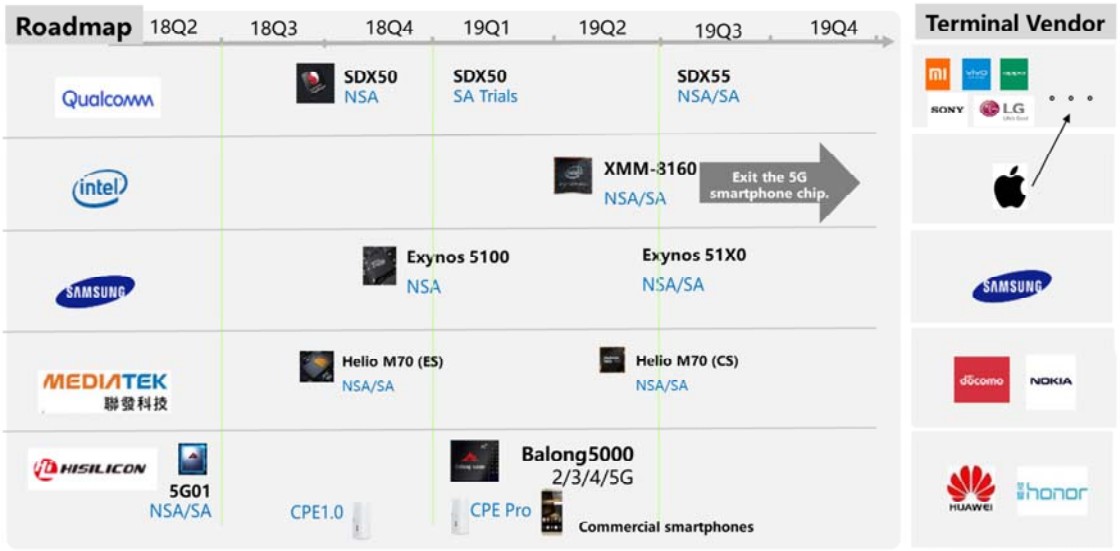
- Application: EE CEO thinks that users will explore and apply new technologies and will not sit and wait for the industry plan.
- Standards: R15 NSA/SA standards are mature. Considering more openness and more improvement, and more industry participation in 3GPP, R16 may be frozen in the first quarter of 2020.




- One important feature of 5G is "simplified ", the ecosystem, network, and business model are simplified. A simplified chip supports all 5G and earlier RATs. The simplified network adopts the co-site, co-antenna, and single-core network modes.
- Because it is simplify, the development speed of 5G will be beyond imagination: It takes 10 years for 3G to reach 500 million users, 5 years for 4G, while for 5G will be 3 years based on prediction.

# 5G Chipset



# Balong 5000

**World-Leading**:2G/3G/4G/5G Multi-Mode Single-Chip Modem

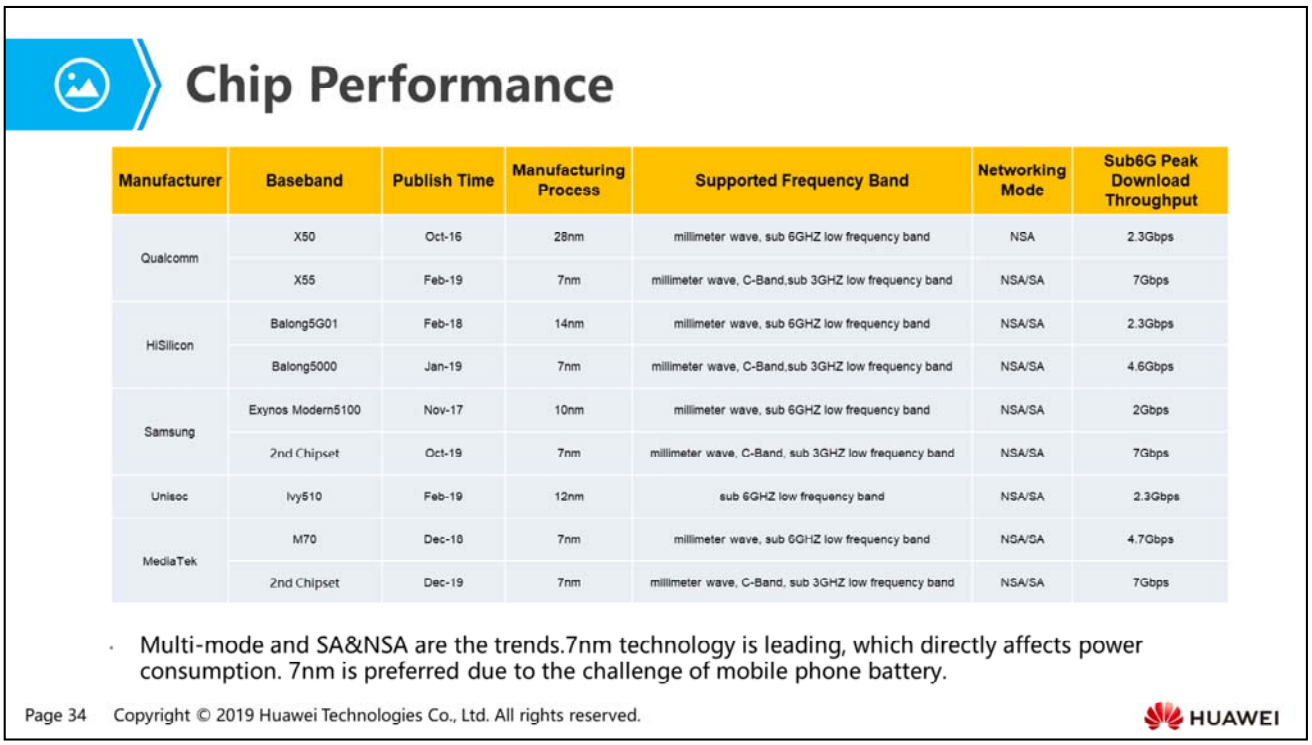
**World's Fastest**: Speeds @Sub-6 GHz 200MHz:
Downlink Speed-4.6 Gbps
Uplink Speed- 2.5 Gbps

**World's First**:
Uplink/Downlink Decoupling


**World's First** : Chipset That Supports Both NSA and SA Architectures

**World's Fastest** : Peak Downlink Speed @mmWave 800MHz: 6.5 Gbps

**World's First**: R14 V2X on 5G Chipset




- The second generation chipset of the mainstream chip vendors is expected to be available in 2019Q4. Other than the C-band and N41 frequency bands, chip vendors have planned for the Sub 3G FDD frequency band. It is estimated that 700M is the first FDD frequency and its terminals will be ready by 2019Q4.

# 5G Terminal


5G CPE Pro

On February 24, Huawei held a new launch event in MWC19. The first 5G foldable mobile phone Mate X was officially unveiled and planned to be sold in the middle of this year.

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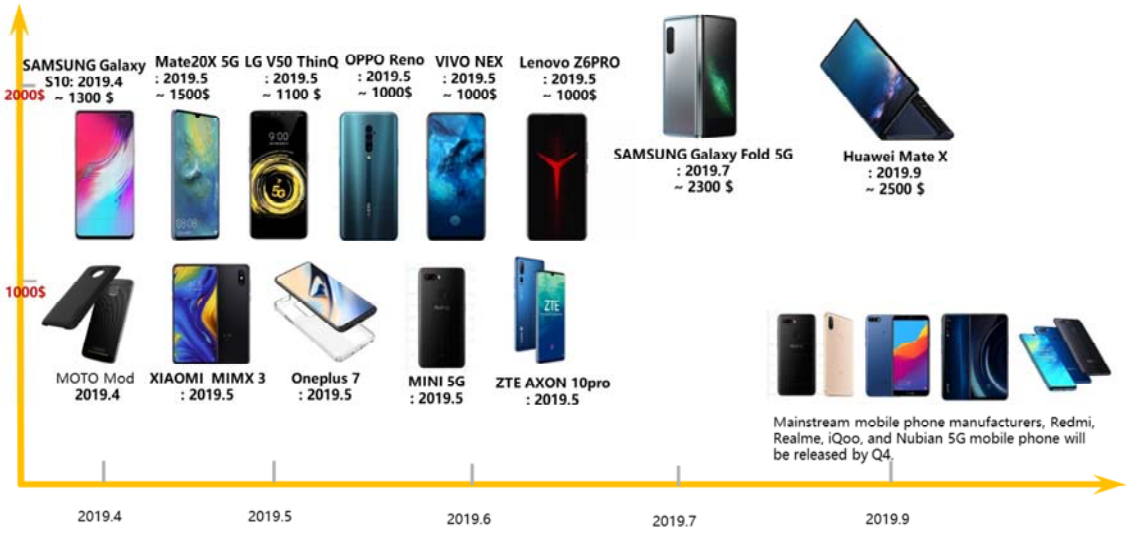
- The Kirin 980 integrated with Huawei Balong 5000 will be installed on Huawei's first 5G foldable mobile phone Mate X.

# 5G Terminal



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# 5G Terminal Released at the MWC in 2019

| Manufacturer | Model | Processor | Expected Launch Date |
|---|---|---|---|
| **Huawei** | Mate X | Balong 5000 | 2019.9 |
| **Huawei** | Mate 20x5G | Balong 5000 | 2019.5 |
| **Lenovo** | Z6 Pro (China 5G variant) | Qualcomm Snapdragon 855 platform with X50modem | 2019.5 |
| **MOTOLORA** | MOTO MOD | Qualcomm Snapdragon 855 platform with X50modem | 2019.4 |
| **LG** | V50 ThinQ | Qualcomm Snapdragon 855 platform with X50modem | 2019.5 |
| **Nubia** | Mini 5G | Qualcomm Snapdragon 855 platform with X50modem | 2019.5 |
| **OnePlus** | OnePlus 7Pro 5G | Qualcomm Snapdragon 855 platform with X50 5Gmodem | 2019.5 |
| **Oppo** | Reno 5G | Qualcomm Snapdragon 855 platform with X50 5Gmodem | 2019.5 |
| **Samsung** | GalaxyFold 5G | No data | 2019.9 |
| **Samsung** | GalaxyNote 10 | No data | 2019.11 |
| **Samsung** | Galaxy S10 5G (North America) | Snapdragon 855 platform with X50 5G modem | 2019.5 |
| **Samsung** | Galaxy S10 5G (Europe and Asia) | SamsungExynos 5100 | 2019.4 |
| **Sony** | Xperia 5G | Qualcomm Snapdragon 855 platform with X50modem | 2019.12 |
| **TCL** | Alcatel7 5G | Snapdragon 855 platform with X50modem | 2019.12 |
| **Vivo** | NEX S 5G | Qualcomm Snapdragon 855 platform and X50modem | 2019.5 |
| **Xiaomi** | Mi Mix 35G | Qualcomm Snapdragon 855 platform with X50 5Gmodem | 2019.5 |
| **ZTE** | Axon 10Pro 5G | Qualcomm Snapdragon 855 platform with X50 5Gmodem | 2019.6 |

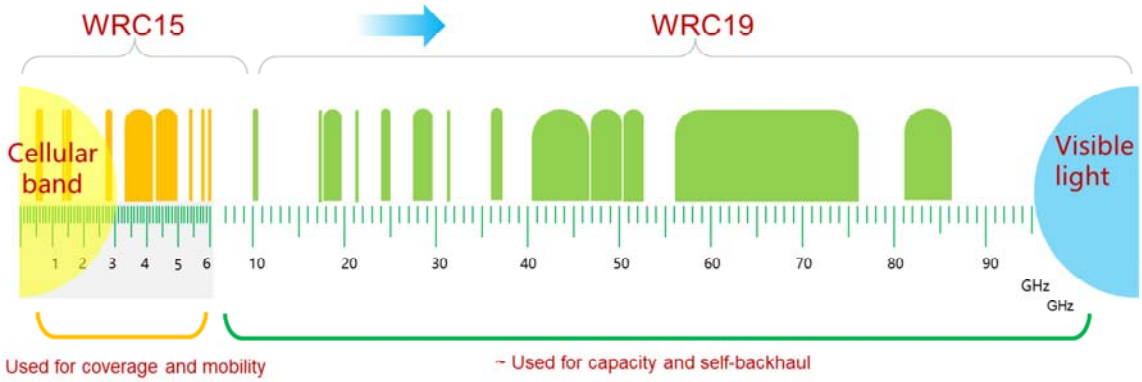
- 3/4G used up to three years to launch the first mobile phone from the standard freeze date while 5G is only used up one year to release the first 5G phone.
- The price will be cheaper in another 2 years.

# 5G Data Terminal CPE

| Manufacturer | Model | Size | Chipset | Frequency | Speed | Launch Date |
|---|---|---|---|---|---|---|
| HUAWEI | 5G CPE | 275*137 | Balong5G01 | 3.4-3.8GHz,2.6GHz,mmWave | DL:~2Gbps UL:~500Mps | 2018.02 |
| HUAWEI | CPE2.0(Indoor) | 215*107*99 | Balong5000 | 3.3-4.2GHz,2.6GHz | DL:~4Gbps UL:~1Gbps | 2019.06 |
| HUAWEI | CPE2.0(Outdoor) | ODU(3.5L,2.5KG), IDU(2L,1.5KG) | Balong5000 | 3.3-4.2GHz,2.6GHz | DL:~4Gbps UL:~1Gbps | 2019.06 |
| D-link | DWR-2010 | TBC | x55 | sub-6 GHz and mmWave | TBC | 2019H2 |
| ZTE | MF-302 | 225*154*87 | x50 | N41/N78 | DL:~1Gbps UL:~100Mbps | 2019Q2 |
| SAMSUNG | 310 | 199*189*39 | S5100 | 27.5-28.35GHz,Sub-6G (TBC) | DL:~1Gbps | 2018.10.1 |
| INSEEGO | R1000 | TBC | x50 | TBC | TBC | 2018.10.1 |
| NOKIA | FastMile 5G | 240*140 | x50 | N78 | TBC | 2019Q2 |

The industry data terminal is mainly CPEs, ZTE and Nokia CPEs will be launched in the Q2.

# 5G Will Aggregate All Frequency Bands



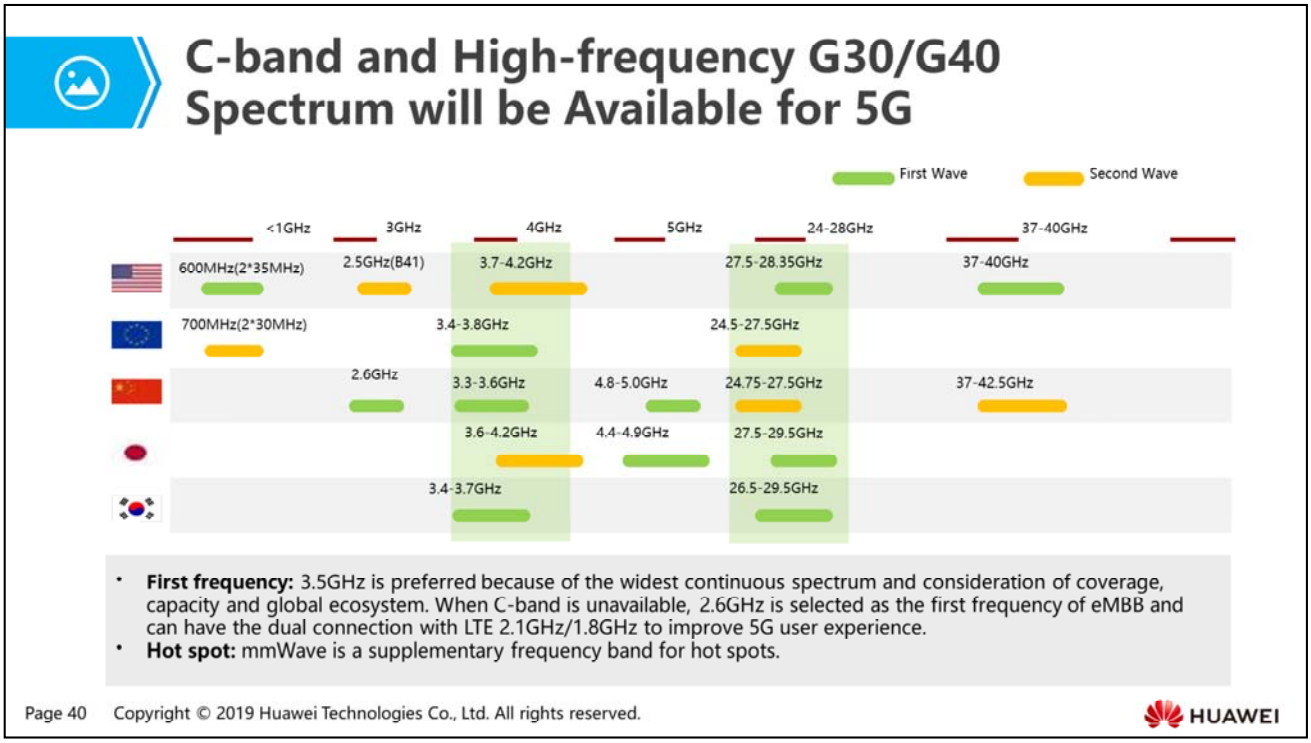

Used for coverage and mobility

~ Used for capacity and self-backhaul

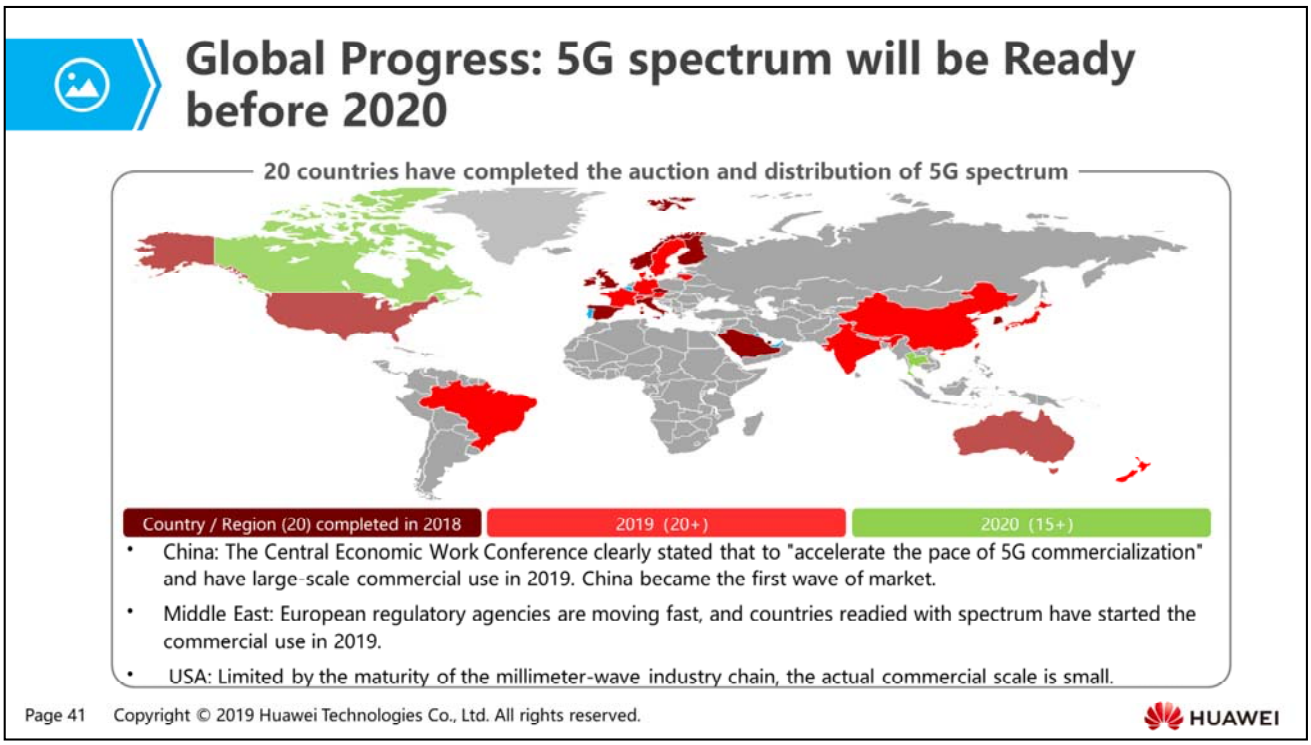
Frequency band C (3.4~3.6GHz) can provide many 200MHz global frequency bands.

Candidate IMT frequency band that exceeds 6GHz WRC 19: 24.25-27.5, 37-40.5, 42.5-43.5, 45.5-47, 47.2-50.2, 50.4-52.6, 66-76, 81-86 GHz

28GHz (27.5-29.5GHz) is used in some industrial frequency bands.

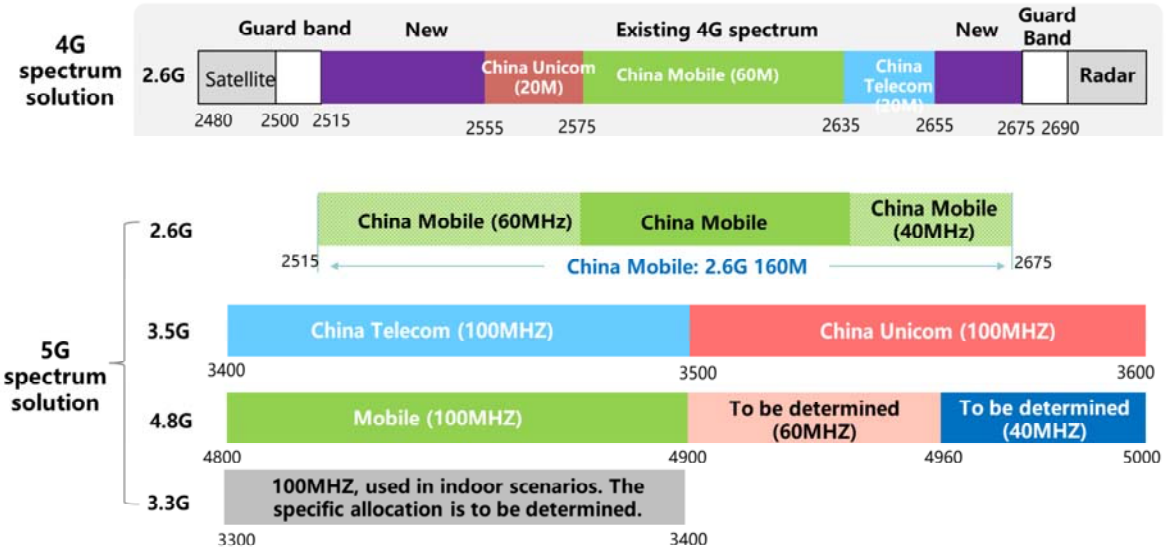



- Spectrum Fragmentation and Radar Satellite Interference
- Secondary harmonic: If C-Band is selected, secondary harmonic interference may occur in the uplink and downlink decoupling /DC/CA.
- Uplink and downlink decoupling: The uplink 1.8GHz is the first choice by considering the industry chain, distance between sites, user experience, and evolution of installed base equipment.
- Roaming frequency: From the perspective of the first frequency of 5G in major regions around the world, C-Band is likely to become a global roaming frequency.




- If the frequency band is not specified, it is referred to C band.
- Many of the C-band spectrums that are auctioned before 2018 are used for LTE TDD, WiMAX, and other fixed services.

# Low-Frequency Band Allocation in China



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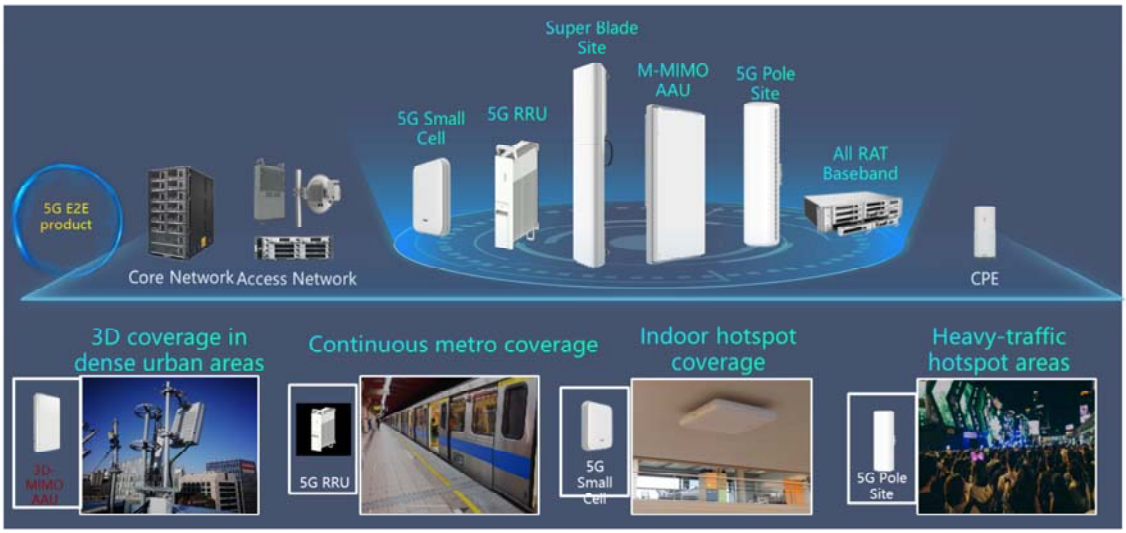
# E2E Solution Required by 5G is Ready



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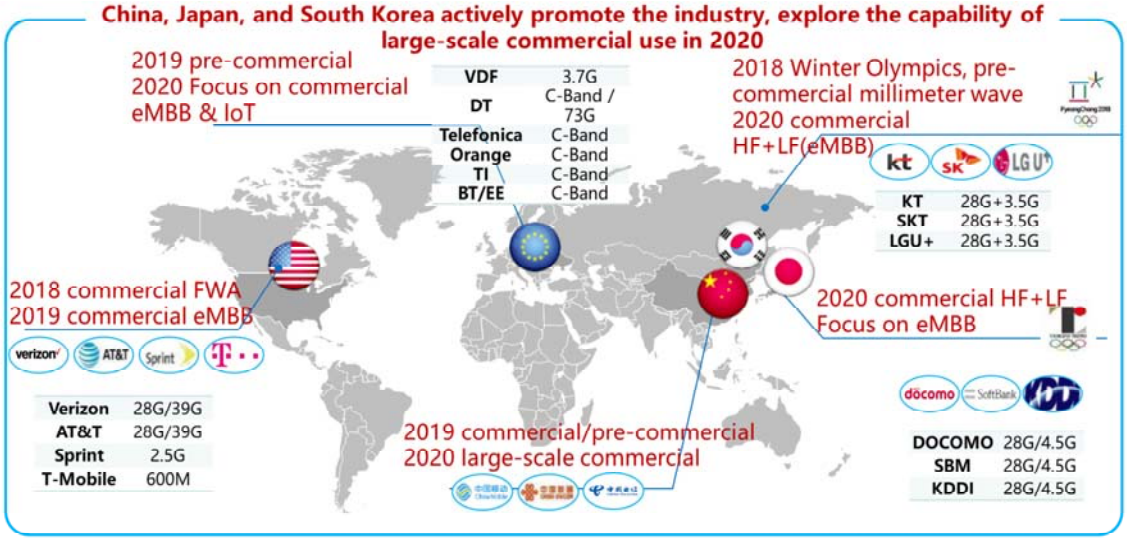
# The First Wave of 5G is Focused on eMBB Services



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# Focus on eMBB Services in the Early Stage

## In the early stage of 5G, focus on eMBB large-bandwidth services

AR/VR/ HD video / UAV application


### Terminal Industry Matured Gradually

**2K screens become a standard feature for mid and high-end terminals**

AR of mobile game "Galaga" was introduced at Apple's new launch conference in 2018 Sept.

**Mainstream vendor is developing on foldable screen mobile phone**

Huawei, FPC, Samsung, Apple, Xiaomi, VIVO, etc.

At MWC19, Huawei unveiled its first 5G foldable screen mobile phone Mate X.

## mMTC extends 4G IoT, uRLLC needs to be nurtured

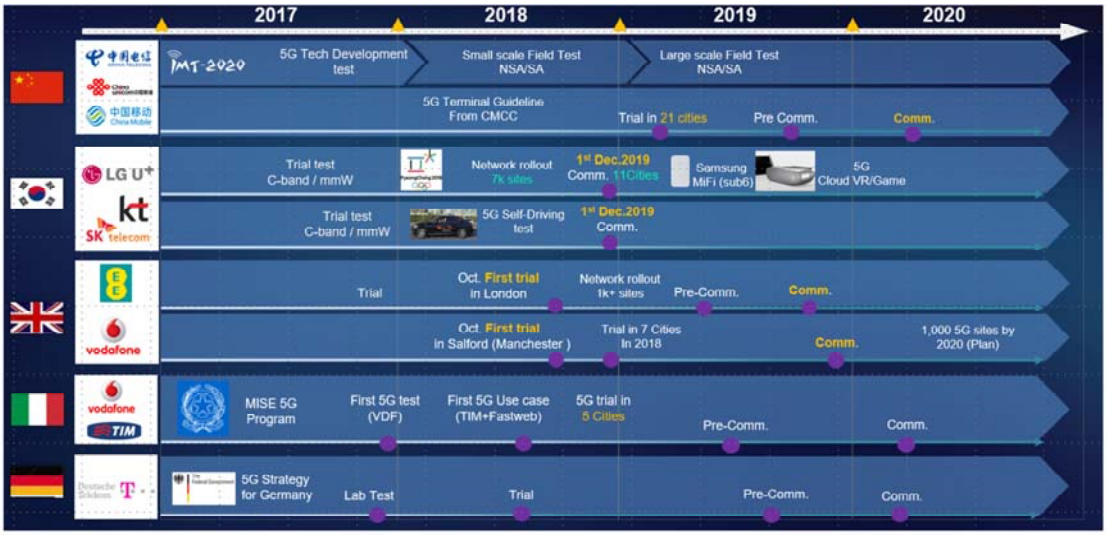
**Cellular IoT Standard Evolution**


- Currently, 5G does not have independent IoT standards and will inherit the air interface standards of NB IOT and eMTC at the initial stage.
- Currently, NB-IoT and eMTC are in the incubation phase. IoT inventory is mainly in 3G and 4G networks. 4G IOT is an important step for 5G IoT.

**Many uRLLC scenarios, typical service application scenarios are still being explored**


- IoV 1 billion connection, 20GB/ vehicle / month; Automatic driving 50 million connection, 200GB/ vehicle / month; 5 million industrial robots / UAVs
- Vertical industry has huge market potential, but the industry is immature and needs long time to develop.

# Global 5G Commercial Plan (1)



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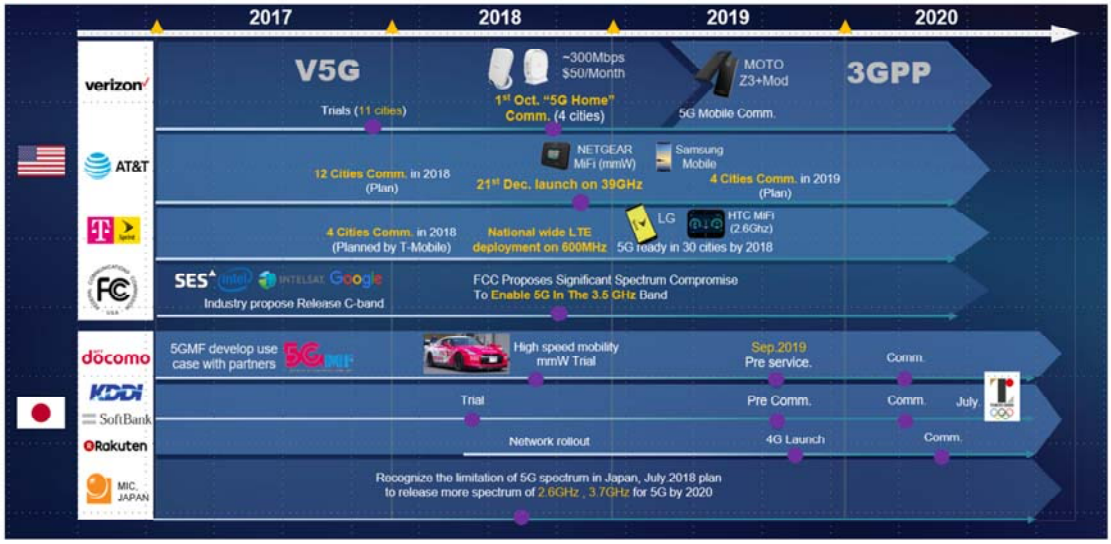
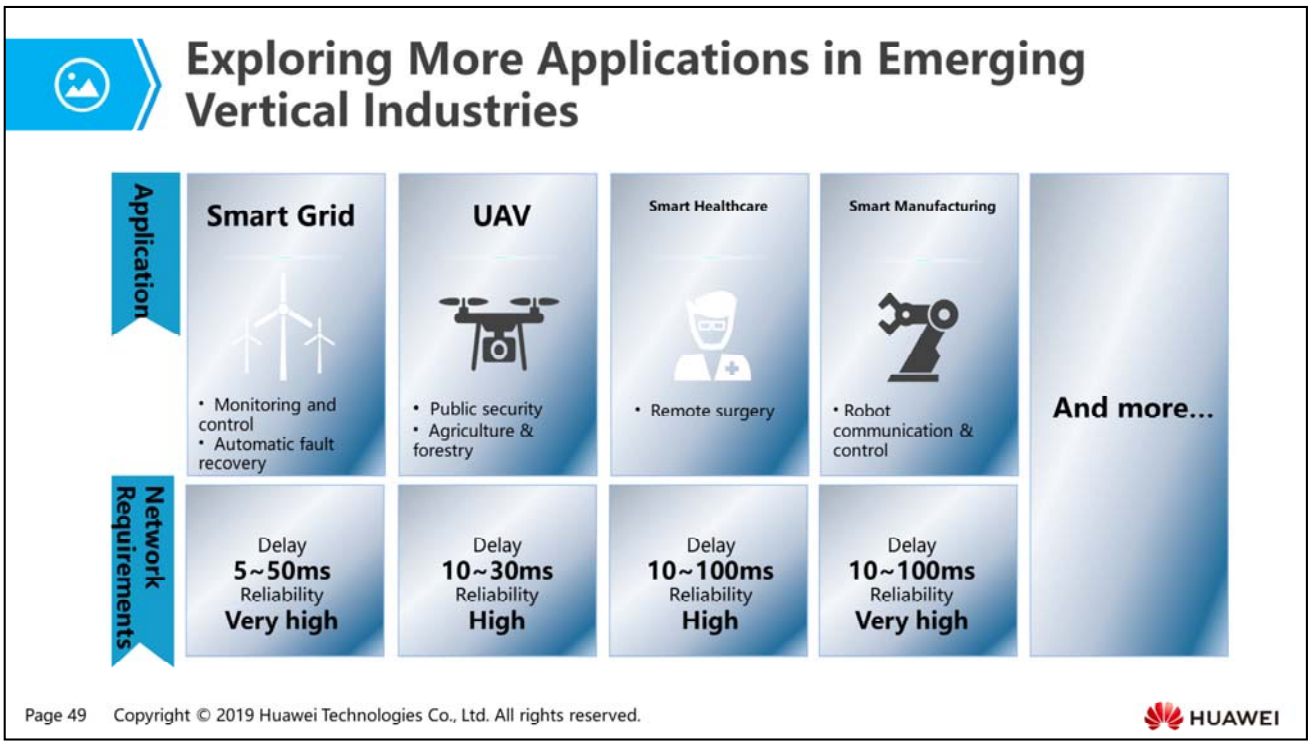
# Global 5G Commercial Plan (2)






- Apart from smart driving, 5G applications in other vertical industries will be introduced.
- Smart grid: The source is the cost of optical fibers. It also requires high reliability and low latency for the network. It mainly focuses on the laying of the last mile. Currently, it has great application opportunities in Europe and China.
- UAV: The value of commercial applications is in agriculture, forestry, and security. To ensure the control of UAVs, the future network needs to ensure low latency and mobility.
- IoT communication is divided into two scenarios which are broadband IoT, which is used for video surveillance, security, and LPWA. Have different network requirements.

# Summary

- Three main scenarios of 5G service: eMBB, uRLLC, mMTC.
- The 5G R15 version has been frozen.
- 5G terminal products and networks are ready.

# 5G Network Architecture and Key Technologies

# Foreword

- 5G poses new requirements for key network capabilities. Wireless network and air interface are one of the most important criteria for achieving 5G network.
- In this course, we will discuss about:
  - What are the key capabilities of the 5G network?
  - To meet these key capabilities, what are the changes in the 5G network architecture and air interface? What key technologies are introduced?

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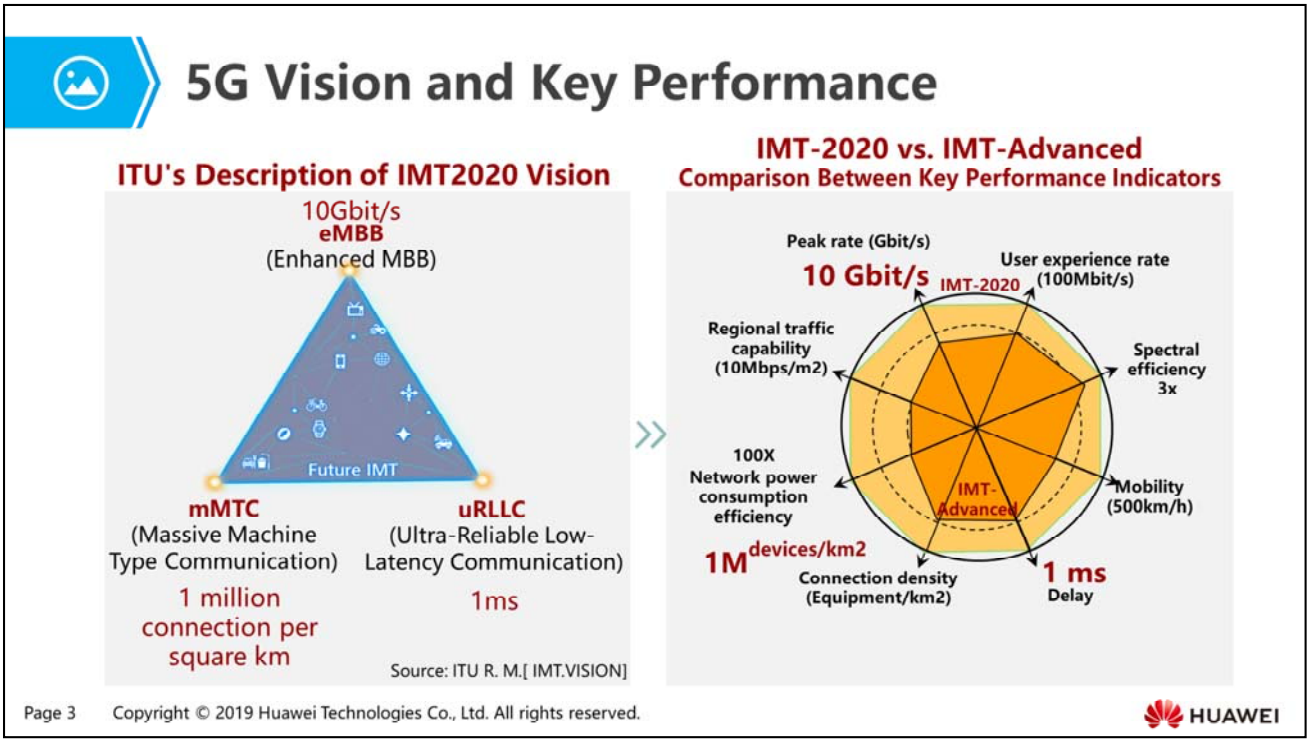
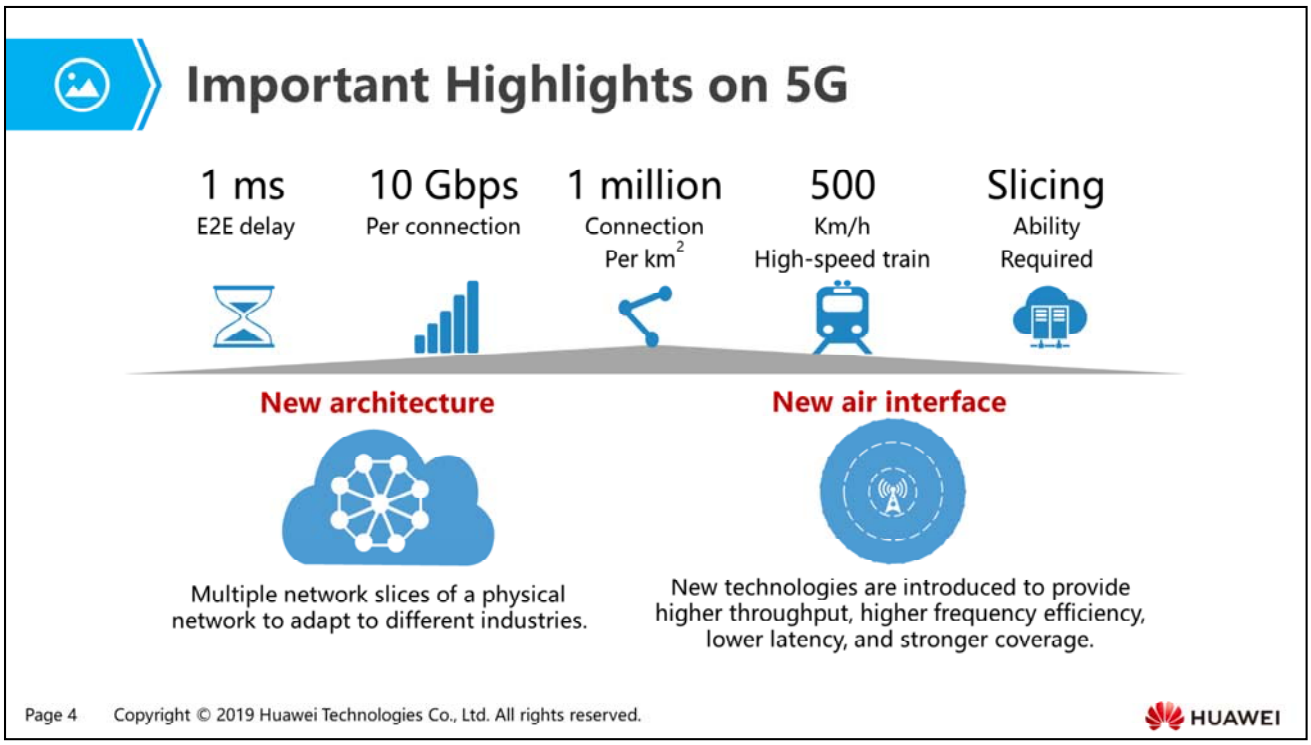



- In June 2015, ITU-R defined 3 biggest application scenarios of 5G in the future, which are eMBB (Enhanced Mobile Broadband), mMTC (Massive Machine Type Communication) and uRLLC (Ultra Reliable & Low Latency Communication), and define the requirements for 5G network from 8 perspectives, including throughput, latency, connection density and spectrum efficiency improvement and etc.
- Huawei predicts that there will be 100 billion connections around the world by 2025.




- To reach the high performance of 5G, we need new spectrum, new architecture, and new air interface.

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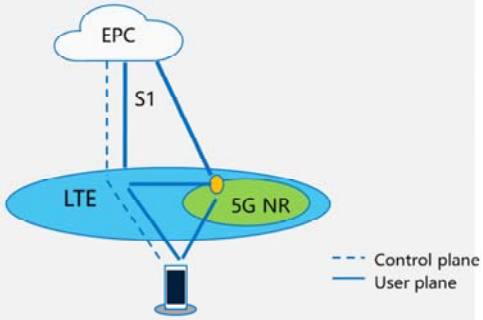
# New Architecture

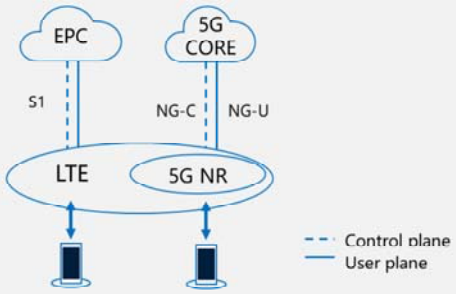
# 5G Networking Scenario

**NSA (Non-standalone networking)**




- eMBB is supported.
- LTE is the anchor point, and the 4G core network is reused to quickly introduce 5G NR.
- The 5G is overlaid on the 4G network without providing continuous coverage.

**Standalone (SA)**



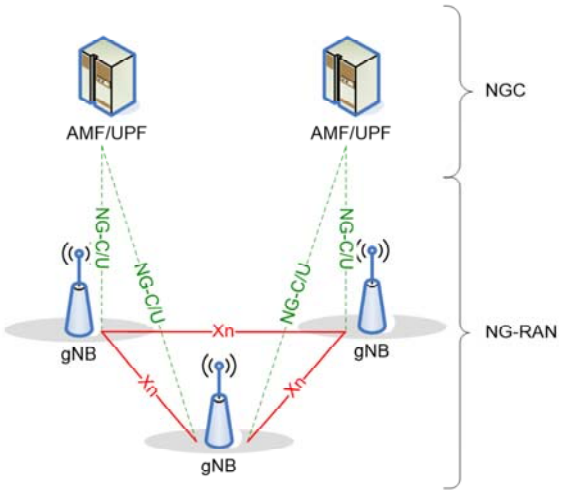

- Supports eMBB/uRLLC/mMTC and network slicing.
- 5G core needs to be build.
- High requirements for continuous coverage of 5G





- For SA/NSA option, can use the example of UE camps on the LTE network in idle mode.
- When the LTE network is upgraded to NSA, is like upgrading the old TV which is connected to a video player to a large-screen TV.
- When the LTE network is upgraded to SA, is like connecting a computer host to a large screen.

# SA Networking




- 5G network consists of the following components:
  - Wireless network: NR (New RAN)
  - Core network: NGC (Next Generation Core)
- 5G wireless network interfaces include:
  - Xn
  - NG-C (control panel)
  - NG-U (user plane)
  - Uu (radio air interface)

# NGC Vs EPC

| EPC NE function | | Corresponding NGC NF |
|---|---|---|
| MME | Mobility management | AMF |
| | User authentication | AUSF |
| | Session management | SMF |
| PDN-GW | Session management | |
| | User plane data forwarding | UPF |
| SGW | User plane data forwarding | |
| PCRF | QoS policy and charging rules | PCF |
| HSS | User profile database | UDM |

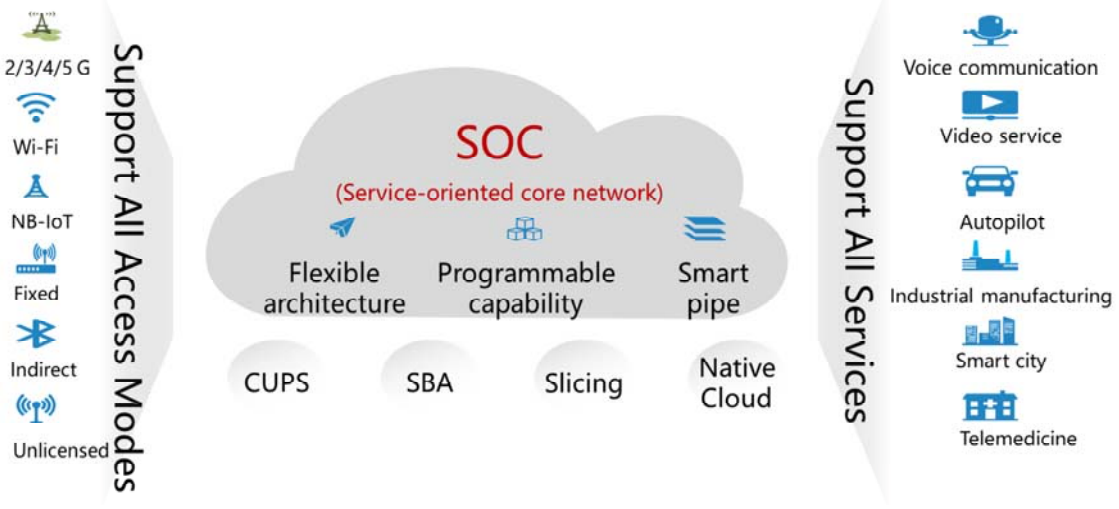




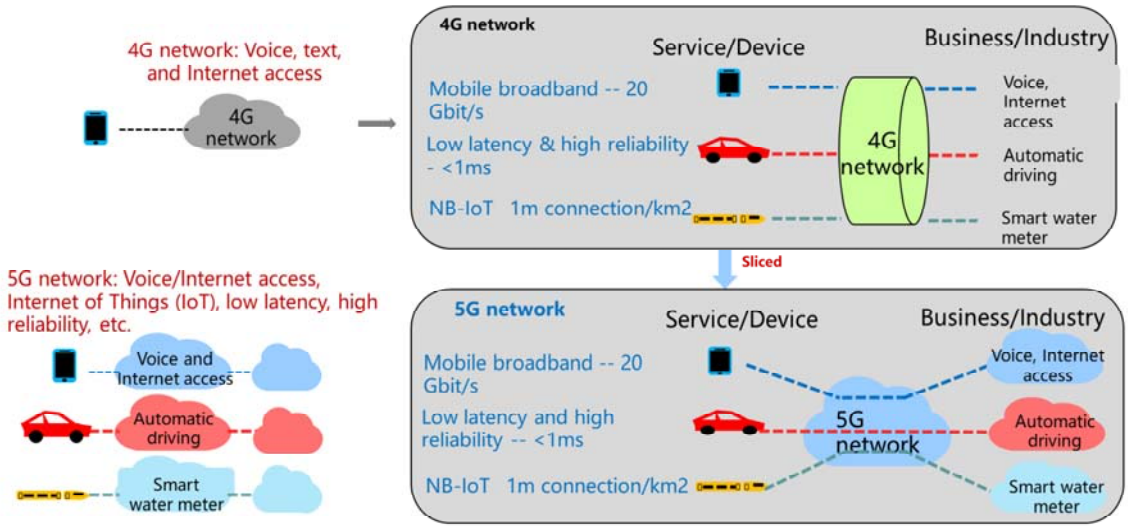
- The network functions defined in NGC is inherit from the EPC NE design. Most network functions have corresponding NE entities in the EPC.
- The main network functions of the NGC are as follows:
  - AMF:
    - End node of the uplink NAS signaling;
    - NAS signaling security;
    - AS security control;
    - 3GPP signaling node for intra-system interoperation;
    - UE reachability management in idle mode;
    - UE location management;
    - UE access authentication;
  - SMF:
    - Session management;
    - UE IP address allocation;
    - User plane function selection and control;
    - Service UPF control;
    - QoS and policy execution;

- Downlink data arrival notification;

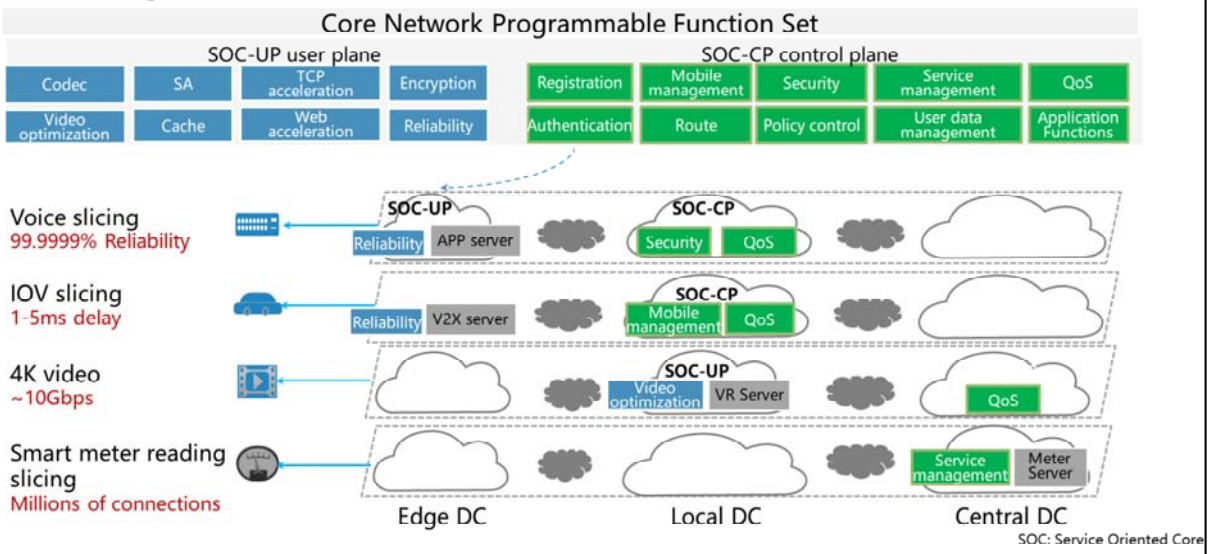
# Service Oriented Core Network Architecture

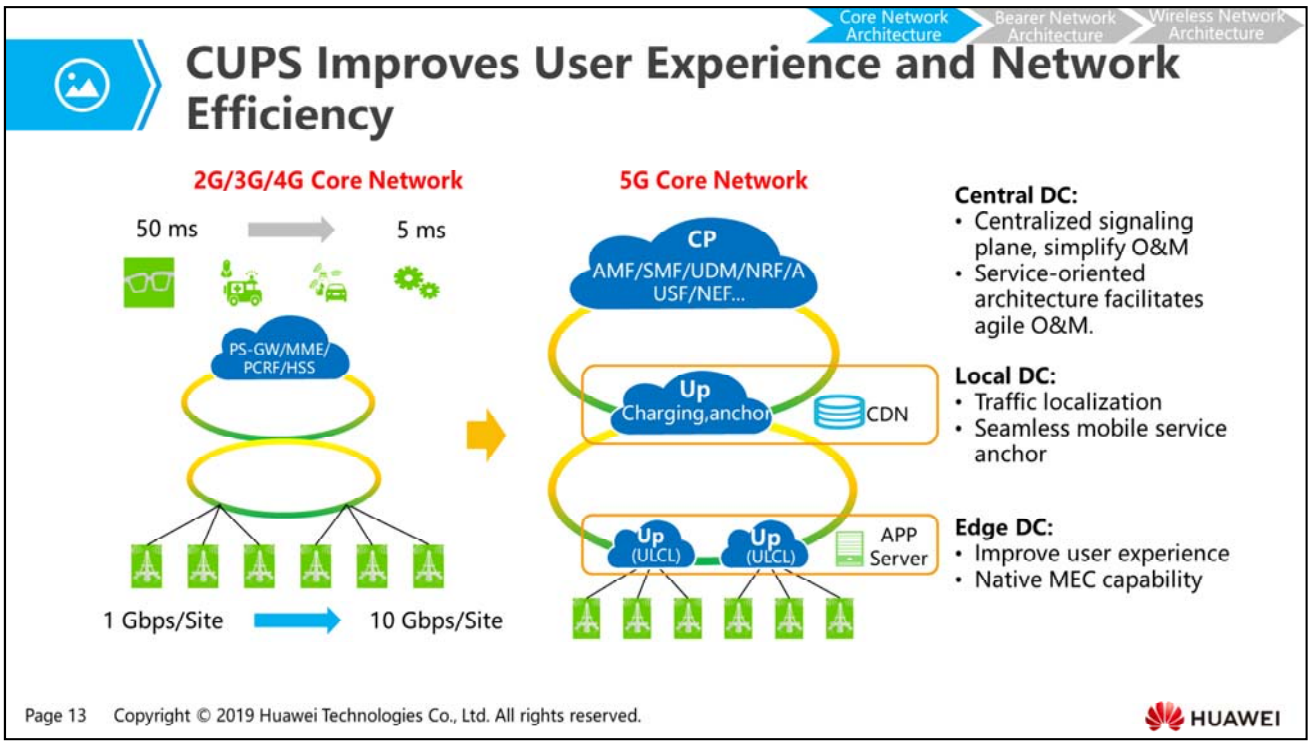


# Why Network Slicing is Required in 5G?

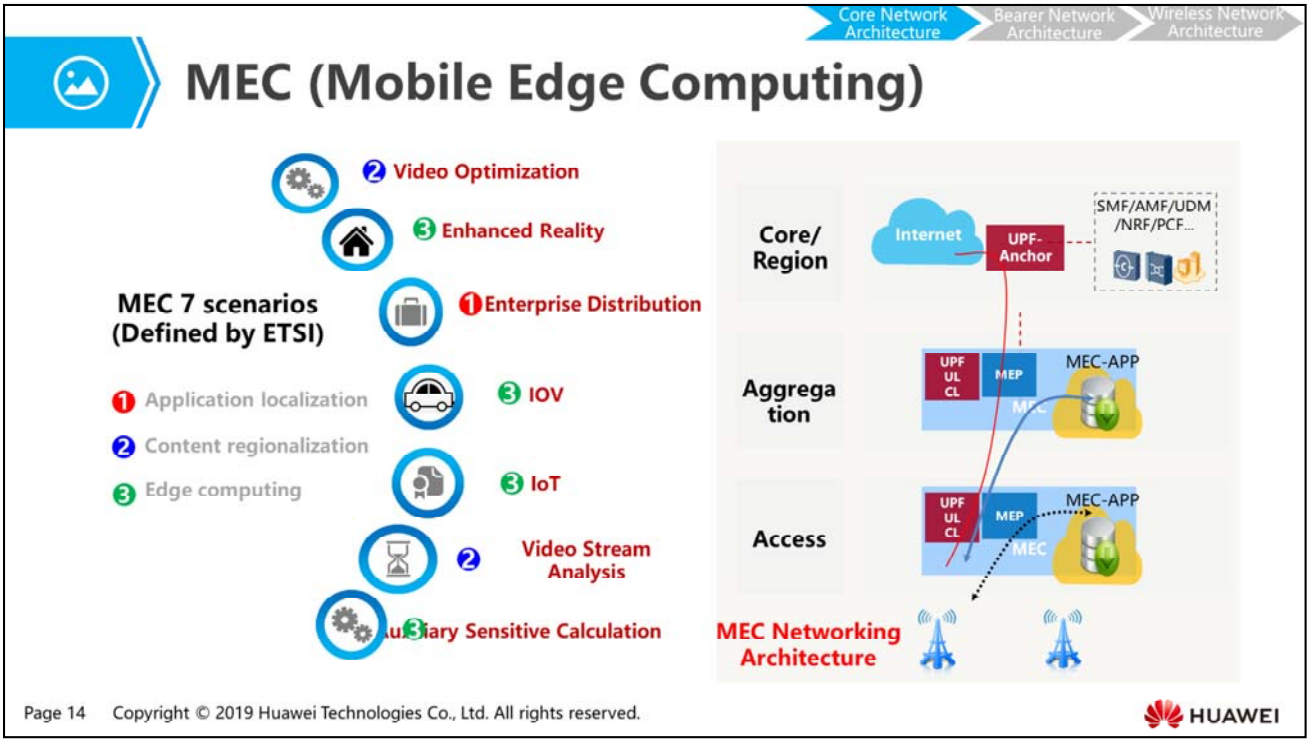


# Through Slicing to Meet Diversified Business Requirements

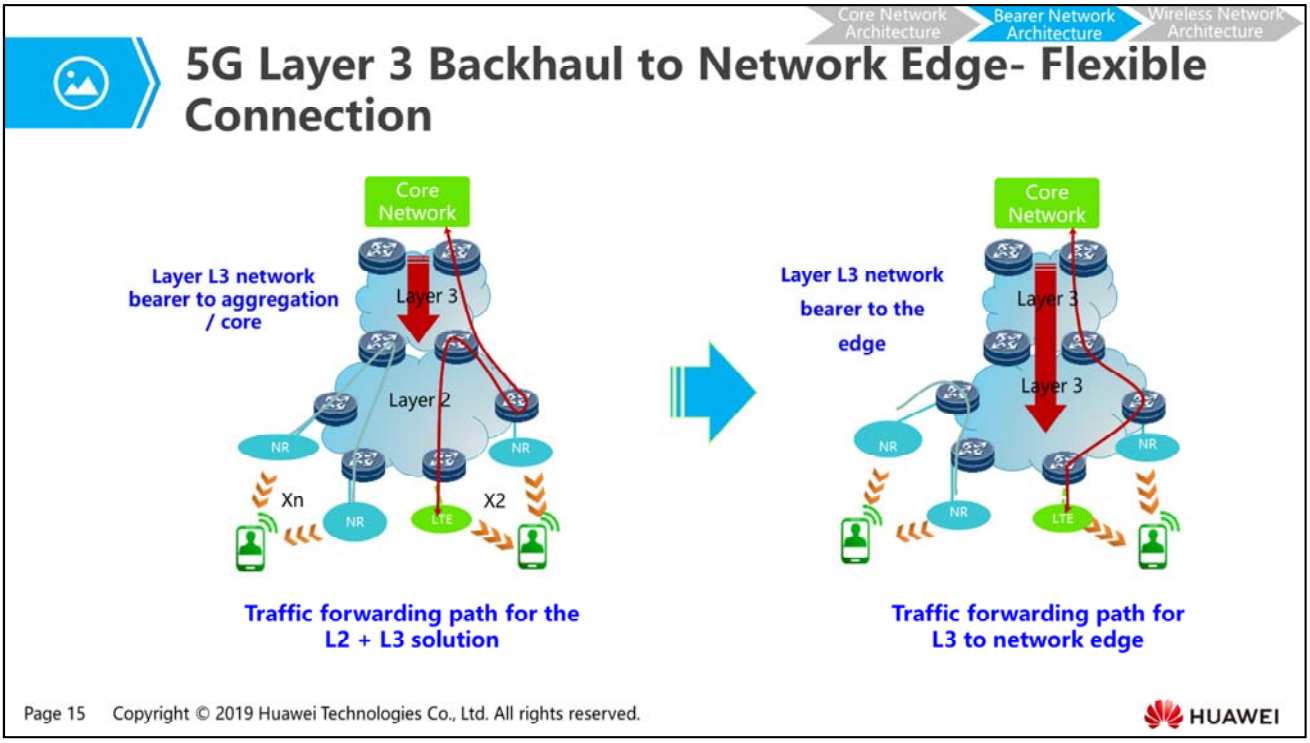




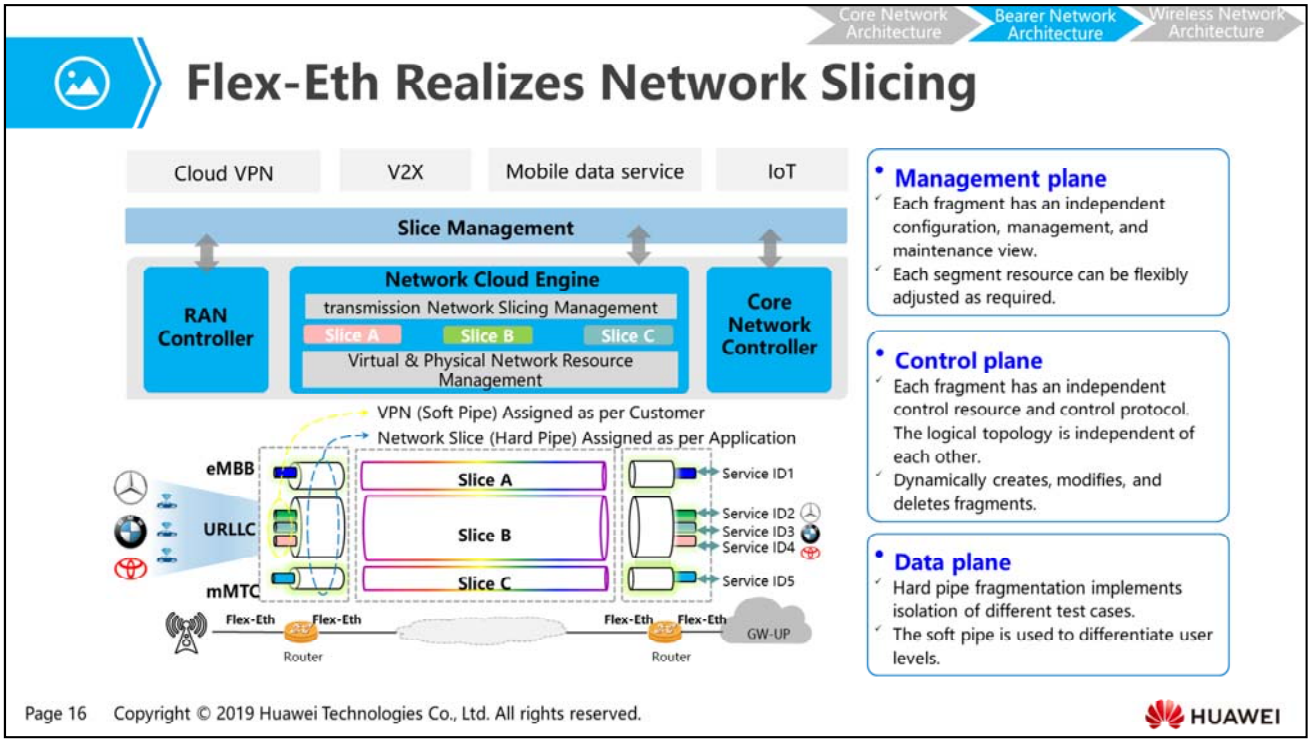

- The centralized CP helps simplify O&M, improve O&M efficiency, and accelerate the deployment of new services.
- Distributed UP:
  - The position of the UP mainly considers the service delay requirement (for example, the vehicle network service).
  - User experience + saving bandwidth




- Video optimization: Deploy wireless analysis applications at the edge to assist TCP congestion control and bit rate adaptation.
- Enhanced reality: Edge applications fast process user locations, camera images and provide auxiliary information to users in real time.
- Enterprise distribution: Traffic on the user plane is distributed to the enterprise network.
- IOV:MEC analyze the data of sensors on the vehicle and road side, and send the delay sensitive information such as dangerous information to surrounding vehicles.
- IOT: Aggregates of MEC application and analyzes messages generated by devices and generates decisions in real time.
- Video stream analysis: Analyzes and processes videos at the edge to reduce the costs of video collection devices and reduce the traffic sent to the core network.
- Auxiliary sensitive calculation:The MEC provides high-performance computing, performs delay-sensitive data processing, and sends the results to the device.

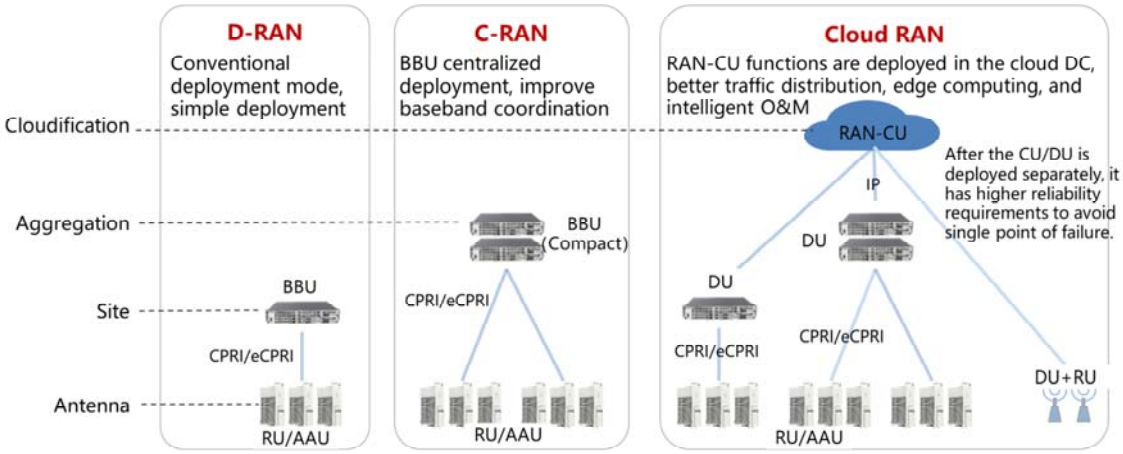



- Through L3 to network edge to realize a flexible service scheduling. We believe that L3 should be at least moved to the aggregation layer in the 5G bearer network. It is better if move the L3 to the access layer.




- In terms of network slicing, Flex-Eth is used as the core to construct pipes. As Flex-Eth uses the TDM timeslot allocation mode, services can be completely isolated, and E2E hard pipe slicing can be implemented. Each slice network corresponds to the same types of service or similar requirements. In each slice, different users can be isolated by using the current VPN and QoS mechanisms. At the management and control layers, each segment has its own view and resource allocation.

# Wireless Cloud RAN Evolution

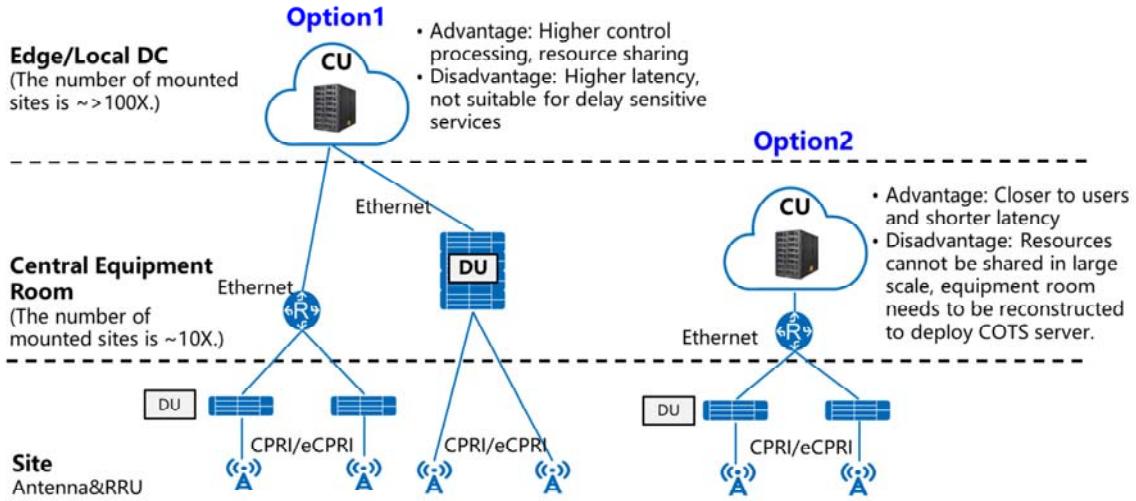



Early stage of 5G deployment

5G flexible networking supports various requirements

D-RAN: Distributed Radio Access Network C-RAN: Centralized Radio Access Network

# CU Deployment Solution



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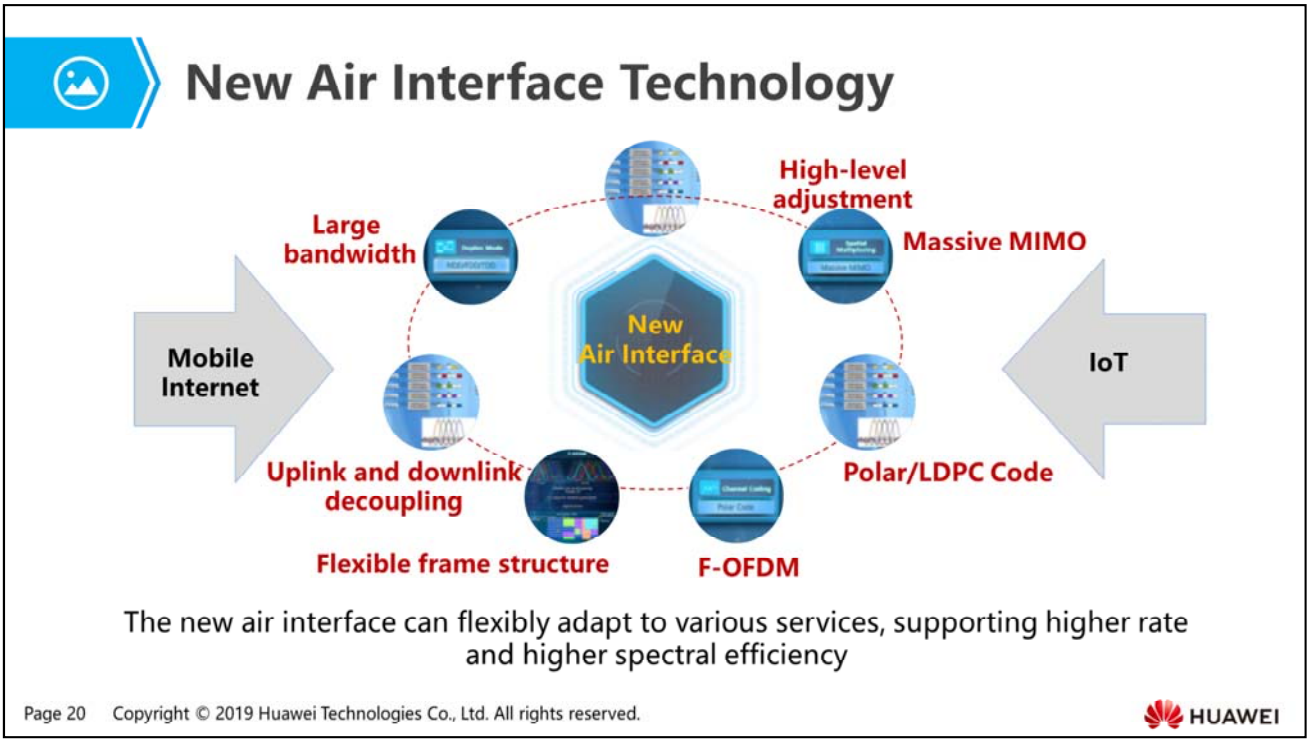
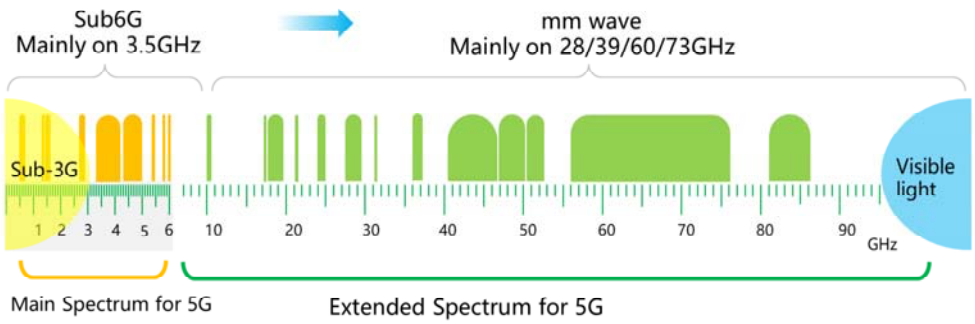
# New Air Interface




- The data channel uses the LDPC code to perform channel coding, and the control channel uses Polar code to perform channel coding. LDPC codes are suitable for data transmission with large data volume and low delay due to its better performance and decoding delay. Polar coding is used as the coding scheme for control channel due to its excellent performance on small packet transmission.

# 5G Spectrum- Sub 6G & mm Wave




- 5G Frequency Range (FR) defined in 3GPP:
  - FR1: Sub6G Hz, include: sub 3G Hz and C-band
  - FR2: mm Wave, 5G extended spectrum resources



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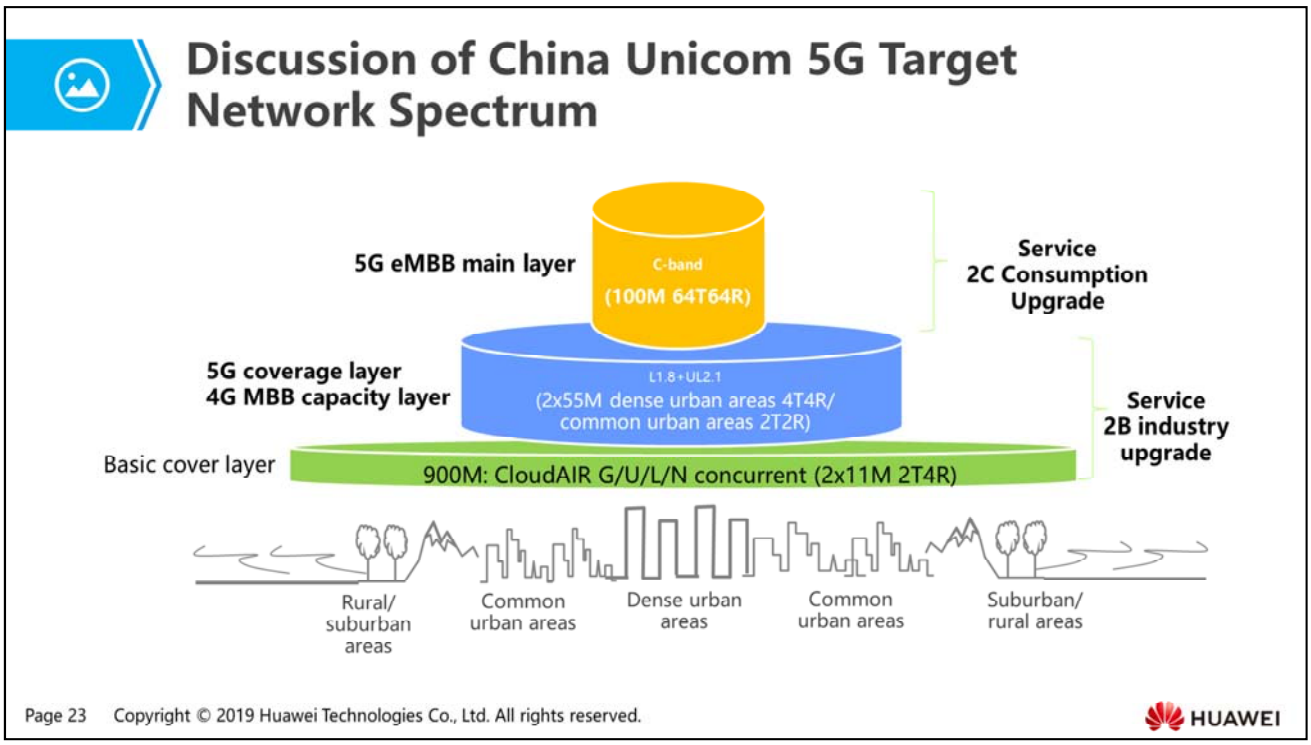
- FR1: The Sub 6G frequency band which is the low-frequency band and the primary frequency band of 5G. The frequencies below 3 GHz are called sub3G, and the other frequency bands are called C-band.
- FR2: Millimeter-wave that more than 6GHz which is the high-frequency band and is the extended frequency band of 5G, which is rich in spectrum resources.

# Large Bandwidth

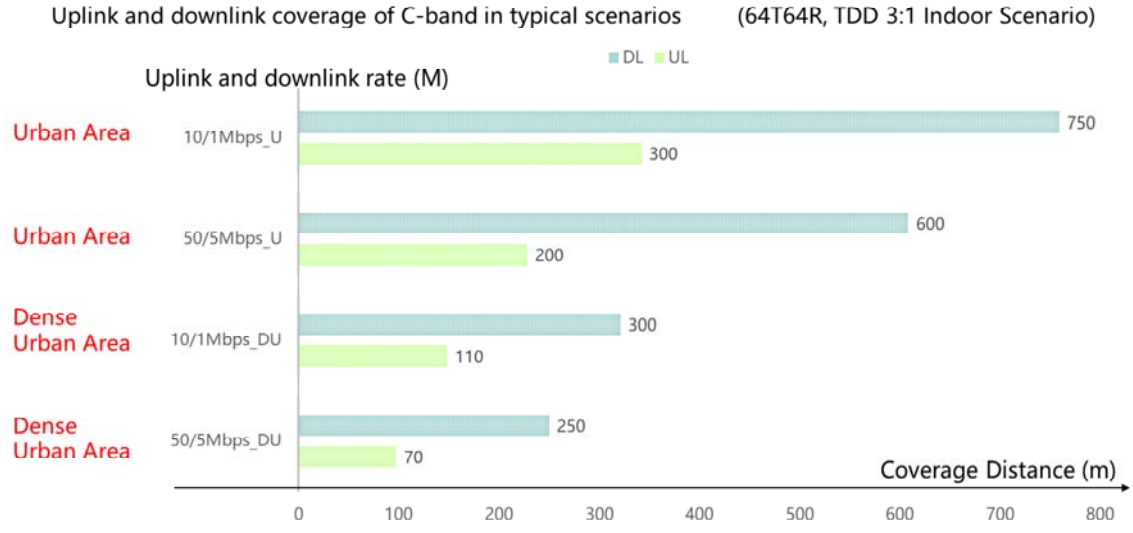

- Large bandwidth is a typical feature of 5G.
  - Maximum cell bandwidth of a Sub6G cell is 100 MHz
  - Maximum cell bandwidth of a millimetre wave cell is 400 MHz
  - The bandwidth below 20 MHz is defined to meet the requirements of the existing spectrum evolution.




- Due to different situations in China Unicom, there are some uncertainties in frequency usage. However, the group needs to unify the frequency assignment.
- Generally, China Mobile has 100MHz bandwidth in 2.6 GHz. In order to compete with China Mobile, China Unicom and China Telecom need to have sufficient spectrum to ensure that the rate is not lower.
  - China Unicom has 100 MHz bandwidth in 3.5 GHz. If the 1.8 GHz (2*30M) or 2.1 GHz (2*30M) can be used for 5G, 160M spectrum resources can be used for 5G. Therefore, the frequency is sufficient.
  - As for whether to use 1.8 GHz or 2.1 GHz for 5G spectrum, the general principle is to minimize the impact on the existing network, that is, to use a relatively light-loaded spectrum for 5G.
    - As shown in the preceding figure, the 1.8G is heavily loaded and the 2.1G is lightly loaded. Therefore, the 2.1G is used as the 5G bearer. However, due to the discontinuous coverage of 2.1G in some areas, frequent handovers of 5G users will occur. Therefore, need to evaluate the sites where 2.1G needs to be supplemented.
    - If the 5G coverage is good, the 1.8G can be used to carry the 5G. However, if 1.8G is used to carry the 5G, it will have a great impact on the existing LTE and 3G users.
- If the 1.8G or 2.1G is used to carry the 5G, need to consider the impact of the 5G on the existing 4G and 3G networks.

- It is recommended that you discuss with the customer based on their situation.

# C-Band Coverage Performance



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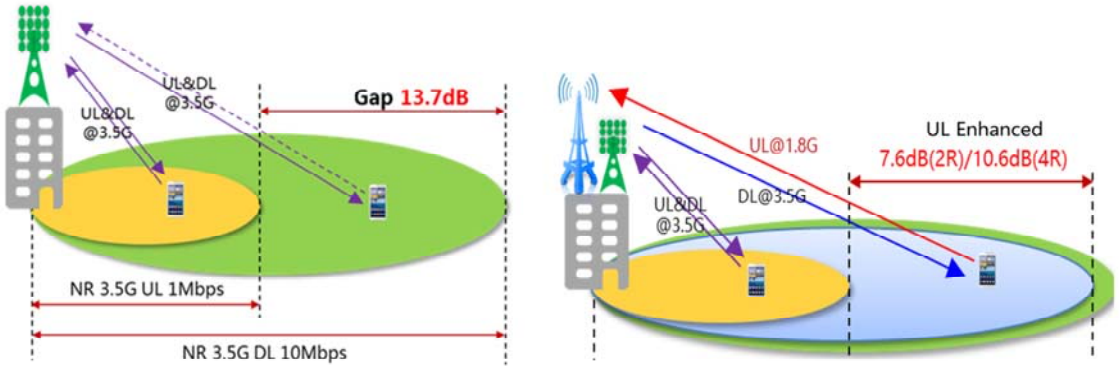
- The downlink coverage of 2.6G is 6.5 dB higher than the 3.5G band (estimated by RND), and the estimated coverage area is 40% more. The propagation loss of the 64T DL 2.6G is greater than the DL 3.5G by 6.5 dB (including 3dB penetration loss).

# Uplink and Downlink Decoupling (SUL)

- SUL is a technology to compensate the C-Band' s short uplink coverage
- Compared with downlink coverage, the C band has a coverage gap of 13.7 dB.
- The uplink coverage problem can be effectively compensated by switching the uplink transmission to the 1.8G.




SUL: Supplementary UpLink

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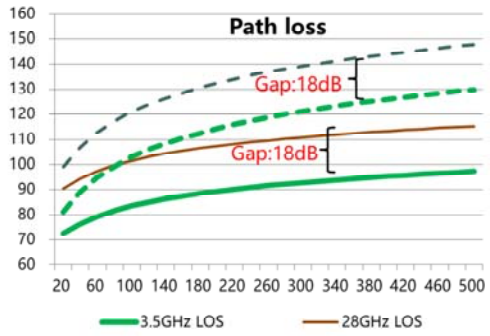
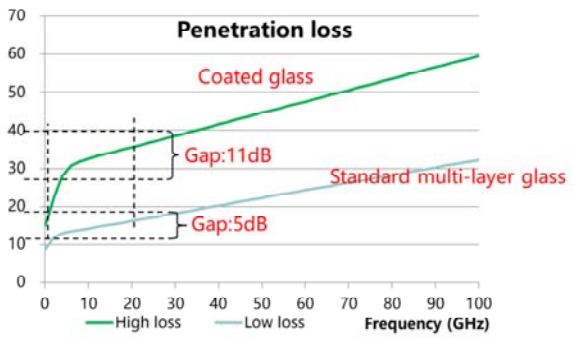
- Compared with the downlink coverage, the uplink of the C band has the 13.7dB coverage gap.
- Uplink and downlink decoupling band defined in RAN15.0:
  - DL 3.3G~3.8G + SUL 700/800/900/1800/2100M
  - DL 4.4G~5.0G + SUL 900/1800M

# Challenges of mm Wave Deployment




| NLOS (Distance) | path loss 3.5GHz(dB) | path loss 28GHz(dB) |
|---|---|---|
| 100m | 103 | 121 |
| 300m | 121 | 139 |
| 500m | 130 | 148 |

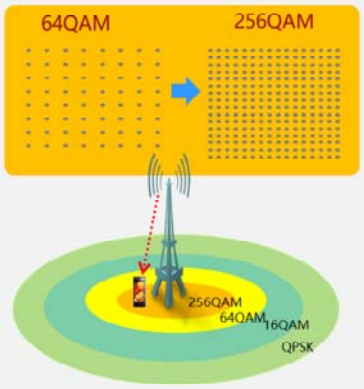
| Penetration Loss | 3.5GHz | 28GHz |
|---|---|---|
| Standard Glass | 13 | 18 |
| Coated Glass | 27 | 38 |

NLOS: NLOS path loss




- Standard glass
- Coated glass

# Modulation Technology -QAM Modulation



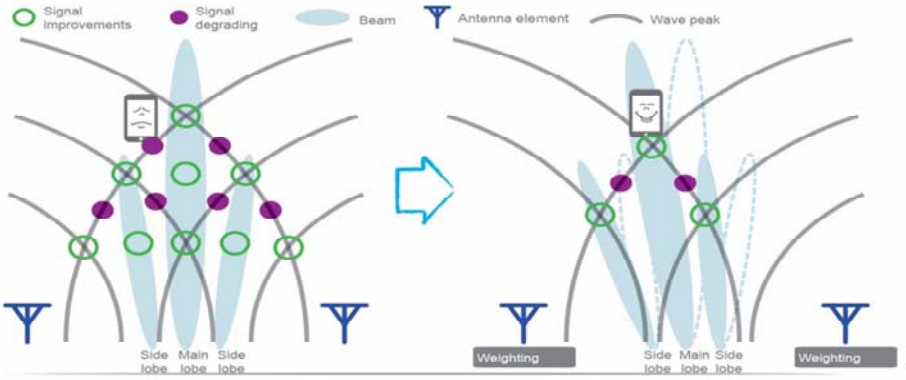

Each symbol of 256QAM can carry eight bits of information.

| | LTE | 5G |
|---|---|---|
| **Uplink** | QPSK, 16QAM, and 64QAM | QPSK, 16QAM, and 64QAM **256QAM** |
| **Downlink** | QPSK, 16QAM, 64QAM, 256QAM | QPSK, 16QAM, 64QAM, 256QAM |

- 5G is compatible with the LTE modulation mode. In addition, the (256QAM) is introduced in the downlink, which is higher than the LTE modulation technology. This further improves the spectral efficiency.
- The maximum modulation technology of the current protocol version is 256QAM.

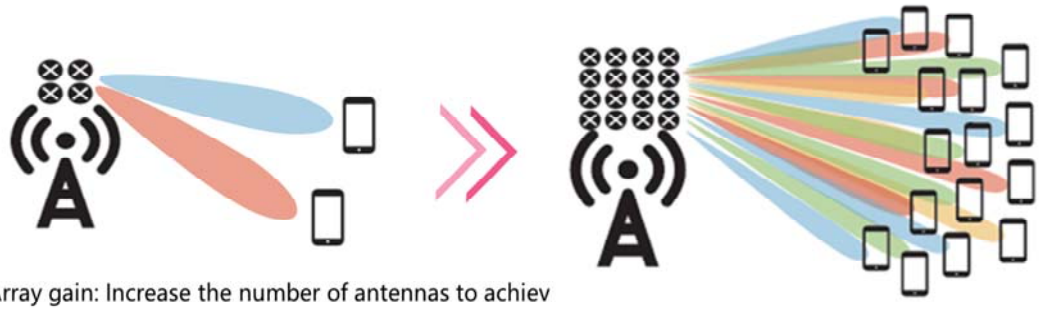
# MIMO Principles

- Massive MIMO(multiple-input multiple-output): Large-scale antenna array




By using antenna weighting method to control the antenna arrays, thereby further improves the wireless coverage.

# Massive MIMO Gain



- Array gain: Increase the number of antennas to achiev
- Beamforming gain: Beamforming is enabled in both horizontal and vertical directions to improve coverage and number of users.
- Multiplexing gain: A maximum of 16 data streams are supported, improving the system throughput. Spatial multiplexing to support more users
- Diversity gain: By increasing the number of antennas to form more data space transmission paths, improving data transmission reliability.

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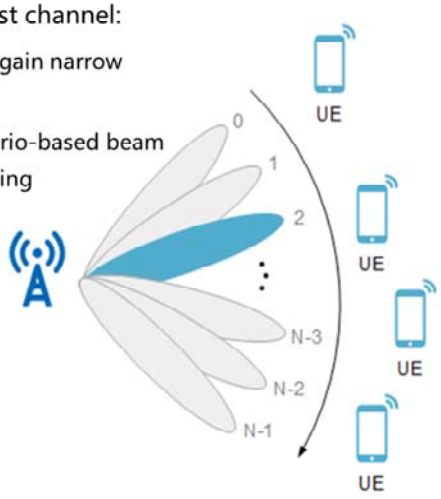
- In the current phase of the terminal, the 2T4R, supports 8-channel reception in the future.
- In the 4G era, MM is a capacity improvement solution. However, in the 5G era, MM is a common macro site requirement.

# NR Massive MIMO Gain - Broadcast Beamforming

- Traffic channel:
  - High-gain narrow beam
  - Dynamic adjustment of the beamforming direction
- Broadcast channel:
  - High-gain narrow beam
  - Scenario-based beam scanning


*The gNodeB uses multiple antennas to receive the PUSCH data, improving the signal-to-noise ratio (SNR) and stability of received signals*

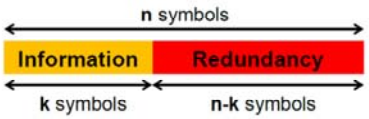
 

- Compare with LTE beamforming, NR massive MIMO introduces broadcast beamforming technology to enhance broadcast channel coverage.
- With the beam scanning technology, beam optimization is introduced on the basis of traditional RF optimization.

# Higher Spectral Efficiency- Channel Coding

- The concerns of Channel Coding selection:
  - Performance: Error correction capability and coding rate
  - Efficiency: Complexity level and energy efficiency
  - Flexibility: Length of coder, support of IR-HARQ...
- Turbo Code:
  - Good performance, but low efficiency for high speed
- **LDPC (Low Density Parity Check Code) for eMBB Data Channel**
  - **Low complexity, good for high speed service (parallel processing)**
- **Polar Code (used in control channel)**
  - Good Performance for small data block

*For mMTC and uRLLC, channel coding is not yet determined*




| | Turbo | LDPC | Polar |
|---|---|---|---|
| Low speed Performance | 😐 | 😐 | 🙂 |
| Low speed Efficiency | 🙂 | 🙂 | 🙂 |
| High speed Performance | 🙂 | 🙂 | 😐 |
| High speed Efficiency | ☹ | 🙂 | 😐 |

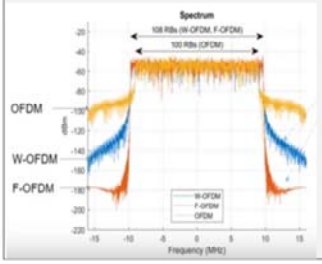
# F-OFDM Improves Spectral Efficiency

OFDM → F-OFDM

10% guard band

<10% guard band

- The 5G air interface introduces a better filtering technology to reduce the guard bandwidth requirement and improve the frequency utilization




Frequency usage (Sub 6G is used as an example)

| Subcarrier spacing (kHz) | System bandwidth | | | | | |
|---|---|---|---|---|---|---|
| | 15 MHz | 20 MHz | 40 MHz | 60 MHz | 80 MHz | 100 MHz |
| **15** | 94.8% | 95.4% | | | | |
| **30** | | 91.8% | 95.4% | 97.2% | 97.65% | 98.28% |
| **60** | | | | | | 97.2% |

OFDM: Filtered Orthogonal Frequency Division Multiplexing

# Flexible Air Interface -Numerology

Structure of a subframe (1ms)


Numerology: a flexible frame format which is SCS (SubCarrier Spacing, bandwidth) in NR and its flexible configuration on parameters such as symbol length and CP length.

| Frequency Range | Data channel SCS |
|---|---|
| <1GHz | 15kHz, 30kHz |
| 1-6GHz | 15kHz, 30kHz, 60kHz |
| >6GHz | 60kHz, 120kHz |



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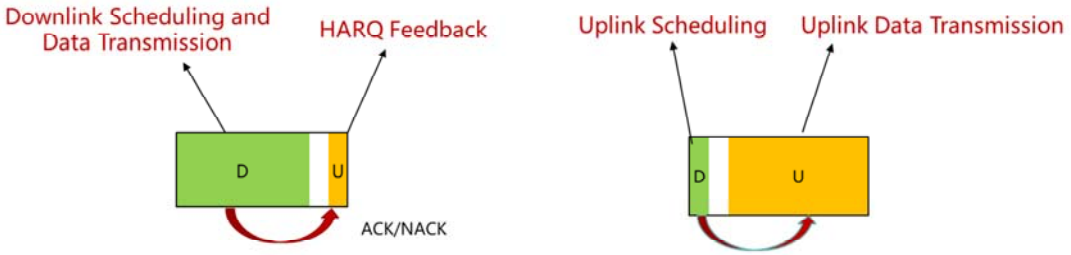
- The 3GPP TS 38.211 R15 specification introduces the flexible numerology, which defines the different subcarrier bandwidth. The bandwidth of different subcarriers corresponds to the frame structure of the time domain.

# Self-contained Slot

- In NR, there are two special slot structures, which are called self-contained timeslots. The purpose of the design is to shorten the RTT delay of uplink and downlink data transmission, including the below two scenarios:
  - Downlink self-contained timeslots:
    Downlink data transmission and corresponding HARQ feedback in one timeslot.
  - Uplink self-contained timeslots:
    Uplink scheduling information and uplink data transmission.



# Summary

- 5G network architecture:
  - Networking mode: NSA (non standalone networking) and SA (standalone networking)
  - Features of the core network architecture: CUPS (separation of the control plane and user plane), native cloud, service-oriented architecture, and network slicing
  - Wireless network: DRAN –> CRAN –> Cloud RAN evolution
  - Bearer network: L3 sink
- 5G key technologies:
  - High rate: Large bandwidth, massive MIMO (multiplexing), high-order modulation, and LDPC code
  - High spectral efficiency: F-OFDM, flexible frame structure
  - Coverage enhancement: SUL (uplink and downlink decoupling) and Massive MIMO (beamforming)
  - Low latency: CUDU separation and self-contained timeslot

# 5G Use Case

# Objectives

- Upon completion of this course, you will be able to:
  - Describes the progress of the 5G service.
  - Describes the business applications of the 5G five key industries.
  - Describe the development steps of the 5G service.

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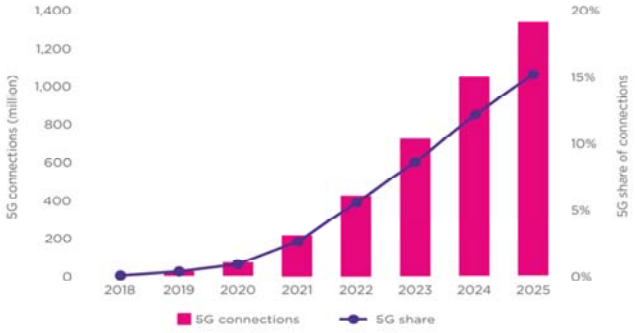
# GSMA Increases 5G Connection Forecast: 1.4 billion by 2025


**2018 GSMA Official Predictions:**

1. By 2025, around **1.2 billion 5G connections**
2. 5G networks cover **40%** population.
3. USD **500 billion** investment in the next three years (2018-2020)

**2019 GSMA Increased the official forecast. The number of 5G connections will reach 1.4 billion in 2025.**



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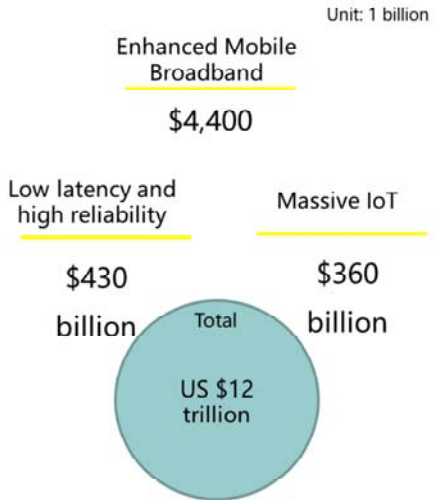
# In 2035, 5G will Drive US$ 12 trillion Global Economic Activity

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- To understand the impact of 5G's economy on the global economy, IHS Markit (Information Handling Service) Chairman and Chief Executive of Berkeley's research team, Professor Thomas · W · Tosch, developed an economic model of potential global sales activities across multiple industries.
- For more details, please refer to: ihs-5g-economic-impact-study; The URL is as follows: https://onebox.huawei.com/p/4e25a6b15e1a7d1b80324753f08d4682

## Highlight in MWC 2019: 5GaaP


- 5GaaP: 5G as a Platform, 5G will become a platform. 5G ecosystem can be more open to promote the development of the 5G industry.

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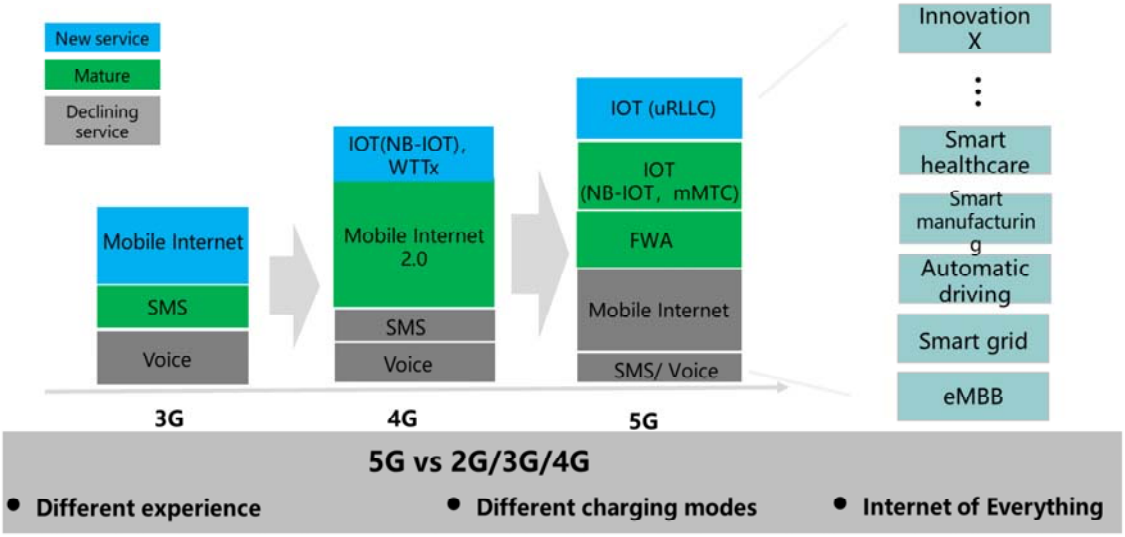
- Dr.Hwang, the KT president of South Korea Telecom, focuses on how to implement 5G applications and how 5G changes life.
- KT released a customized mobile phone and announced it will be put into commercial in March. Dr.Hwang committed to commercial the 5G in 2015, and many people did not believe it. As of today, he had realized the services like 5G Mobile Live, Cloud VR/AR, 360 real-time monitoring, Smart Factory, e-Brain (combined with AI).

# 5G Brings New Business Opportunities




**5G vs 2G/3G/4G**

- **Different experience**
- **Different charging modes**
- **Internet of Everything**

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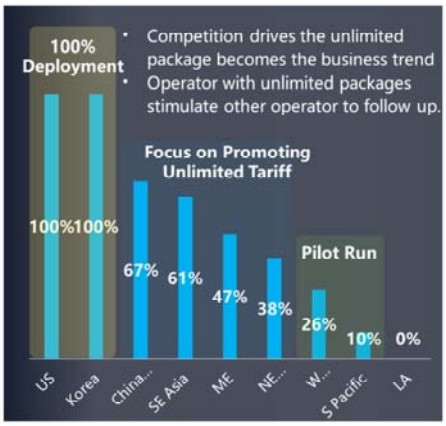
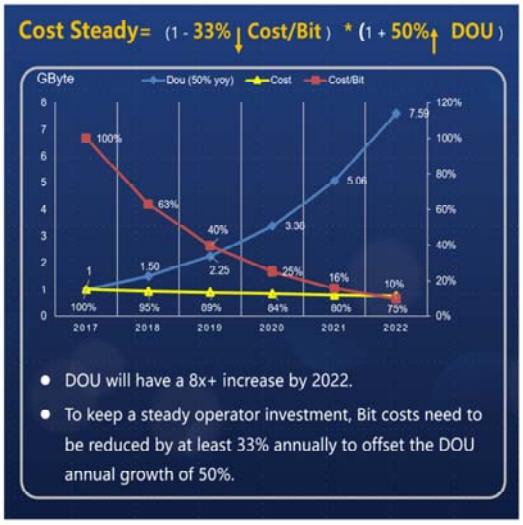
# Tariff Evolvement, Unleashing the Potential of MBB

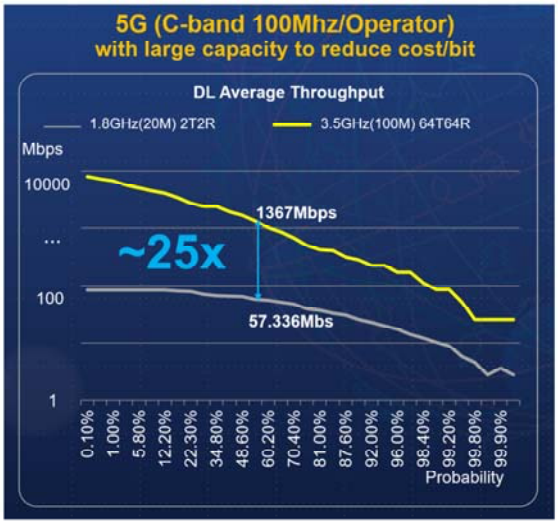





Traditional 4G networks face challenge of traffic growth → **4G** Empowered with **5G** NR M-MIMO

# 5G Enables Operators to Support 10 Times DOU Growth



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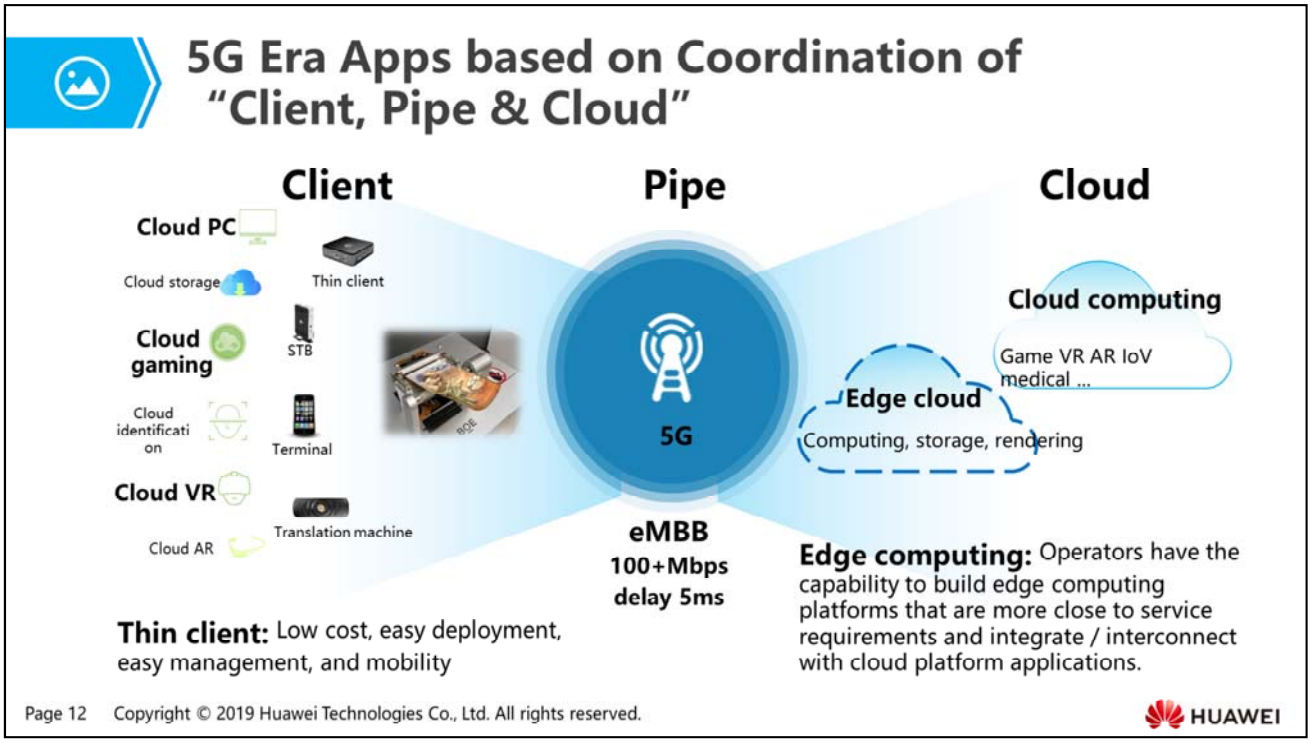
# Cloud X Three Important eMBB Services

## Cloud PC

## Cloud Gaming

## Cloud VR/AR




- In our view, applications in the 5G era will be mainly based on device-pipe-cloud synergy in mobile scenarios. Huawei is defined it as the Cloud X service.
- 5G brings brand-new eMBB pipes and edge computing to users, which is expected to change the entire business chain.
- Device-side, ubiquitous 5G connections, and edge cloud capabilities enable the computing, storage, and rendering capabilities on the client to be placed on the cloud. Terminals will become "thin", lower costs, and more mobility. More importantly, they can reduce the threshold for service deployment and popularization, the vitality of the service is enhanced.
- On the cloud side, a large number of services are integrated on the cloud and rely on the capabilities of pipes, edge computing, and future network slicing, thereby further highlighting the importance of the network capabilities and enhance the operators' control capabilities.


- From the perspective of content, VR can be divided into two types: 360° live video and CG virtual video generated by computers. The former is more of a lightweight video viewing, while the latter requires immersive, highly interactive experience.
- In the future, CG VRs will be widely used in games, medical care, social networking, and education, and are expected to become one of the future man-machine interfaces.
- [Background]
  - Answer to VR mobility problems:
  - VR can be classified into two types based on content: 360° video based on real scenes and virtual video based on computers. The latter requires stronger immersion and higher interaction requirements, which does not require high mobility.
  - In the current phase, "5G mobile phone +VR glasses" is used to attract users through the "new strange" experience of the 360° video, highlight the high-speed and anytime anywhere features of the 5G, and become a highlight for building the initial brand of the 5G.
  - On the one hand, the 360° video does not have high requirements on immersive experience. Users mainly to have watch experience, and use the 5G to watch some VR short videos anytime and anywhere.
  - On the other hand, 5G+ mobile phone + glasses, compared with home Wi-Fi access, can provide better VR watching experience for users, thereby highlighting the value of 5G experience.

# Cloud Resolves VR Key Bottlenecks, 5G Boost VR Industry

## Terminal: Cloud Solve Experience Pain Points

Cable free, reduce the threshold, anytime and anywhere.

Cloud-based rendering +4k decoding < ¥2000

## VR is the real 100 Mbit/s eMBB service

| 5G | Pre-VR | Entry-Level VR |
|---|---|---|
| Video source | Full view 4K 2D | Full view 8K 2D |
| Field angle | 90 | 90 |
| Equivalent TV | 240P | 480P |
| Bandwidth | 25Mbps | 100Mbps |
| Delay | 40ms | 30ms |

## Content: Vertical Operation, Aggregation, and Monetization

LETINVR · CLOUDWAVE · 3D福福 · VR 爱奇艺VR · 微鲸VR · VRplay · 巧克互动 · NINEP

VR聚合

VR Live Broadcast | VR VOD | VR education | VR game

## Build 5G brand based on VR experience

BT/EE | LG U+

Live broadcast of VR games | VR platform

5G VR experience package

VR coupon / live ticket +5G traffic

20-minute VR experience, 2.5GB traffic consumption

## Build a VR content aggregation platform for future man-machine interaction

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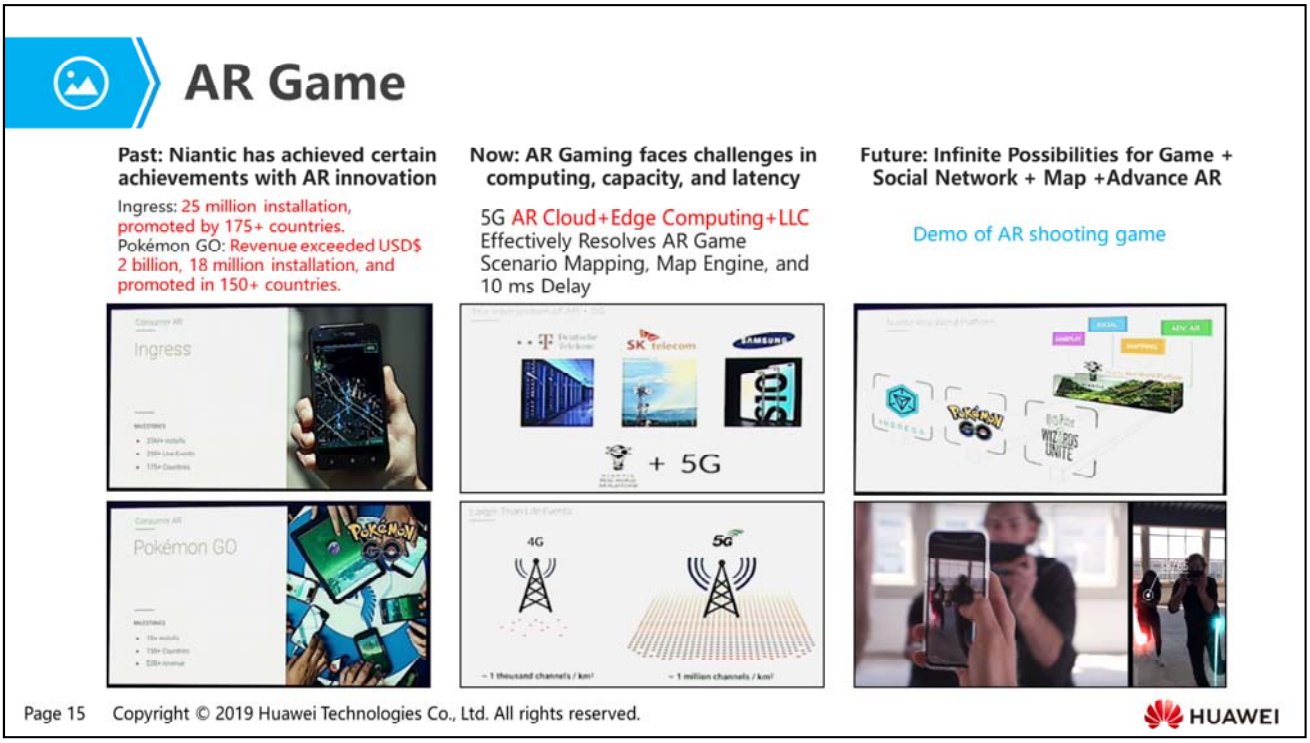
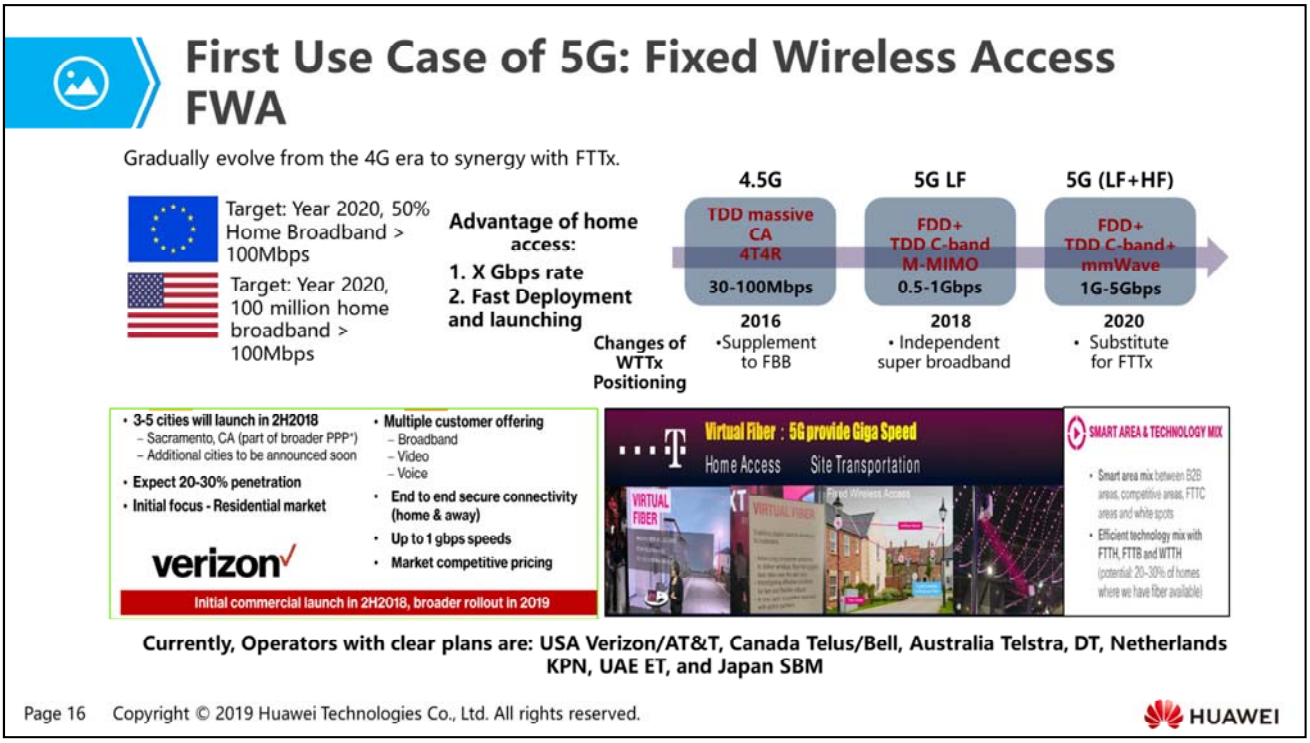


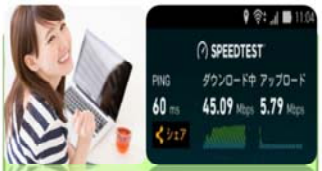

- Demo of multi player competition AR shooting game (Codename: Neon *)
- Part of the game is expected to be released in year 2019 ( might be Harry Potter Wizards United).




- DT: Deutsche Telekom
- The customer expects to use the 5G 3.5G, 26G as FWA in 20-30% and supplement the FTTH. Currently, we are going to select Kassel (sub-urban) and (urban) in Berlin, and select typical regions for ROI analysis.

# Case Study : Keys for End User Acquisition

Better User Experience
Cost-effective Package

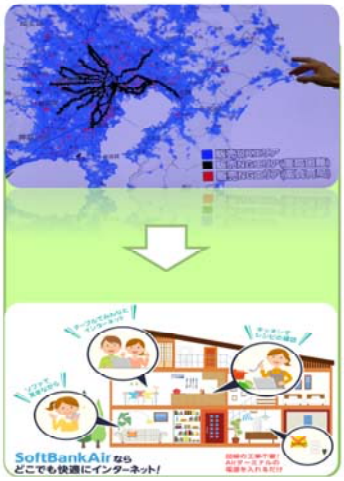



| | | |
|---|---|---|
| Softbank Air2 (unlimited data) | 3,800 JPY/M | ※ basic price x4880<br>1~24 Month Discount:<br>-1080 JPY/month(pcs) |

Vs

| FTTH | House | Department | Installation charge |
|---|---|---|---|
| NTT | 5200円/M | 4200円/M | 15,000 – 37,500 JPY depend on network condition |
| Softbank | 5200円/M | 3800円/M | |
| KDDI | 5100円/M | 3800円/M | |

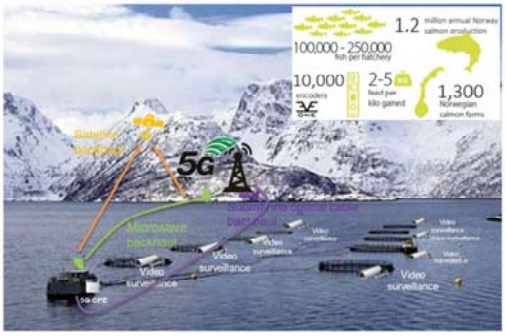
Precise and Fast Service Provision




Precise Marketing Strategy

# Norway Telenor Fishing Farm Video Surveillance

Norway Telenor fishery monitoring case: 5G video surveillance assists high labor cost reduction, feed savings




## Access Mode Selection


**5G**
High bandwidth, easy to deploy
The fishery is even willing to build together

**Submarine cable**
High cost (100,000 $ / km)
Front end position is not flexible

**Satellite**
High cost (40,000 US dollars / year)
Low bandwidth (128k/2M)


**LTE**
QOS is difficult to protect
Tourism area bandwidth bottleneck

**Microwave**
Point-to-point deployment
Low efficiency and easy to interfere

### Customer Pain Points

- ✓Fishing ground 10-15km from the beach
- ✓Offshore operations, labor costs
- ✓The weather has a big impact on the job
- ✓Feeding is not accurate, waste is big

### Business requirements

- ✓Real-time data collection and query
- ✓24-hour HD video surveillance
- ✓Remote feeding and monitoring
- ✓High-definition monitoring combined with feeding equipment to accurately feed bait

### Network Requirements

- ✓Wide coverage: 10-15km
- ✓High bandwidth, uplink 25Mbps/camera, 200Mbps/fishery
- ✓Real-time. 24 hours a day

| Cost Type | Onsite operation cost | Subsequent remote operation costs | Cost saving |
|---|---|---|---|
| Manpower Cost | 590000€/ years<br>• 6 persons for large fisheries<br>• 99000€/ years/person | 309000€/ years<br>• 3 persons, 297000€<br>• 5G: 12K€/ Year/Fisheries (est.) | 281000€/ years 48% |
| Feed Cost | 6000000€/ Period/Fisheries<br>• 1€/kg feed<br>• 5kg feed/kg fish<br>• 1200000 kg fish | | • 300000€<br>• Precise feeding saves 5% feed. |



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# Wide Application in Mobile Live TV and Surveillance scenarios

| | PGC Live TV | UGC Live Broadcast | Monitoring |
|---|---|---|---|
| |  |  |  |
| Scenario | Marathon, outdoor concerts, etc. | Individual outdoor live broadcast and live broadcast on high-speed railways | Vehicle-mounted cameras such as taxis and buses |
| Market space (China) | 50,000 live broadcast activities per year | Live TV active users on China Mobile:2017:176 million, 2022: 500 million<br>Mobile subscribers who pay for live TV services:2017: 6.2 million, 2022:19.8 million | 100 million street cameras, 5% requiring mobile bearer; 1 million taxis, buses and other public transport installed with cameras |
| Network Requirements | Generally, at least two shooting location are required. The bandwidth of a single shooting location is as follows:<br>4K: 25~40Mbps<br>8K VR: 100Mbps | 1080p: 6Mbps<br>4K: 25Mbps | 1080p: 6Mbps<br>4K: 25Mbps |

# Huawei Supports CCTV and Operator to Establish a New Media Platform

**2019.1** New Year Eve
5G 4K Live

**2019.2** Congress
5G live broadcast by multiple TV stations

**2019.4** World Congress
VR 5G live broadcast

**2019.4** Navy Anniversary
E2E live broadcast of 5G+ mobile phones

**2019.5** *Dialog* 5.9
Onsite demonstration of high-end interviews, Live broadcast of the UHD industry conference

**2019.9** National Day
Live broadcast, 4K, and multiple VR channels

# 5G Live Broadcast has Technical Advantages

| Backhaul Solutions | Satellite Broadcasting Vehicle | Private Line | 4G | 5G |
|---|---|---|---|---|
| Network |  |  |  |  |
| Cost | Extremely high<br>Satellite communications costs: 350,000 RMB/Mbps/Year<br>Live broadcast vehicle: RMB 50+ million | High<br>100M leased line rental fee: 56000RMB/Month<br>Live broadcast vehicle: RMB 50+ million | Low | Low |
| Speed | Few Mbps | ~100Mbps | ~10Mbps<br>480p/720p/1080p | ~100Mbps<br>2~4 4K Camera |
| Mobility | x | x | √ | √ |
| Reliability | Interference with the C-band frequency band | High | Normal. SIM cards of multiple operators are aggregated to provide rate guarantee. | High |
| Deployment Time | >1 day | >1 day | Plug-and-play | Plug-and-play |
| Summary | Advantages:<br>1. The broadcast area is not restricted.<br>2. Integrate with television stations<br>Disadvantages:<br>1. Fixed location video collection<br>2. High cost, long deployment time<br>3. Limited live broadcast bandwidth | Advantages:<br>1. High video quality<br>2. Support multiple shooting location<br>Disadvantages:<br>1. Fixed location video collection<br>2. The private line deployment time is long. | Advantages:<br>1. Mobile video collection<br>2. Rapid deployment<br>Disadvantages:<br>1. The live TV bandwidth is limited.<br>2. The live video quality is limited. | Advantages:<br>1. Mobile video collection<br>2. Rapid deployment<br>3. Supports multi-channel high-quality video streams. |

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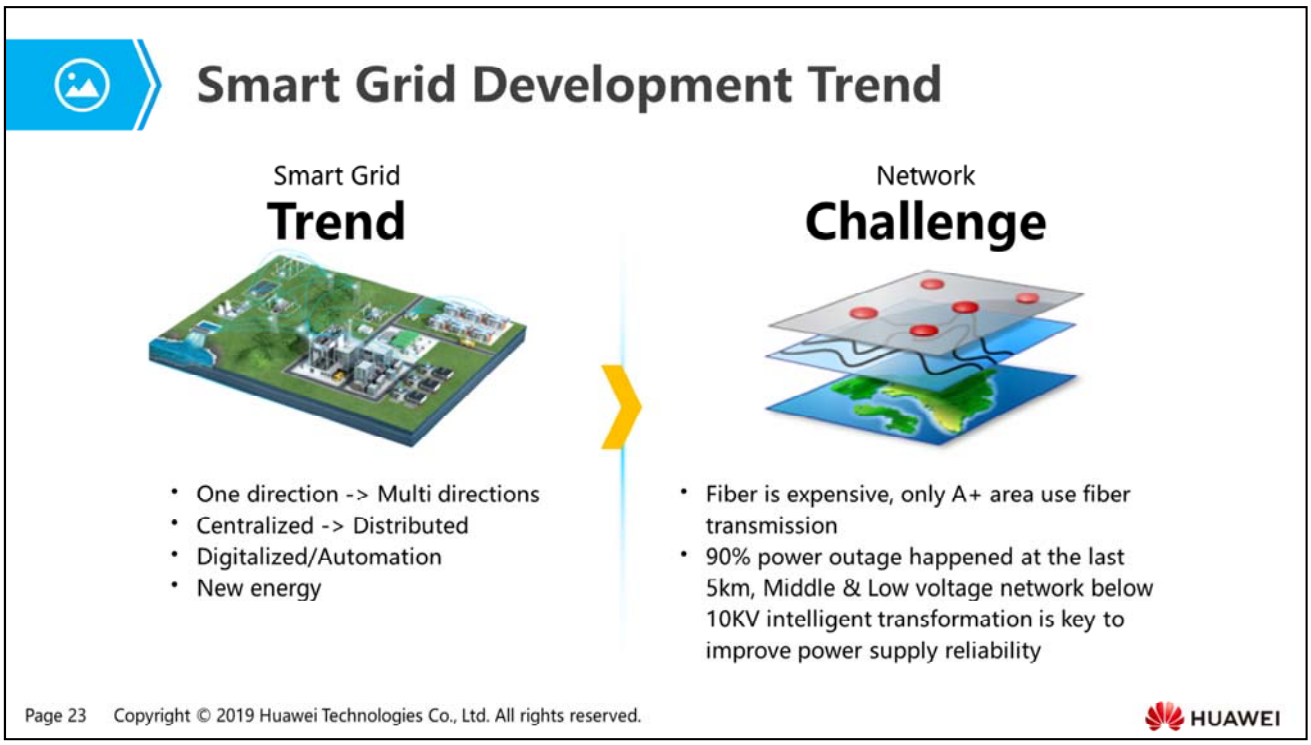
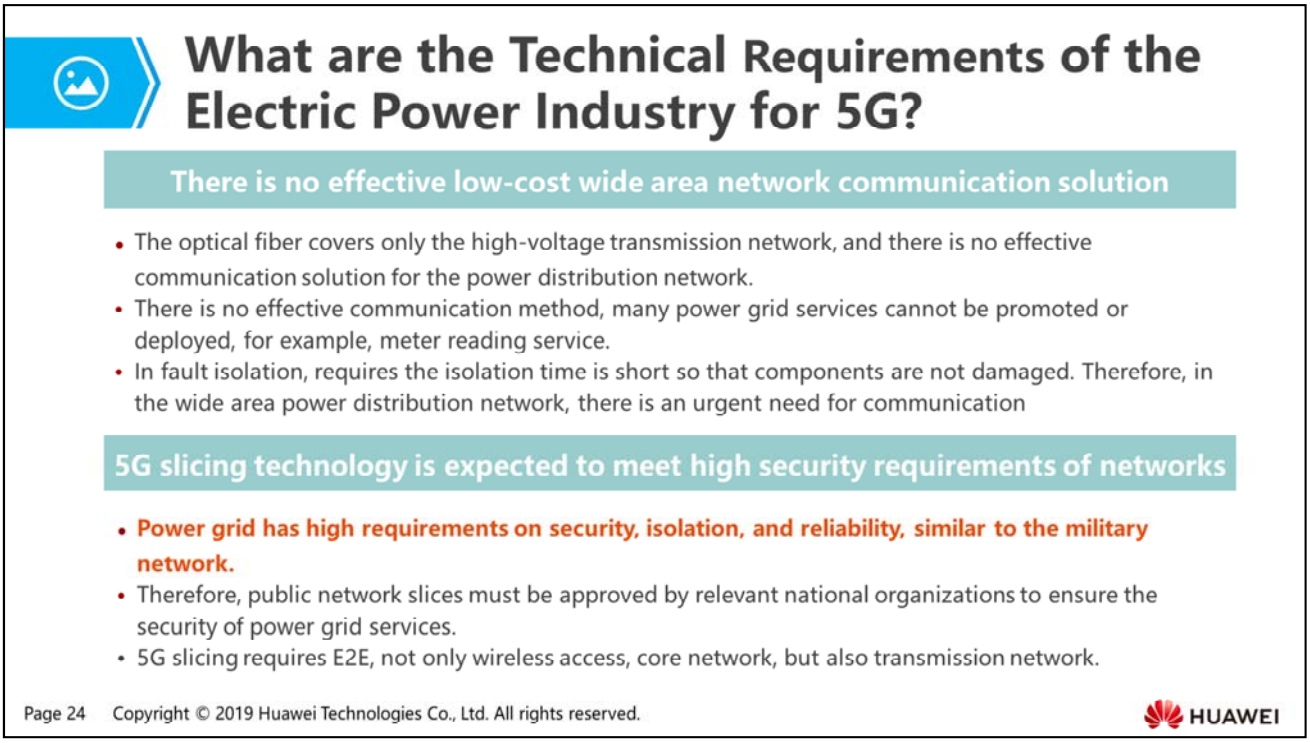



- Sanxin
- New energy: Wind power and solar energy: Intermittence, randomness, and two-way, sometimes power generation or charging.
- New user: Charging pile, and can be charged when the electricity is cheap.
- New requirements: Continuous power supply and precise load
- Unidirectional to multi-direction: Refers to the original power grid. The flow direction is from the power station to the user terminal. But now that the user may have installed solar energy, it may also generate electricity for other users.

- Intelligent automatic power distribution
- Millisecond-level precise load control
- Low-voltage power consumption information collection
- Distributed power supply




- China Telecom cooperates with the State Grid and Huawei to conduct in-depth exploration of power grid requirements based on the national special topics and study the feasibility of 5G slicing in the power grid to meet special service requirements, such as high reliability and low latency.

# Connection Requirements of Wireless Service Smart Grid

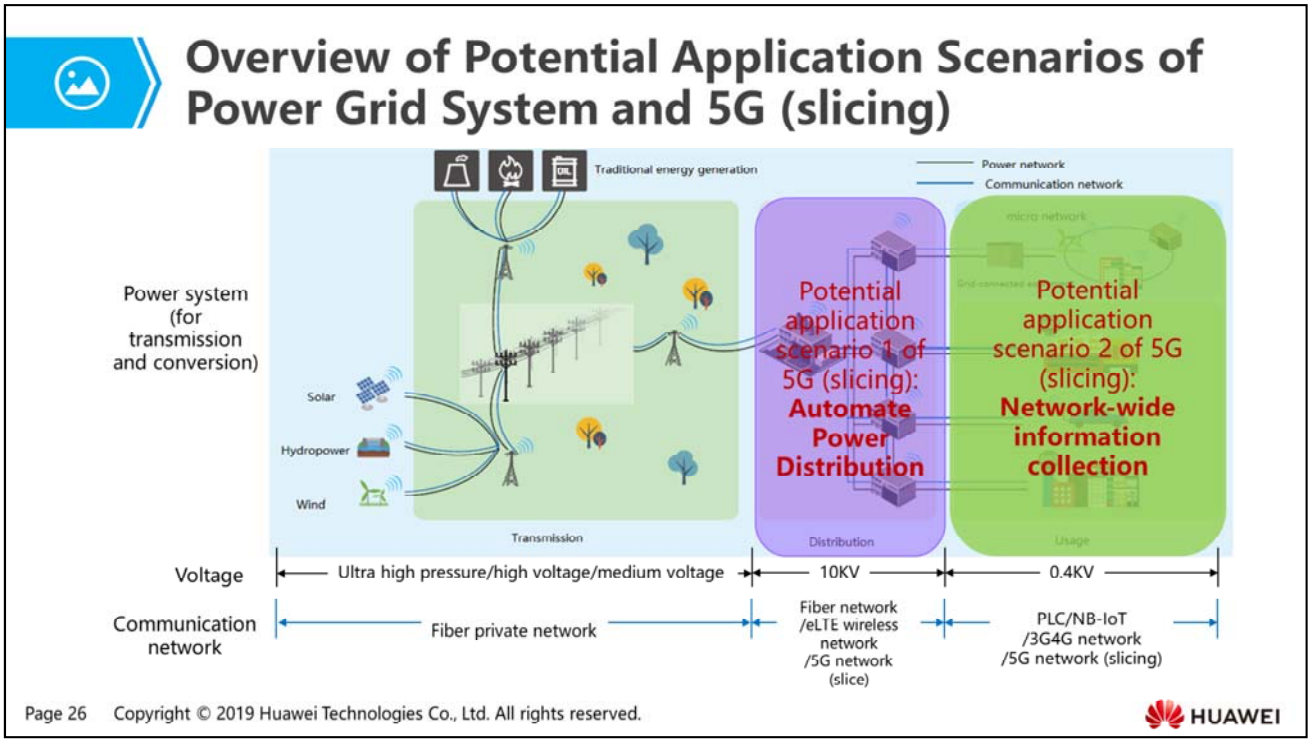
Grid

| Generation | Transmission | Transformation | Distribution | Usage |
|---|---|---|---|---|
|  | | | |  |
| **Mainly wireline, wireless as supplement**<br>• less nodes<br>• 100% fiber to the station;<br>• Substation robot inspection, mobile video surveillance | | | **Wireless & wireline**<br>• Mass nodes, requiring low cost<br>• Global average fiber rate <10%<br>• E2E cost savings of 70% with wireless | **Wireless Based**<br>• Wireless AMI with single station coverage of several transformer ranges, suitable for small areas and distribution scenarios |

Service

| Surveillance | Scheduling | Distribution Automation | Smart Metering |
|---|---|---|---|

| Service | E2E Latency | Telecommunication Latency | Bandwidth | 5G Character |
|---|---|---|---|---|
| Distribution Network Protection and Control | <100ms | <10ms | <2kbps | uRLLC |
| Time Service | <100us | <10us | <2kbps | uRLLC |
| Voice Scheduling (Cluster Scheduling) | Second Level | Second Level | <4Kbps | eMBB |
| Smart Metering | Second Level | Second Level | <10kbps | mMTC |
| Online surveillance | Second Level | Second Level | 100kbps | mMTC |
| Video Surveillance | Second Level | 100 Millisecond Level | 100Mbps | eMBB |
| Mobile task | Second Level | 100 Millisecond Level | 100Mbps | eMBB |




- The three networks are the core backbone network of the power grid. Only the fiber private network can be used. The wireless network cannot be used and will not be touch.
- The potential opportunities of 5G are mainly in the distribution network and the network.
- Smart grid. The source is also from the laying of optical fiber costs. In addition, high reliability and low latency are required for the network, which mainly focuses on the last-mile deployment. Currently, it has great application opportunities in Europe and China.

- Distributed FA: feeder automation
- Trip: tripping operation
- Weak current: light current;
- Mechanization: mechanical device

- For the stability and security of the 22V system, the time limit for removing the fault is between 100ms and 120ms, and for the 110V system is 200ms to 500ms.
- Fault detection + fault location + fault isolation = 100ms， so Communication delay requirement= 10ms

# 5G Smart Grid has High Potential Demand

## 2020 China

Power line (Camera /2.5Km)

**20M Km**

Network power distribution terminal

**20M**

Electric meter

**500M**

Charging pile

**4M**

- **State Grid & China Southern Power Grid**: 5G will become the main solution for power distribution networks and terminals.
- **European Subnetwork of America Mobile**: Propose a smart grid plan for 5G services.
- **Vodafone, Italy:** Smart grid is an important part of the VDF 5G application in Italy.
- **Germany:** Operators plan to expand the smart grid market through network slicing.

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## 2. 5G Business Applications and Cases



 

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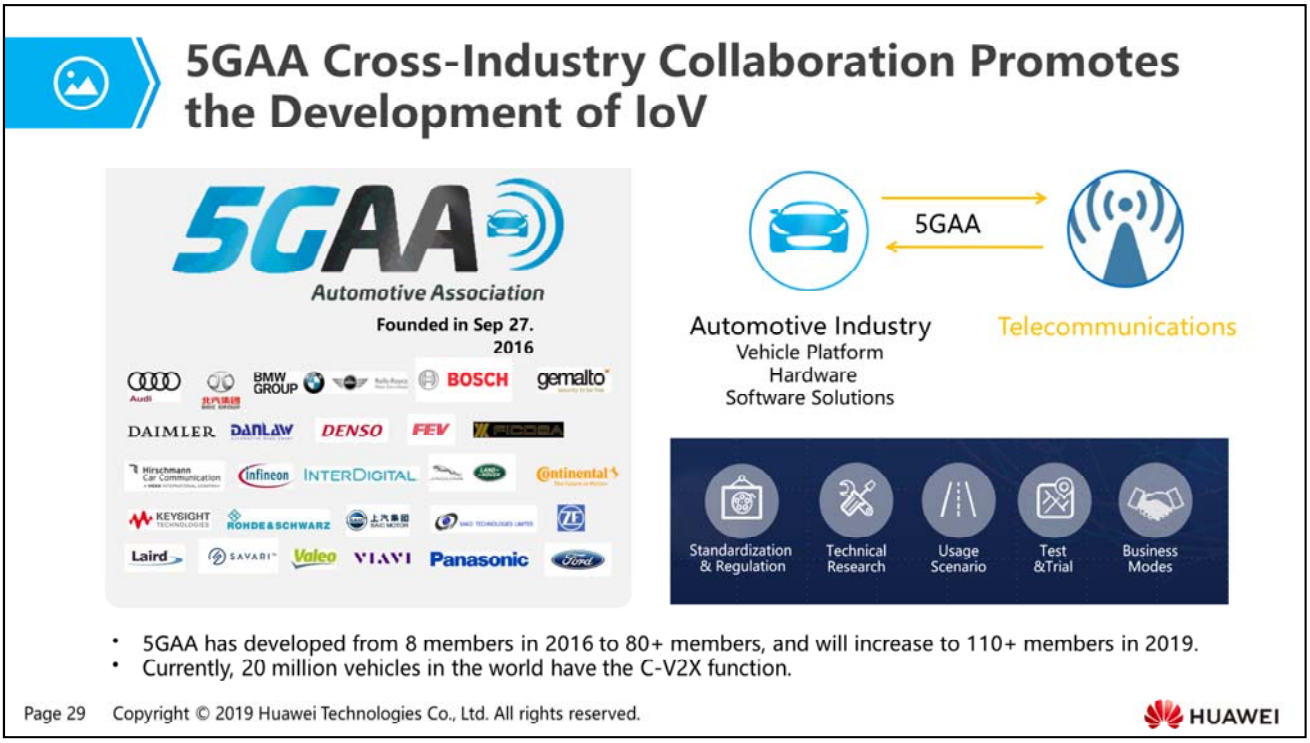
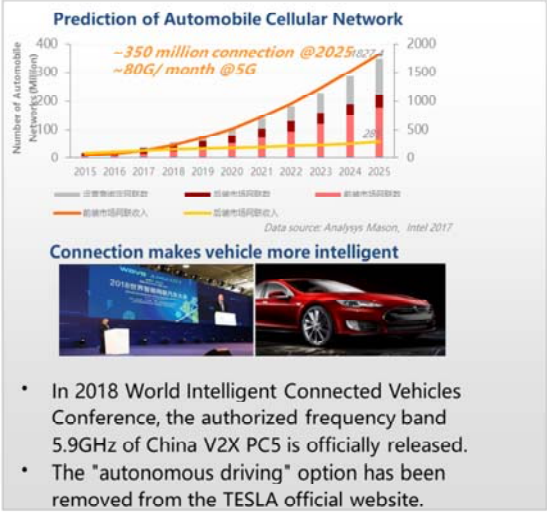



- Six key tasks in 2019: New spectrum, V2N, ecosystem, V2S, edge computing, and interoperability.
- 5G Edge DC can meet RTT 10 ms latency requirements (air interface 8ms+ bearer 2 ms). It should be applied to IOV in 2023.
- 700Mbps/3ms/5ms application requirements, that is, applications that need to be deployed at the end DC, are expected to be widely used in 2030.
- 5GAA V2X defined the six key tasks in the future. Currently, 20 million vehicles in the world have the C-V2X function.

# 5G Smart Driving

Direction of IoV




- In 2018 World Intelligent Connected Vehicles Conference, the authorized frequency band 5.9GHz of China V2X PC5 is officially released.
- The "autonomous driving" option has been removed from the TESLA official website.

5G enables Internet of Vehicles

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- 5G enables smart driving, and operators can develop terminals, applications, and vertical scenarios based on connections.

Discussion:

- Which of the following IoV services will be put into commercial use first? Why?

# 5G Remote Driving ToD (Tele-Operated Driving)

**Uplink video transmission (~100Mbps)**


**Downlink vehicle control (E2E delay <20ms)**

**Solution:**

- The camera and sensor in the vehicle can transmit the scenario within the 360 degree range of the vehicle to the control room. The driver determines and operates the vehicle based on the scenario.

**Value scenario:**

- Fixed line: Shuttle bus, port transportation
- Harsh environment: Mining area, garbage, waste, coal seam, etc.
- Collaboration/supplementation of automatic driving: Manual Takeover When the Automatic Driving Algorithm Is Faulty





- In addition to the 76% transportation efficiency, the 76% reduces the energy consumption of the 46% and reduces the traffic accident rate of the 15%.Fixed line: Shuttle bus, port transportation
- Harsh environment: Mining area,, garbage, waste, coal seam compaction, etc.
- Vehicle allocation: Drive the shared car to a high-demand area remotely.
- Collaboration/supplementation of automatic driving: Manual Takeover When the Automatic Driving Algorithm Is Faulty

# Autonomous Driving Use Case

Use Case description : In-Campus Autonomous Driving Shuttle Bus


**Driving force and business pain points**

- High labor costs, low operation efficiency
- Cost reduction: Laser, radar and other key components prices continue to decline.
- Most of countries prohibit the autonomous driving in the public road.

**Business and technical feasibility**

- The environment is simple: less traffic flow, low building density, less intersection, and the route is relatively fixed,
- Low-speed operation: The driving speed is less than 30km/ hours, and the security risk is low.
- Satisfactory: As the traveling speed is low, and 5G end-to-end delay is as low as milliseconds, so 5G can meet the requirements



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- The current autonomous driving mainly uses video cameras, radar sensors and laser range finder.
- At present, autonomous driving is prohibited on public road in most of the countries. There is no clear definition for in-campus area.

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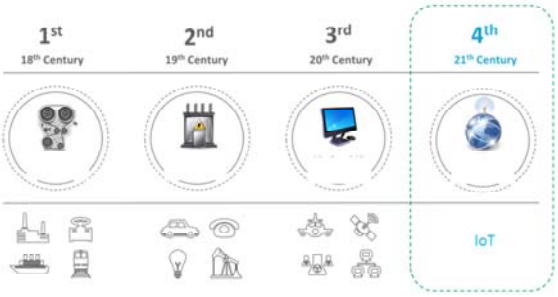
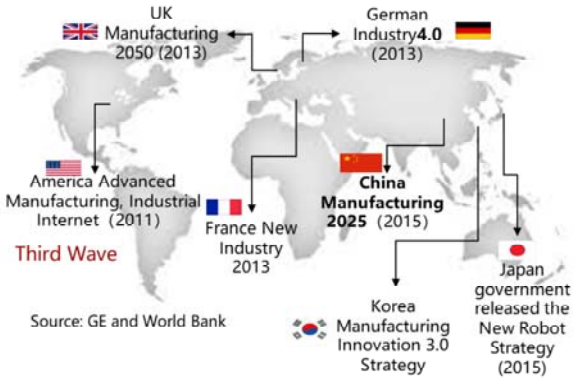
# The Fourth Industrial Revolution Promoted the Upgrade of the Manufacturing Industry

**The Fourth Industrial Revolution**




**Some manufacturing countries plans to promote smart manufacturing**




Source: GE and World Bank



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# 5G Enables Intelligent Manufacturing to Achieve Business Model Upgrade and Transformation

5G-ACIA

Wireless PLC
M to M collaboration control

AGV
Positioning & Transportation

Industrial AR
Real-time Operation Guide

Machine vision
Visual positioning & detection

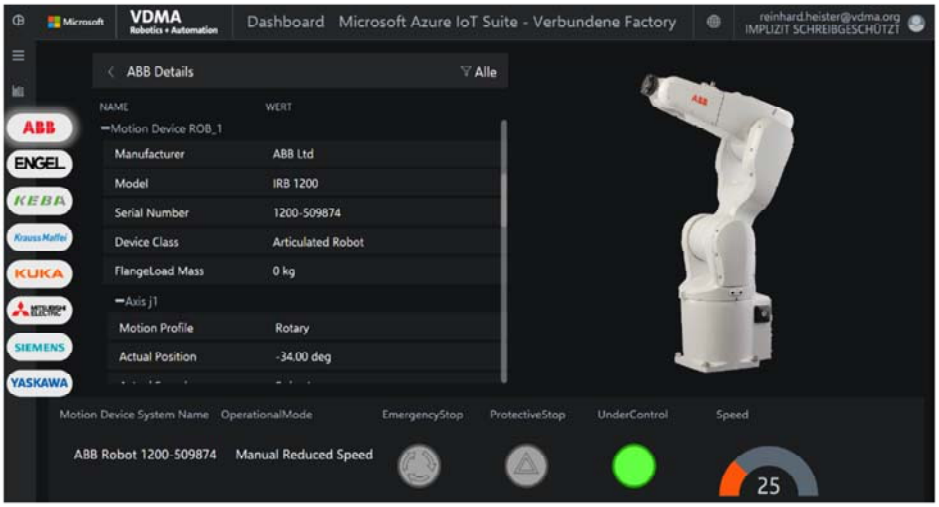
Forecast maintenance
Device maintenance

| High reliability and ultra-low latency | Massive connections | Enhanced mobile broadband Low latency |
|---|---|---|
| Control and load control<br>Delay: Millisecond, nanosecond<br>Packet loss: 1e-8 | Status monitoring<br>Number of connections: 100000, million | AR assistance<br>Bandwidth: Mbit/s and Gbit/s |




- M to M: Machine to machine

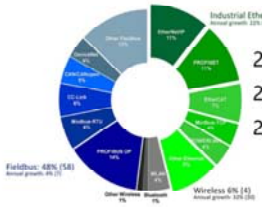
# OPC-UA Enables Interconnection and Interworking Between Different Machines




**Access to any robot anytime, anywhere**

# 5G will Play an Important Role in Manufacturing Industry

Rapid growth of wireless communications connections in the manufacturing industry

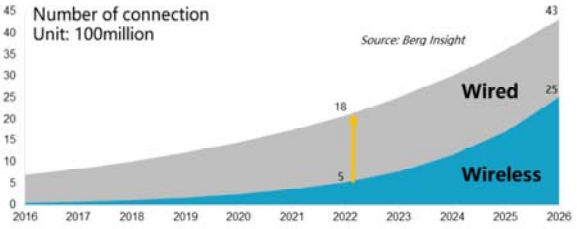


2017: Wireless connection is 6%

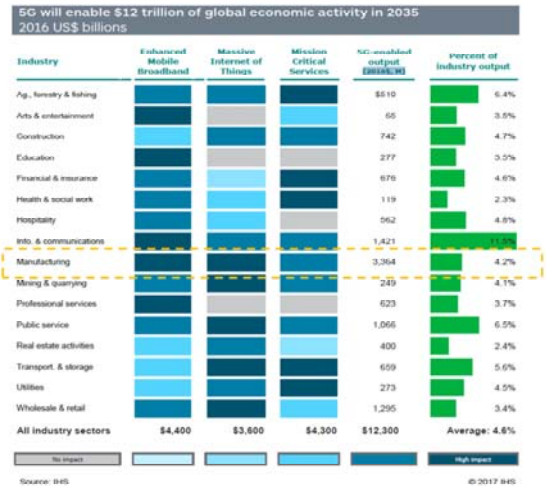
2022: Reaching 27%

2026: Reaching 58%

Source: HMS 2017




Manufacturing Occupies the Largest Share in 5G







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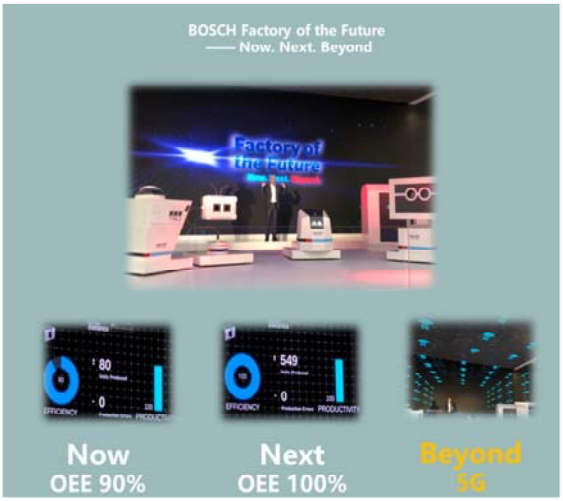
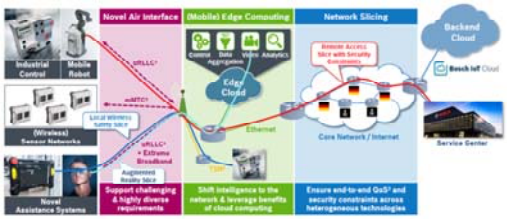
- IHS predicts that manufacturing will account for 28% of the total 5 G output in 2035.

# BOSCH Future Factory: Maximize the OEE, 5G-oriented Network Architecture




BOSCH Future Factory Network Architecture




Requirements for 5G Networks in Three Scenarios

| | Motion Control | Safety Traffic | Condition Monitoring | Augmented Reality |
|---|---|---|---|---|
| Latency / Cycle Time | 250 µs – 1 ms | ~10 ms | 100 ms | 10 ms |
| Reliability (PER¹) | 1e-8 | 1e-8 | 1e-5 | 1e-5 |
| Data Rate | kbit/s – Mbit/s | < 1 Mbit/s | kbit/s | Mbit/s - Gbit/s |
| Typical Data Block Size | 20-50 byte | 64 byte | 1-50 byte | > 200 byte |
| Battery Lifetime | n/a | 1 day | 10 years | 1 day |

uRLLC² → most challenging

Massive MTC³ Extreme Broadband → Low Latency

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- overall equipment effectiveness (OEE)

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## 2. 5G Business Applications and Cases



 

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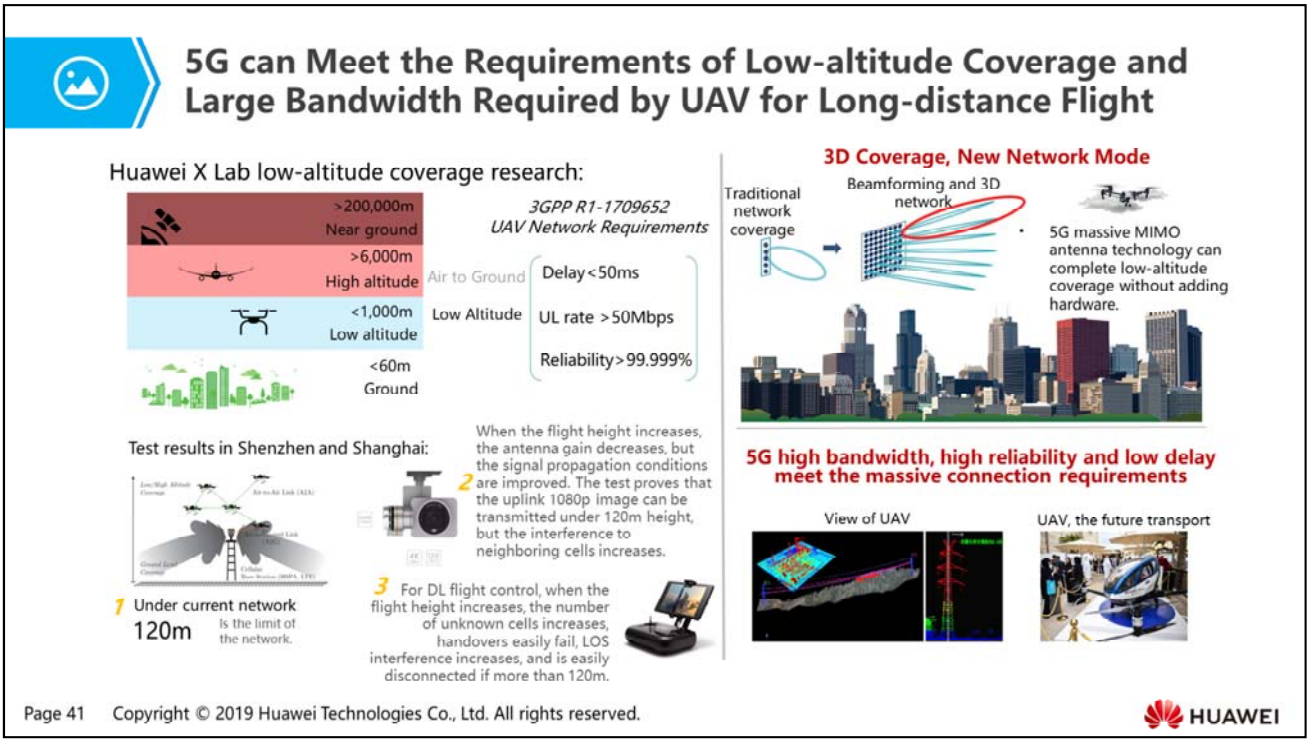
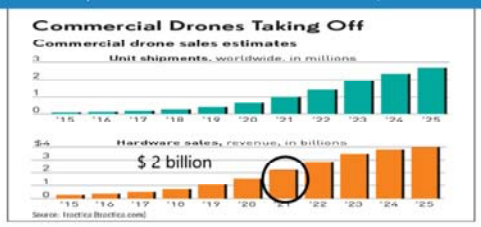


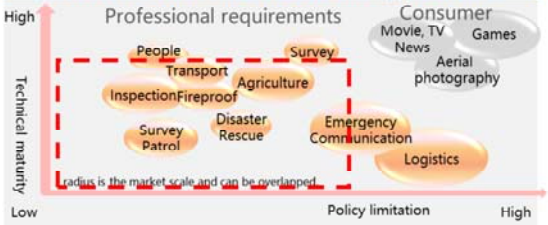

- 5G high bandwidth, high reliability and low delay meet the massive connection requirements

# UAV Industry: The Market will Reach $2 billion

## In 2021, the UAV market will reach $ 2 billion



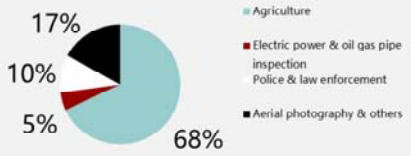

## Agriculture, forestry, security, and electric power industries will take the lead in application




## Active Support from Government and Operators

| Policy Encourage development, priority to low risk application | Operatos Active participation |
|---|---|
| • **US FAA will complete the over-the-horizon rule** In the over-the-horizon scenario, UAV has higher priority over public emergency and key infrastructure openness. | • **Verizon** plans to launch the UAV tariff package (1GB/25$ and 10GB/80$)<br>• **AT&T\E///\Nokia\QC** The testing for cellular UAV connection has been started. |
| • **Ministry of Industry and Information Technology China uses UAV as a strategy for industry development** Three dedicated frequency bands 840.5-845MHz, 1430-1444MHz, and 2408-2440MHz | |

**Agricultural is the main application and developed rapidly**




Source: CITIC Securities UAV Industry Report



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- UAV: unmanned aerial vehicle

# Case study and sharing

UAV Company A wants to cooperate with Operator B to use 5G network to achieve more business and business values.

However, UAV Company A is not familiar with 5G and does not have any solution. Assume that you are from Operator B' s operation team and need to communicate with Company A to expand the business.

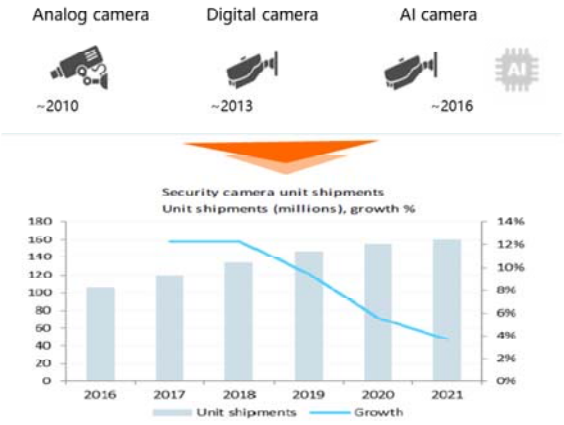
- Group discussion: Discuss the issues and output the solution.
- Presentation: Share the solution.

# Discussion

- Group discussion: Which 5G UAV business cases can be applied?
- Provide at least two types of 5G UAV commercial cases and a simple solution based on the 5G networks.
  - Descript the 5G UAV commercial cases
  - Driving force and pain points
  - Technical advantages and feasibility

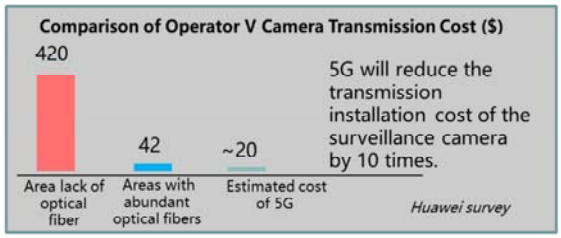
# Low-cost 5G Link Drives the Online AI Camera

**Development of visual AI enables smart city cameras to flourish**




- HSI forecast: 8% CAGR, shipment 160M/year in year 2021
- Current China is170M, estimated to be 600M by 2020

**5G WTTc installation cost is an advantage in areas where optical fibers are not developed**




**Large capacity of 5G can meet the requirements of typical cameras**

***Density of cameras in Shenzhen***

30-45/ square kilometers *Huawei survey*

| Camera resolution | Bit rate (Mbps) | Theoretical capacity of a 5G cell camera | |
|---|---|---|---|
| | | 3.5G (4:1) | mmWave (4:1) |
| 720P | 4 | 165 | 640 |
| 1080P | 8 | 90 | 320 |
| 4K | 30 | 23 | 85 |

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- It is expected that the number of cameras installed in China will increase to 626 million in three years. The current scale is 170 million.
- The number of fixed broadband users in China is 200 million-300 million.

# Summary

- Development of 5G is fast.
- Vertical industries are the top priority for 5G development.
- eMBB's vertical industry will be the first wave of 5G development.

# Acronyms and Abbreviations

- ADAS: Advanced Driver Assistant System
- AMI: Advanced Metering Infrastructure
- DOU: Data of Usage
- FWA: Fixed Wireless Access
- IPC: IP camera
- M&A: Mergers & Acquisitions
- ToD: Tele-Operated Driving
- V2I: Vehicle-to-Infrastructure
- V2V: Vehicle-to-Vehicle
- UAV: unmanned aerial vehicle
- OEE: overall equipment effectiveness
- OPC-UA: Object Linking and Embedding for Process Control Unified Architecture

# Typical Industry Application Solutions of 5G

# Foreword

- 5G will outperform earlier generations of mobile communications. For example, 5G can deliver a peak rate of 20 Gbit/s in the downlink and over 10 Gbit/s in the uplink, and shortens the end-to-end (E2E) latency to less than 5 ms and improves overall efficiency. 5G preludes an era of opportunities backed by three ideas: Mobile Beyond Gigabit to transmit data faster than optical fibers, Real-Time World to deliver higher real-time capabilities than industrial buses, and All-Online Everywhere to enable omnipresent connections.
- 5G provides novel business models for mobile operators and their customers. These business models require future networks to efficiently provision various new services based on service levels and performance requirements. Operators must be able to provide as well as quickly and effectively commercialize services for customers in various industries.

# Objectives

- After completing this course, you will be able to learn:
  - 5G technology evolution
  - Application prospects and practices of 5G in various industries
  - How does 5G meet the requirements of the mobile communications industry

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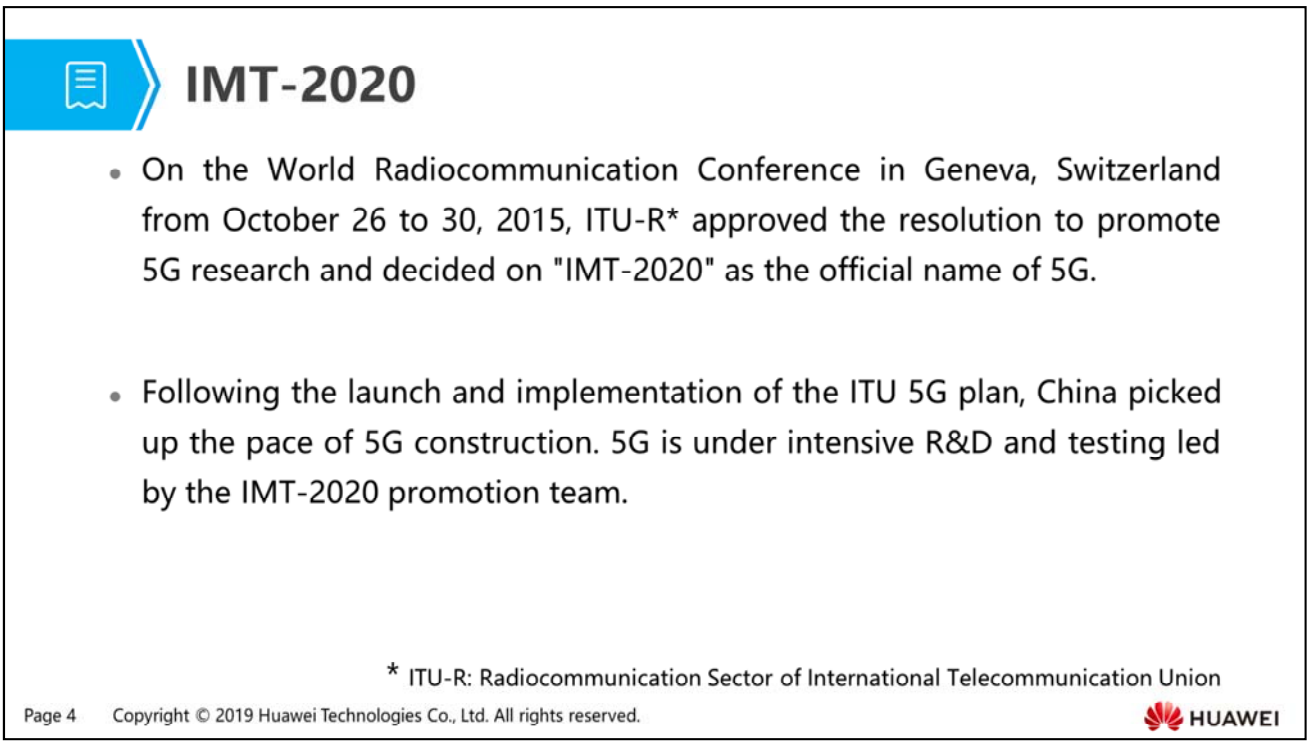
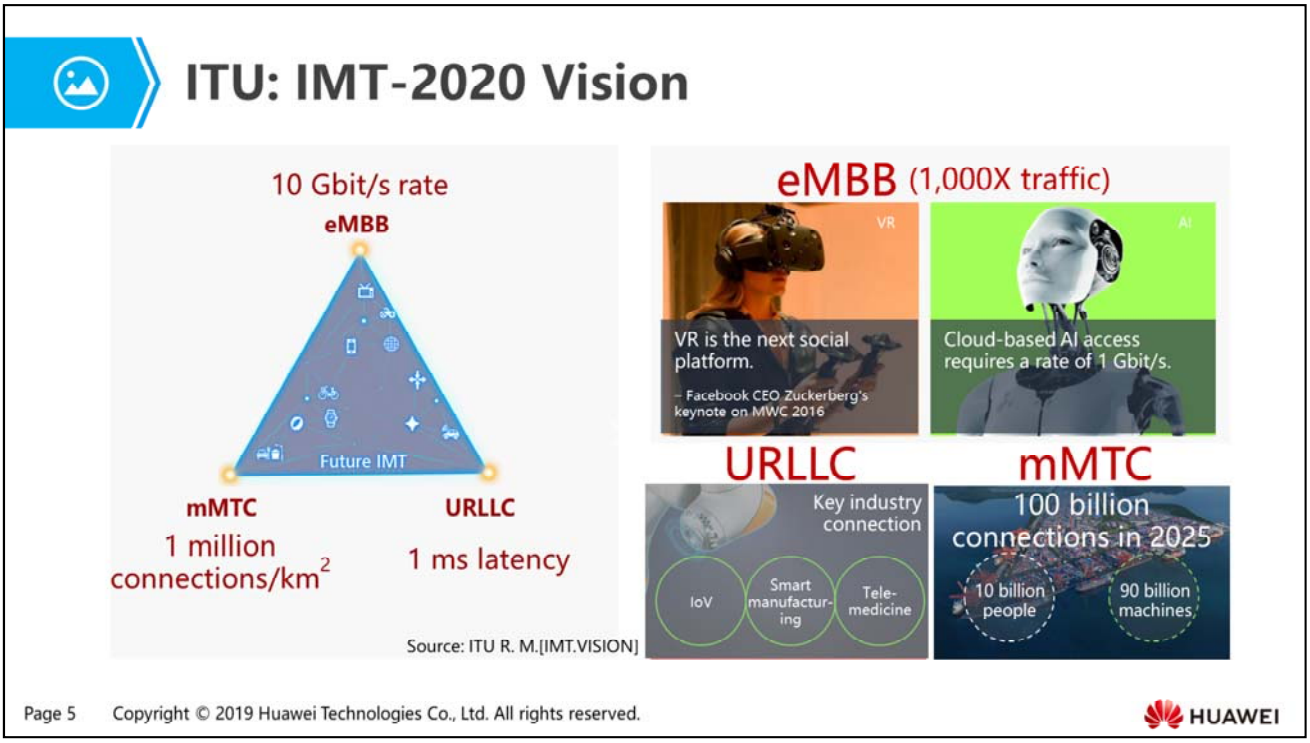
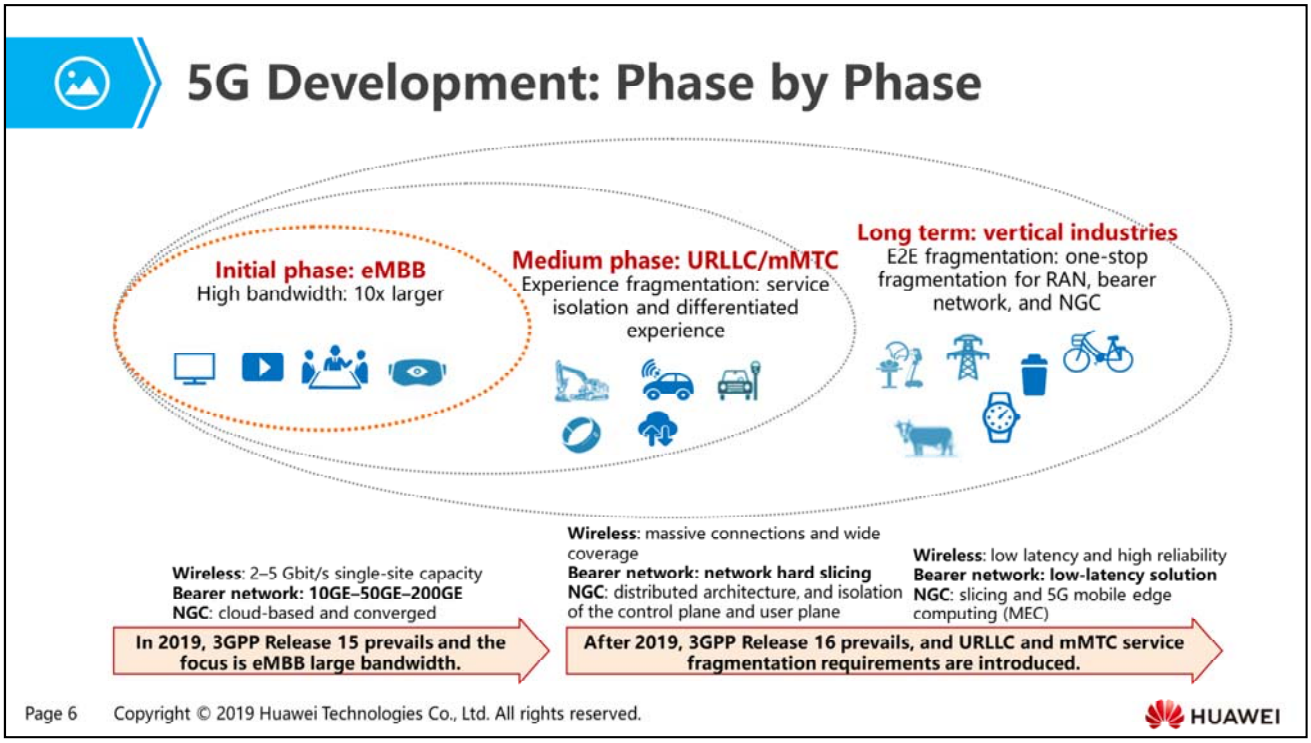



- According to the related specifications of the ITU, the next-gen mobile communications network (5G) was officially named IMT-2020 in 2015 (Beijing Time).
- The ITU has long started organizing researches on the 5G vision and technology trend in the global industry. In early 2012, the ITU set up a project team named International Mobile Telecommunication (IMT) for 2020 and Beyond.
- Recently, the ITU set up a new Focus Group to formulate the network standardization requirements of IMT-2020.
- IMT-2020 is set to deliver the wireless communications rate and reliability previously available only on the optical fiber infrastructure. The application of IMT-2020 will go beyond voice and audio to many other fields, such as healthcare, industrial automation, virtual reality (VR), unmanned driving, and robotics. IMT-2020 can empower machine control at an ultra-low latency, and latency of a technical system is crucial in people-machine communications.
- "Notwithstanding the rapid development of air interface and radio access network, we should pay more attention to the network connection in IMT-2020. Wired communications will support significant changes in IMT-2020. ITU standardization and wireless communications organizations will see to it that both wired and wireless technologies play a part in future networks," said Zhao Houlin, ITU Secretary General.
- IMT-2020 network standardization will be chaired by ITU-T. Study Group 13 (SG13) of ITU-T will convene a meeting in December 2019 before which the new Focus Group plans to complete the related research. As a standardization expert group of the ITU, SG13 is responsible for future networks, cloud computing, and mobile communications networks.




- ITU-R has defined three major 5G application scenarios in June 2015, including Enhanced Mobile Broadband (eMBB), Massive Machine-Type Communications (mMTC), and Ultra-Reliable and Low-Latency Communications (URLLC), as well as eight capability specifications, including the throughput rate, latency, connection density, spectrum efficiency, and others.
- Huawei predicts that 100 billion connections will be set up worldwide by 2025.




- Test results of three scenarios in phase 2 of Huawei:
  - **eMBB**: The downlink peak rate of cells exceeds **20 Gbit/s**.
  - **URLLC**: The user-plane latency is **0.407 ms**, which is less than the 1 ms standard defined by the ITU.
  - **mMTC**: The number of connections exceeds 10 million per MHz per cell, greater than 1 million/km2 defined by the ITU.

# 5G Application: Commercial Adoption in 3 Waves

**Wave 1: eMBB**

**AR/VR/HD video/UAV**


**AR/VR/HD video**

**2K screen is standard configuration for mid-range and high-end terminals.**

iPhone 8 and 8 Plus
Samsung Galaxy S8 and S7 Edge
Huawei Mate 9 and Honor V9
LG, Meizu, and VIVO

AR applications on new iPhone models at the launch event

**Wave 2: URLLC**

**IoV**

**Cloud-based AI robotics**

**Smart manufacturing**

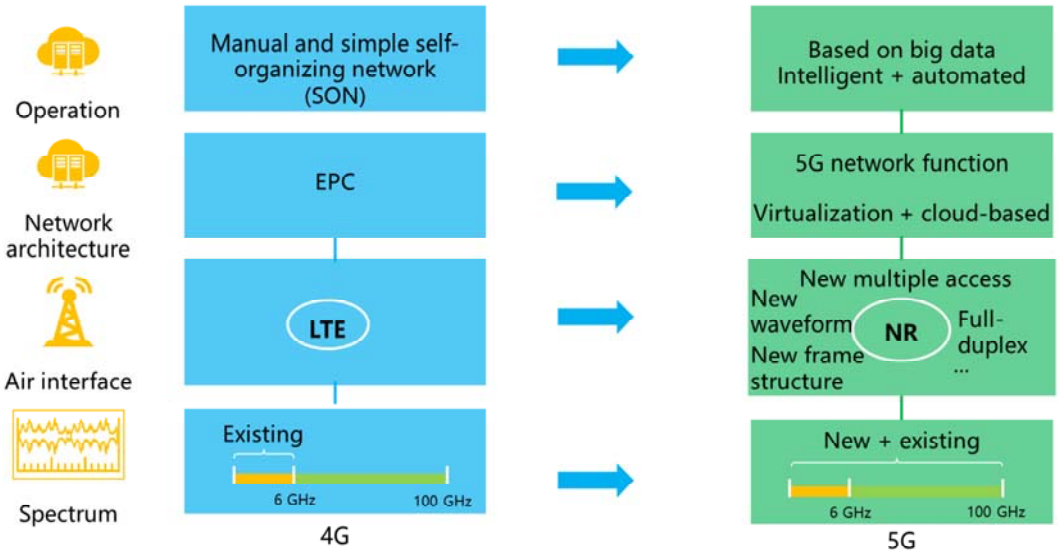
**Joint exploration of typical applications**

**5G industry chain and ecosystem.**

**Wave 3: mMTC**

**4G IoT will be the first step to explore vertical industries for 5G and is important to verify 5G services.**

# 5G Evolution Roadmap



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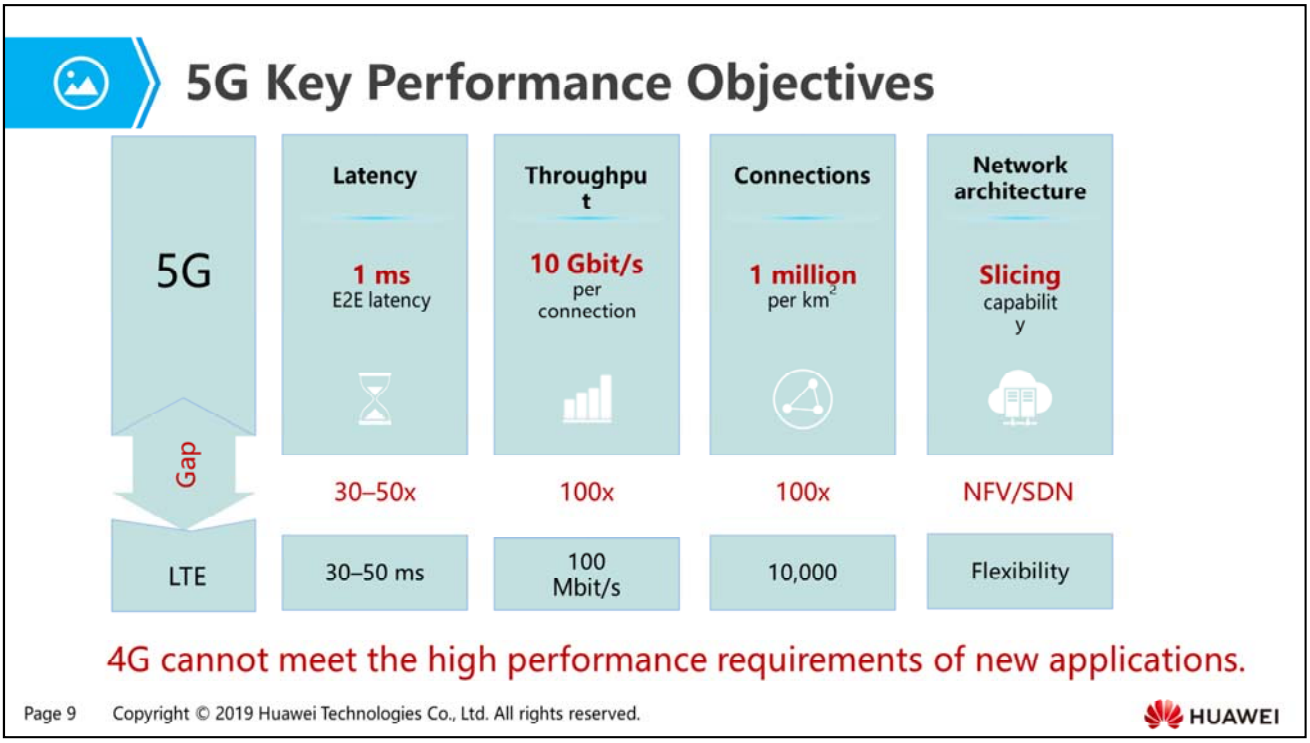



- 4G cannot accommodate a large number of applications in the future and meet related requirements for latency, throughput, and connections.

# 5G as a National Strategy

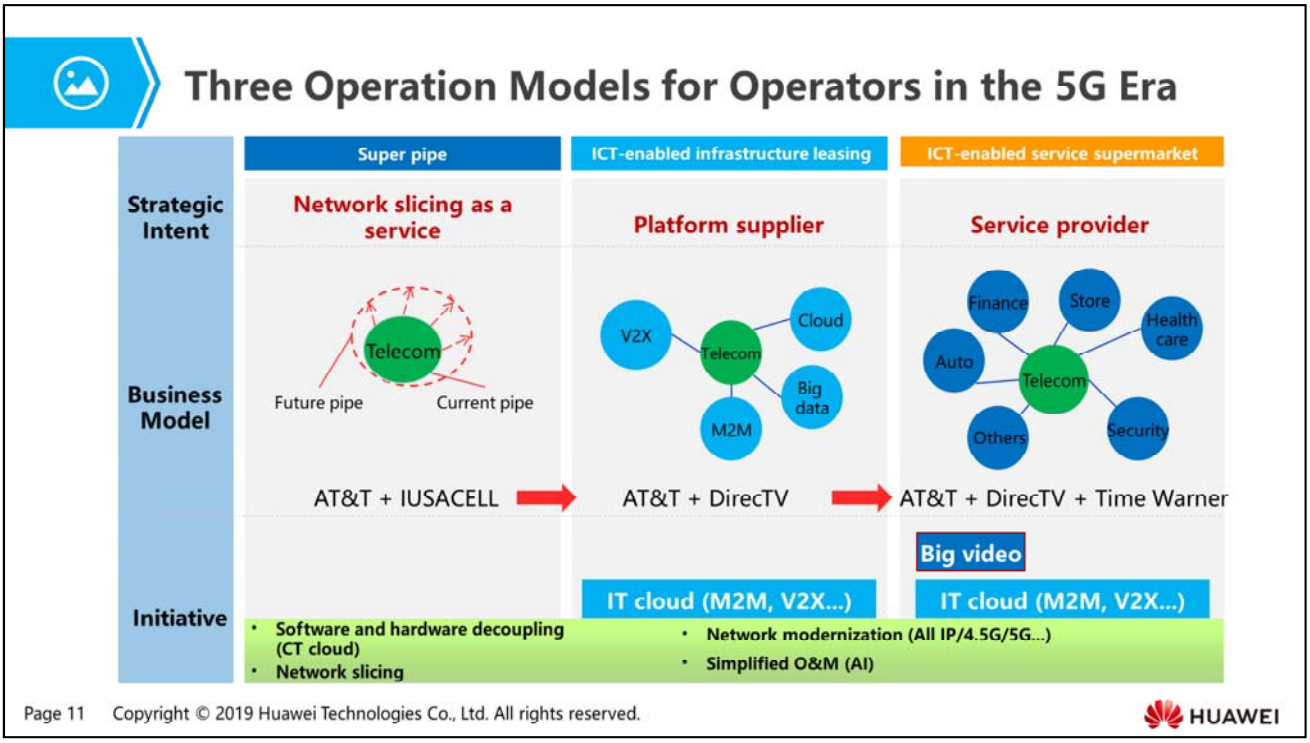
**Change in oversight focus to boost economy**

Managing competition & fairness → Encouraging investment & innovation

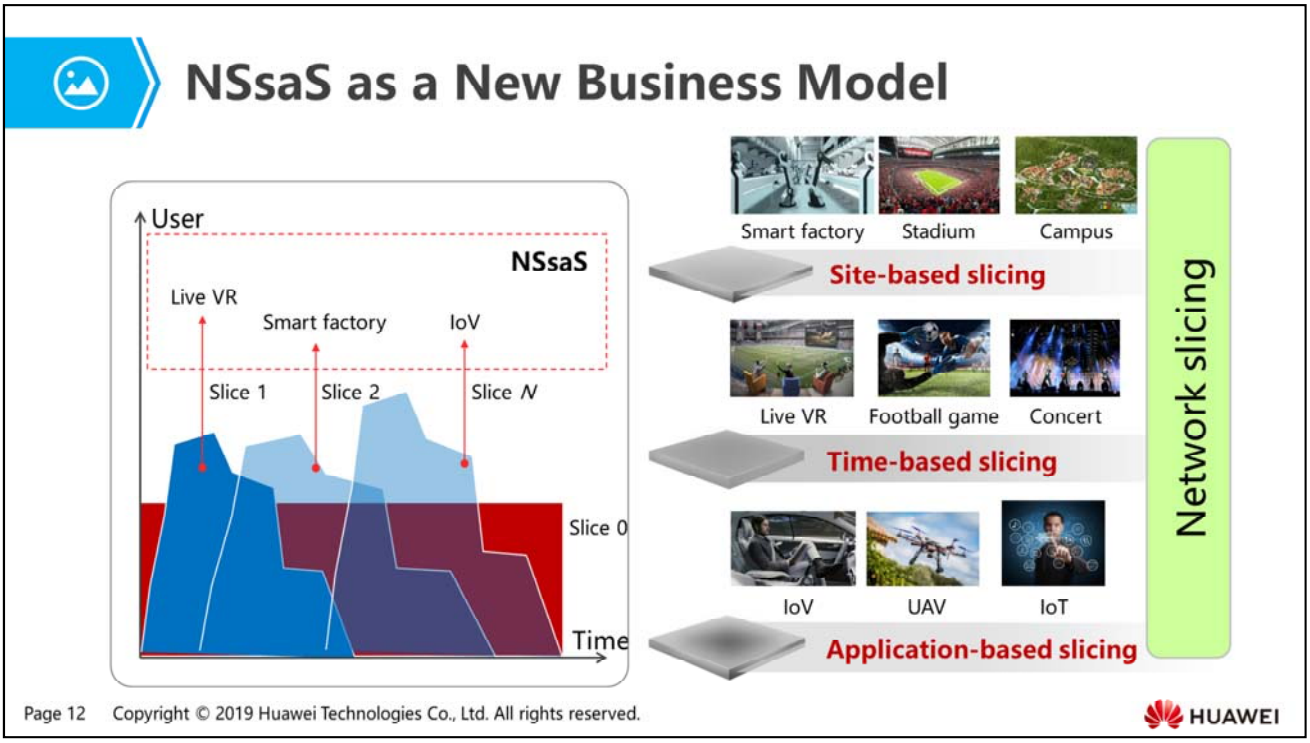
- Governments lay hopes on high-tech industries to boost the long-term feeble economy.
- 5G is expected to interconnect industries and usher in the digital era.
- Management authorities decide the opportunities of future economic development.

**5G is not simply just for communication, but crucial for national industry.**

| Country | Strategic Plan | 2018 | 2019 |
|---|---|---|---|
|  | **Active layout and large-scale pilot**: IMT-2020 (5G) promotion team was set up in 2013. | Field test | Pre-commercial |
|  | **Early commercial use to seize market**: ≥ 24 GHz high-frequency spectrum | mmWave commercial (pre) | mmWave commercial (pre) |
|  | **Quick commercial use during PyeongChang Olympics**: GIGA Korea, 2020&Beyond KT SIG standard (360° VR, time slicing, simultaneous viewing of 3 services) | Roadshow (non-3GPP) | Commercial |
|  | **Quick pilot to keep up**: EC Seventh Framework Programme, FP7, 5G innovation center in the UK | Field test | Pre-commercial |



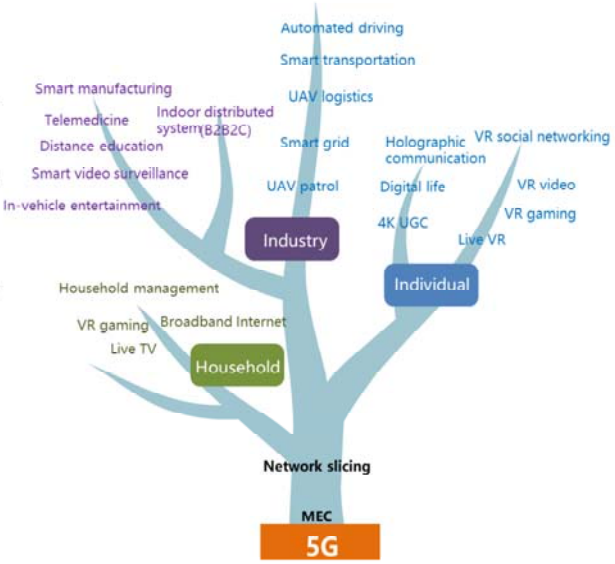

- In addition to NSsaS, operators can have three operation models in the future: super pipe, ICT-enabled infrastructure leasing, and ICT-enabled service supermarket. We will use AT&T as an example to talk about the differences with previous operation models.
- First, let's look at the super pipe model. This operation model is the same as current practices. Operators need to expand their networks and develop multinational operation via pipeline monetization. For example, AT&T acquired Mexico IUSACELL. The future 5G networks will support network slicing, and super pipes will also be smart pipes.
- ICT-enabled infrastructure leasing allows operators to increase revenues by integrating the services of other providers with their own infrastructure platforms (such as M2M and V2X platforms). For example, AT&T acquired DirecTV and obtained a video platform, so that AT&T could cooperate with some content providers to develop video services.
- The ICT-enabled service supermarket allows operators to provide E2E services in a certain domain. Operators develop their own content platforms. For example, AT&T acquired Time Warner in the hope to become a video service provider.
- Super pipe is the basis of the other two models. To build super pipes and meet the requirements of future vertical industries, operators need to do the following: software and hardware decoupling, network modernization, network slicing, and simplified O&M. In addition, a service platform and a content platform must be deployed to support infrastructure leasing and service supermarkets in the future.




- NSsaS is short for network slicing as a service.
- Operators can charge services by site, such as stadiums and smart factories, and also by time at the same site. For example, in stadiums, when there is a concert or sports event, operators can provide live VR services via a time slice which disappears once the event is over. This is a specific manifestation of NSsaS in the future. Therefore, 5G changes the traditional flat-rate charging mode and allows operators to tap more into charging by superimposing different services.

## Industry Application: Key to 5G Business Success

- New business domains: Operators' capabilities and business models in specific industries determine their business potential.
- Differentiation: In the 5G era, efficiency improvement will lead to a sharp decrease in labor costs and unleash new potential for operators. Operators will be able to start from network connection and then gradually build capabilities such as enhanced network, platform integration, and service operation.
- Ecosystem building: Operators can select pilot projects and the first batch of vertical commercial industries based on their geographical business characteristics and advantages.



- Network slicing enables flexible network configuration, allowing for precise translation of operators' network resources into money.
- Low-latency and high-throughput service assurance truly changes user experience and improves control sensitivity.
- The combo of a mature industry and 5G is the focus of 5G industry development and is gradually expanding to more industries.

# Contents



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# What Is IoV?

**The Internet of Vehicles (IoV), also called Vehicle to Everything (V2X), connects vehicles to everything. IoV provides comprehensive network connections through telematics, vehicle-to-vehicle (V2V), vehicle-to-pedestrian (V2P), vehicle-to-infrastructure (V2I), and vehicle-to-network (V2N).**

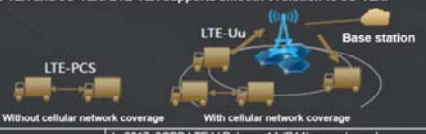

## V2X interaction modes:

- **V2X**: enables vehicles to communicate with each other through in-vehicle devices.
- **V2P**: enables disadvantaged groups in traffic (such as pedestrians and cyclists) to use user devices (such as mobile phones and laptops) to communicate with in-vehicle devices.
- **V2I**: enables in-vehicle devices to communicate with roadside infrastructure (such as traffic lights, traffic cameras, and roadside units).
- **V2N**: enables in-vehicle devices to connect to the cloud platform using the access network or core network.

# IoV Communications Technologies: C-V2X Is More Suitable for Complex Safety Application Scenarios

## C-V2X VS. DSRC

Cellular V2X (C-V2X) is a 3GPP-based global communications technology that includes LTE-V2X and 5G-V2X. LTE-V2X supports smooth evolution to 5G-V2X.




| | |
|---|---|
| Technical Standards | In 2017, 3GPP LTE-V Release 14 (R14) was released.<br>In June 2018, 3GPP Release 15 (R15) that supports LTE-V2X enhancement (LTE-eV2X) was released.<br>In June 2018, the research of 3GPP Release 16 (R16) that supports 5G-V2X was announced. |
| Spectrum | China allocates the frequency band of 5905–5925 MHz to be the LTE-V dedicated spectrum. |
| Chipset | Huawei Balong 765, Qualcomm 9150, and Intel Xeon SoC |
| Module Device | Module: Datang, Quectel, and others<br>Currently, only Datang and Huawei support LTE-V roadside units (RUSs) or on-board units (OBUs). |
| Automotive Enterprise | Audi, BMW, Ford, SAIC Motor, Changan, and others |
| Testing | Since 2015, multiple test demos have been conducted. At present, China is promoting the urban-level demonstration in Wuxi and Yanchong highway demonstration. Italy and South Korea have conducted pilot projects. |
| Delay/Communications Distance | 20 ms (R14) and 1 ms (R16)/450 m at a speed of 140 km/h |

Based on IEEE 802.11p, the Dedicated Short Range Communications (DSRC) technology provides short-distance wireless transmission. V2V and V2I communications are the main application modes.


| | |
|---|---|
| Technical Standards | In 2010, DSRC (802.11p) was released.<br>In 2013, ETSI ITS-G5 was released in Europe. |
| Spectrum | The US, Japan, and Europe have allocated ITS dedicated frequency bands. |
| Chipset | NXP, Autotalk, Renesas, and other commercial chipsets. In 2015, Qualcomm embedded 802.11p into its Snapdragon chipset. |
| Module Device | Bosch, Continental, and Denso<br>Module: Cohda, Savari, and others |
| Automotive Enterprise | General Motors: Installed the DSRC system on Cadillac CT6 in 2009.<br>Toyota: Installed the DSRC system on 100,000 vehicles in Japan in 2015.<br>Other mainstream automobile enterprises: BMW, Benz, Audi, and others have conducted multiple rounds of tests. |
| Testing | The US, Europe, and Japan have DSRC test projects. Tens of thousands of vehicles and dozens of intersections are deployed. However, the activation rate is low. |
| Delay/Communications Distance | < 50 ms/225 m at a speed of 140 km/h |

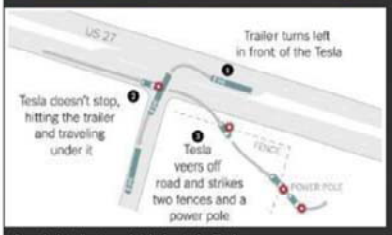




- C-V2X has outpaced its forerunners. Its industry chain has been gradually established. It applies to scenarios with more complex security requirements. It also meets the requirements for low latency, high reliability, and bandwidth.

# C-V2X Provides More Reliable Intelligent Decision-Making and Cooperative Control for Automated Driving

## Case: Tesla Accident




Step 1: A trailer turns left in front of a Tesla.

Step 2: The Autopilot system on the Tesla did not identify the trailer, and the Tesla hit the trailer and traveled under it.

Step 3: The Tesla veered off the road and struck the fences and then a power pole.

Cause: Mobileye's front visual perception system (camera) can identify only the rear of front vehicles, but not their side. The trailer was regarded as a blue sky with white clouds by the camera and a road sign by the millimeter-wave radar. The millimeter wave radar and camera are a part of the automated environment sensing system.

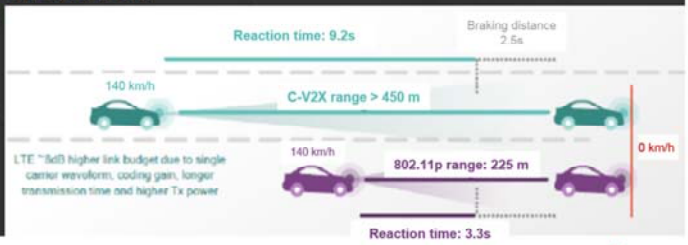
The automated driving system that relies solely on sensors cannot accurately sense all weathers and global road conditions.

## C-V2X Becomes the First Choice for China's IoV Technology Standards

C-V2X ensures effective cooperation among pedestrians, vehicles, and roads.

- DSRC (802.11p) raises the awareness of potential risks of C-V2X.
- C-V2X is the first choice for China's V2X technology standards. The reasons are as follows:
  - China has led the standardization of LTE-V2X of 3GPP.
  - China has the world's largest LTE network and LTE-V evolution technology advantages, although LTE-V is not as mature as DSRC.

## C-V2X vs. DSRC:



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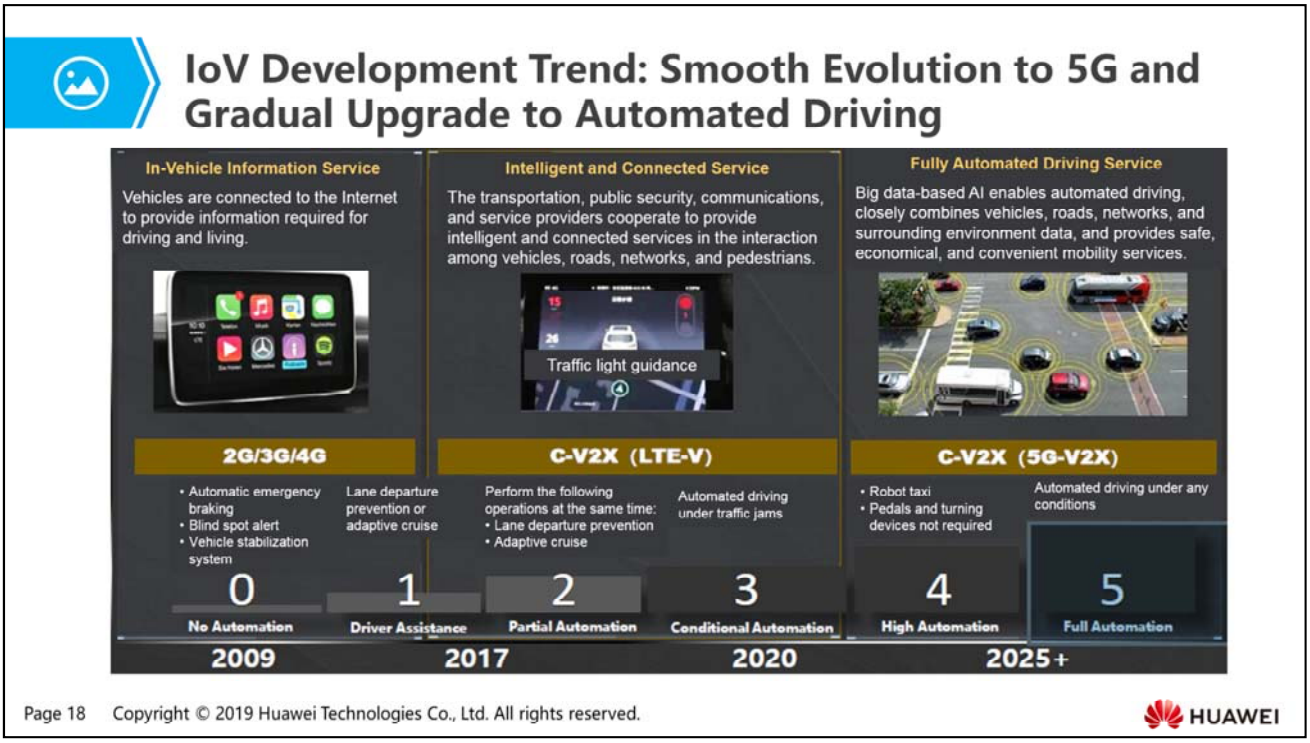
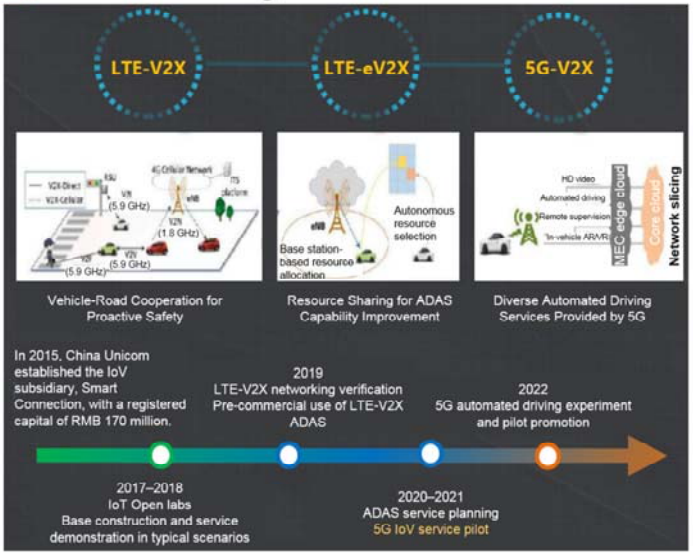



- Automated driving is the highest level of IoV development. According to the automated driving classification standards formulated by the SAE International, IoV needs to improve the intelligence of vehicles, networks, and basic settings from in-vehicle information services to intelligent transformation.

# 5G-V2X Technology and Deployment Roadmap: Pilot Projects and Promotions in 2022



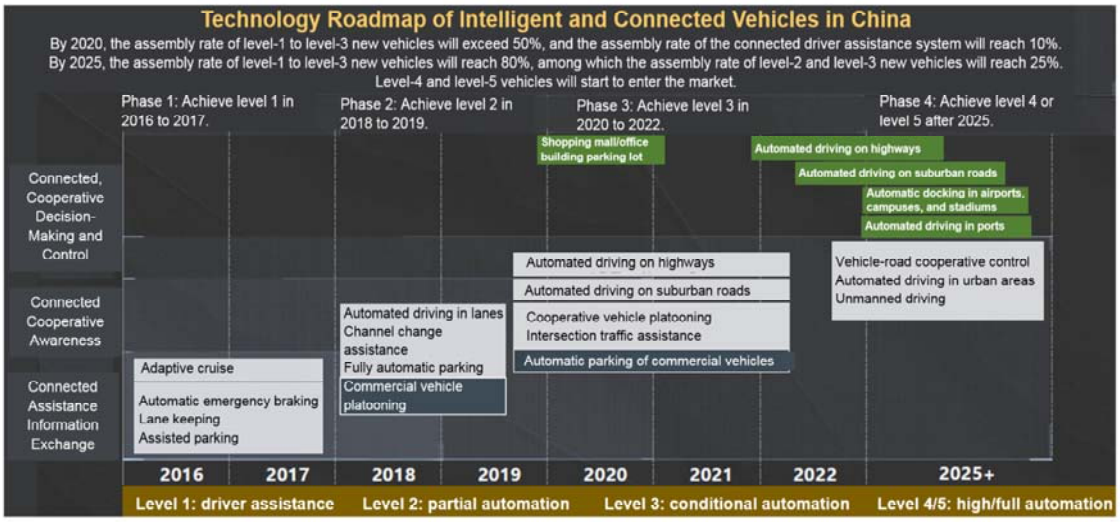

- LTE-V2X: applicable to 27 application scenarios (3GPP TR 22.885) of 3GPP, including proactive safety, traffic efficiency, and information entertainment
- LTE-eV2X: compatible with LTE-V2X, improving reliability, data rate, and latency performance of V2X to partially meet requirements of advanced V2X services
- 5G-V2X: applicable to the following four groups of scenarios related to automated driving (3GPP TR 22.886)
  - Vehicle platooning
  - Overtaking
  - Sensor information sharing
  - Remote driving






- 5G-V2X: applicable to the following four groups of scenarios related to automated driving (3GPP TR 22.886)
  - Vehicle platooning
  - Overtaking
  - Sensor information sharing
  - Remote driving

# China's Automated Driving Industry: Commercial Use of 5G-Enabled Level-4 and Level-5 Automated Driving in 2025



# Why Does Automated Driving Require 5G?

**Interactive Perception**

**Experience Improvement**

1. Reduces latency.
2. Reduces road uncertainty.
   - Distance, speed, location...
   - Vehicle route interaction
   - Vehicle status interaction

**Free from Distance and Environment Constraints**

**Capability Enhancement**

1. Makes up for constraints on sensors due to distance and environment.
2. Meets passengers' requirements for in-vehicle infotainment (IVI), such as AR/VR, games, movies, and mobile office, and high-definition maps.

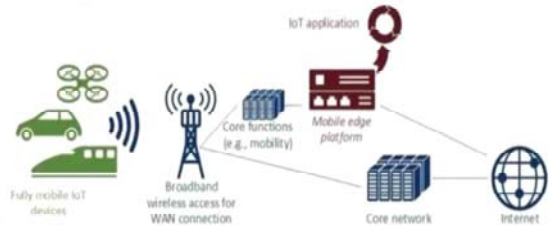
**Getting Rid of Single-Vehicle Intelligence**

**Intelligent Cooperation**

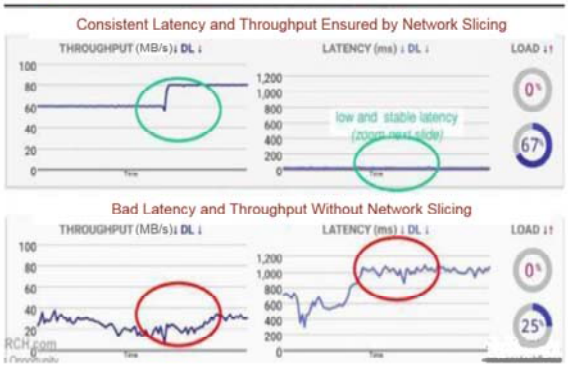
1. Promotes the evolution from single-vehicle intelligence to cooperative intelligence.
2. Increases the possibility of automated driving, helping implement partial intelligent cloud control for vehicles on fixed routes in cities.

# 5G Edge Computing and Slicing Technologies Ensure Automated Driving

**Edge computing is the future of automated driving.**




**5G network slicing technologies provide consistent QoS guarantee.**



- The near real-time HD video transmission and the complementary between V2N and V2V (V2N2V) of 5G enable the automated driving technology to be your eyes and ears and providing 100% safety. The requirements of unmanned driving include traditional coverage, capacity, delay, reliability, speed, mobility, safety, cost, and power consumption.


- 12 basic application scenarios of IoV:
    1. Crossroad collision warning
    2. Collision warning upon lane change
    3. Sudden stop warning
    4. Forward collision warning
    5. Emergency vehicle avoidance
    6. Danger reminder of motorcycle sight blocking
    7. Roadside construction reminder
    8. Congestion notification
    9. Information broadcast of RSUs
    10. Dangerous road broadcast
    11. Dangerous weather warning
    12. Speed limit reminder

# 5G Enables Advanced Automated Driving Scenarios to Improve Efficiency and Safety (2)

## Four high-level scenarios

Vehicle platooning

Overtaking

Sensor information sharing

Remote driving

**Challenges of High-Level Automated Driving to Networks (5G-V2X)**

| High-Level Scenario | Maximum End-to-End Latency | Reliability | Throughput (Mbit/s) | Minimum Communications Range |
|---|---|---|---|---|
| Vehicle platooning | 10–25 ms | 90–99.99% | 50–65 | 80–250 m |
| Overtaking | 3–100 ms | 90–99.999% | 10–53 Upstream: 0.25; Downstream: 50 | 360–700 m |
| Sensor information sharing | 3–100 ms | 90–99.999% | 10–1000 | 50–1000 m |
| Remote driving | 5 ms | 99.999% | Upstream: 25; downstream: 1 | N/A |

**5G Enables Advanced Automated Driving Scenarios to Improve Efficiency and Safety**

- Higher efficiency:
  - ✓ Solves the problem of vehicle driver shortage and improves efficiency.
  - ✓ Vehicle platooning reduces power consumption by 9% (at a following distance of 1.5 m) to 25% (at a following distance of 0.3 m).
- Higher safety:
  - ✓ Updates the dynamic map in real time to avoid construction road sections.
  - ✓ Provides video sharing and cooperative environment awareness to avoid driver blind spots.
  - ✓ The round-trip time (RTT) interaction of the 5G-V2X is controlled within 20 ms, and the response distance deviation is 0.6 m, which is 10% of LTE-V.



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- Four high-level scenarios: vehicle platooning, overtaking, sensor information sharing, and remote driving

# Contents

# Future Transportation: Convenient Mobility and Smart Logistics


**Objective:**

- **Be safe, unblocked, convenient, efficient, and environmentally friendly.**
- **Promote function transformation and structure expansion of cities.**

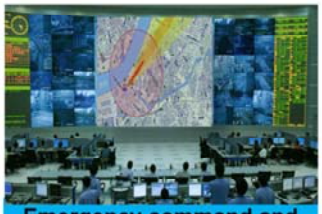
- Comprehensive supervision on three-dimensional transportation
- Visualized traffic operation and scheduling
- Efficient emergency handling
- Efficient, convenient transportation management
- Door-to-door traffic information services
- Efficient, accurate decision analysis
- Integrated public transportation
- IoV with vehicle-road cooperation and automated driving

# Transportation Information Challenges

Traffic congestion

Traffic accident

Pedestrian violation



Emergency command and scheduling

Complex evidence collection for traffic law enforcement


Non-real-time information

# Necessities of Integrated Intelligent Transportation Construction

Multiple government transportation departments can work together and coordinate with each other using unified management functions.

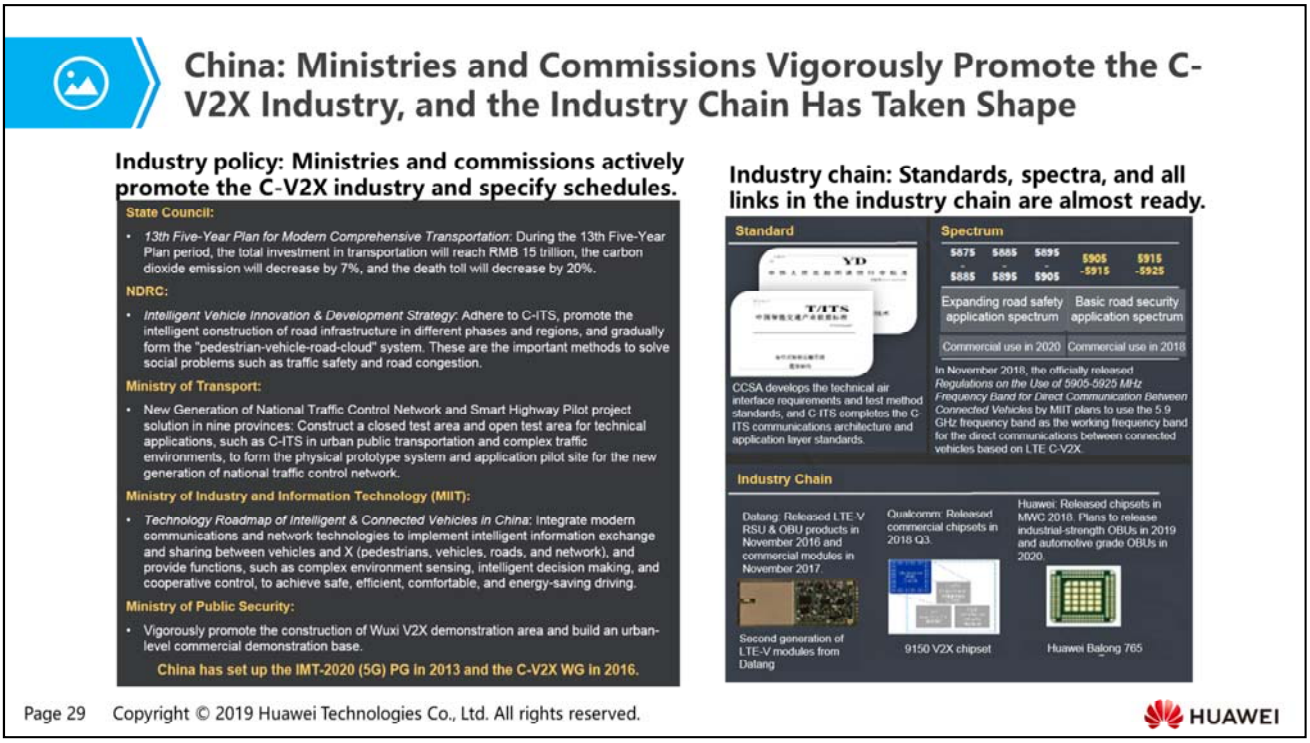
- Build a coordinated command system of traffic operation at ministry, province, city, and county levels.
- Ensure the comprehensive transportation organization, coordination, and command during important holidays and events by means of site co-construction, joint office, and clear labor division.
- Optimize resources and share information to further informatize the entire transportation department by means of central maintenance, unified management.

Enhance comprehensive traffic operation surveillance, improve the response capability of traffic emergency events, and provide auxiliary decision analysis, prediction, and warning.

- Supervise the traffic infrastructure and comprehensive traffic status, and manage and control the road network, waterway, railway, and civil aviation.
- Information instructions can be directly reported and delivered by using flat management to improve the response capability and handle traffic emergencies.
- The combination of 5G network, cloud platform, and big data platform implements multi-source data convergence analysis, provides data support for decision making, and improves the prediction and prediction capabilities for traffic

Improve mobility service efficiency, mitigate traffic congestion, and reduce environmental pollution.

- Release real-time traffic information, provide all-round and multi-way mobility service information, facilitate people to choose a convenient, comfortable mobility mode, and improve public satisfaction.
- Scientifically organize transportation, construct a "big traffic" system, and improve the road capacity and transportation efficiency.
- Mitigate traffic congestion and reduce greenhouse gas emissions and environmental pollution caused by PM2.5.








- China's smart IoV focuses on vehicle sharing, in-vehicle digital life, and automated driving.

# The US, Japan, and Europe Are Also Developing IoV

## US

Strategy:

- Carried out the ITS strategic plan in the 1970s. From 2015 to 2019, the US has proposed two goals and two key points: vehicle connectivity and automation.

Legislation:

- The US appoints the *Federal Motor Vehicle Safety Standards* through legislation to promote the enforcement of DSRC installation on vehicles.
- The National Highway Traffic Safety Administration has appointed guidelines and policy frameworks for automated driving vehicles, set up a transportation transformation research center, and promoted demonstration testing.

By leveraging its advantages in information technologies, the US is leading the development in the industry with many startup enterprises in Silicon Valley.

## Japan

Government promotion:

- Coordinates cross-industry cooperation, takes the lead in establishing business models, and invests in infrastructure construction.
- Cooperates with domain technologies to develop common basic data, information collection, and information processing.

Industry chain:

- Multiple industry chains are interweaving.
- Automotive enterprises have implemented new strategic plans on IoV.
- The closed technology system is opening and the C-V2X technology is being researched.

Relying on market advantages and advanced transportation infrastructure, Japan steadily promotes IoV technologies.

## Europe

Strategy:

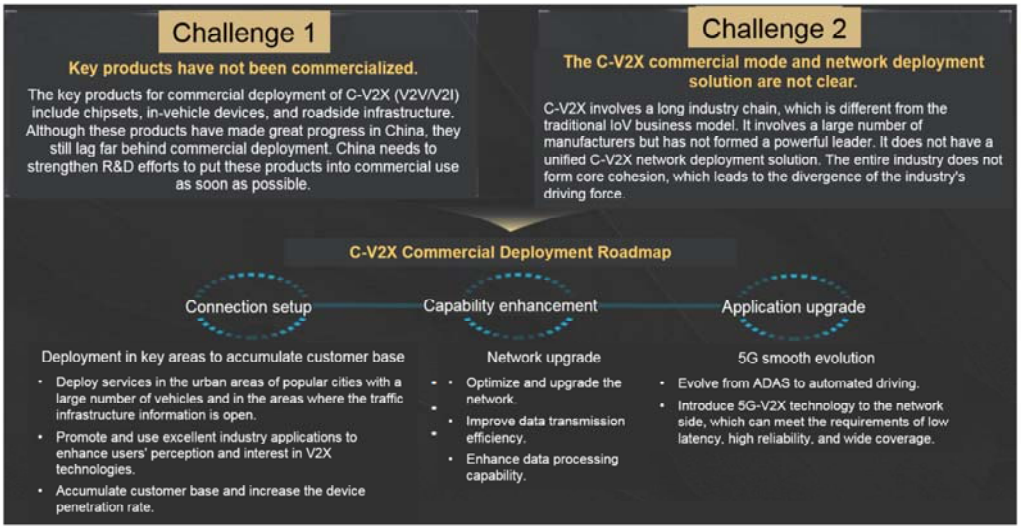
- According to the latest draft, the EU tends to adopt the IoV standards specified by DSRC and reviews the new standards in the next three years. (EU countries have already deployed Wi-Fi for road infrastructure.)

Standard formulation and continuous research:

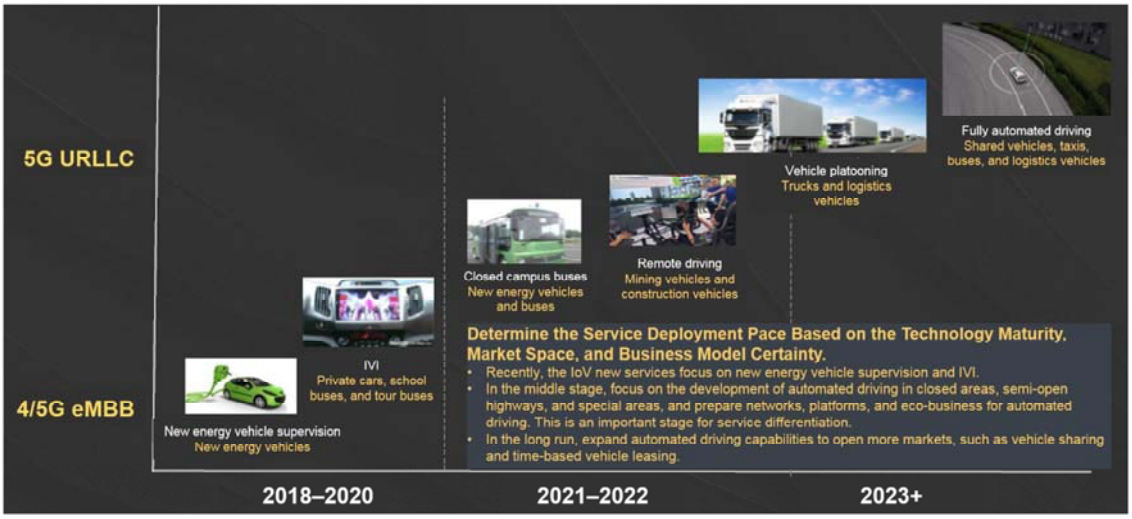
- In 1986, the Programme for a European Traffic of Highest Efficiency and Unprecedented Safety was launched. In 2000, the Keystone Architecture Required for European Networks (KAREN) project, which includes the ITS framework, was published. In 2009, multiple organizations were entrusted to formulate unified ITS standards. In 2011, the Drive C2X IoV project was launched.

With numerous automotive enterprises and smart driving technologies, competitive tier 1 enterprises in Europe have advantages on transformation.

# C-V2X Industry Challenges: Slow Commercial Use and Unclear Business Model



## Suggestions on the Exploration Pace of Carriers' IoV Services: Focus on Industry Applications and Strengthen Industry Cooperation



- C-V2X Industry Map of China

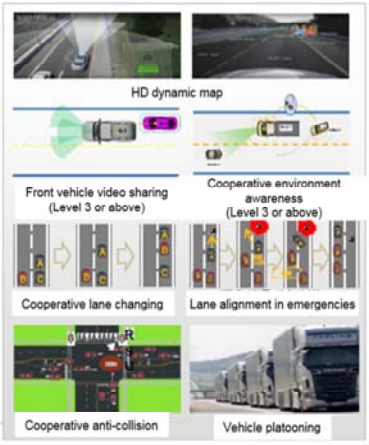
# Contents



## Service Design: In the Middle Stage, 5G Enables Automated Driving Beyond 4G, Which Is More Secure and Efficient

### Application Scenarios




### Value Proposition

**High security**

- HD dynamic map: Notify drivers of road work or traffic accidents in real time.
- Video sharing and cooperative environment awareness: Provide non-line-of-sight (NLOS) environment awareness and cooperation to eliminate blind spots for drivers.
- AR navigation: Use the windscreen as the AR navigation interface, which is more intuitive and secure.
- V2X and ADAS collaborate to improve reliability from 60% to 96%.
- The RTT interaction of 5G is controlled within 20 ms, and the response distance deviation is 0.6 m, which is 10% of the LTE-V. (See note 1.)

**High efficiency**

- Reduce labor costs.
- Free people from repetitive labor and improve production efficiency.
- Vehicle platooning: Reduce fuel consumption by 9% (1.5 m) to 25% (0.3 m). (See note 2.)

### Experience Requirements

| Automated Driving Level | Network Bandwidth | Network RTT |
|---|---|---|
| Level 1: driver assistance | 0.05–4 Mbit/s | 100–1000 ms |
| Level 2: partial automation | | 20–100 ms |
| Level 3: conditional automation | 0.05–25 Mbit/s | 10–20 ms |
| Level 4/5: high/full automation | 30 Mbit/s–1 Gbit/s | 1–10 ms |

Source: 3GPP and Huawei xLab



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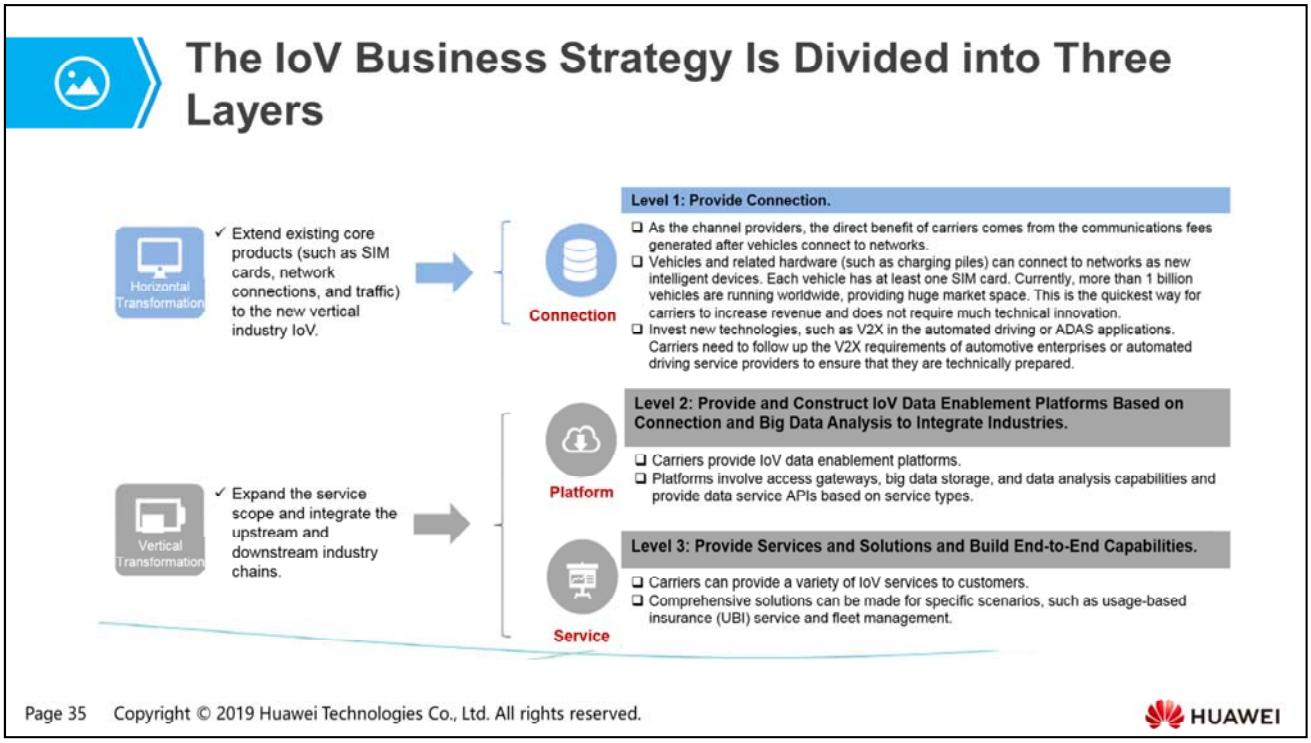
- Note:

  1. Assume that the vehicle speed is 100 km/h and the braking delay of LTE-V is greater than 200 ms.

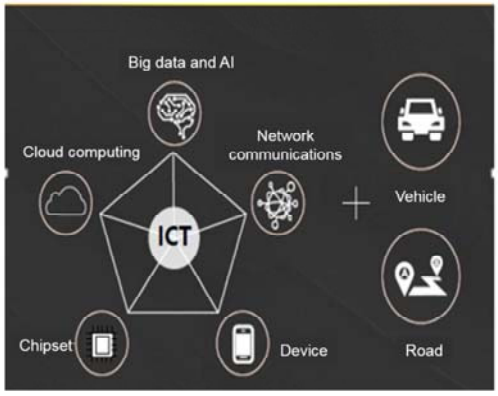
  2. Distance between vehicles.




- IoV can be considered as a new service for carriers to perform horizontal or vertical business transformation. Horizontal transformation is relatively easy to implement. Vertical transformation requires new capabilities or acquisitions.

# IoT Strategy: Leverage ICT to Enable Vehicles and Roads for Future Mobility Transformation

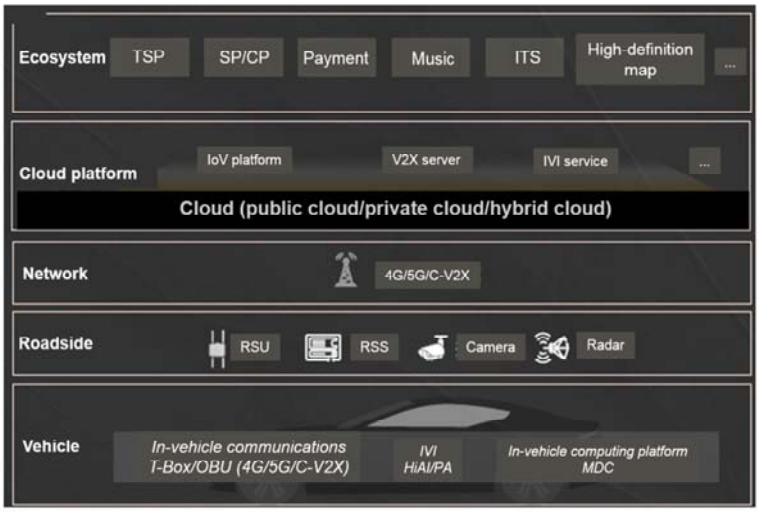
## ICT-enabled vehicles and roads




## Pedestrian-vehicle-road synergy

| | |
|---|---|
| Safe | **ADAS/Automated driving**<br>• NLOS warning<br>• Roadside pedestrian reminder |
| Efficient | **C-ITS**<br>• Real-time road condition perception<br>• Smart route planning |
| Convenient | **Smart driving experience**<br>• Personalized, scenario-based intelligent recommendation<br>• Interactive voice response (IVR) and AR-HUD |

# IoV Solution

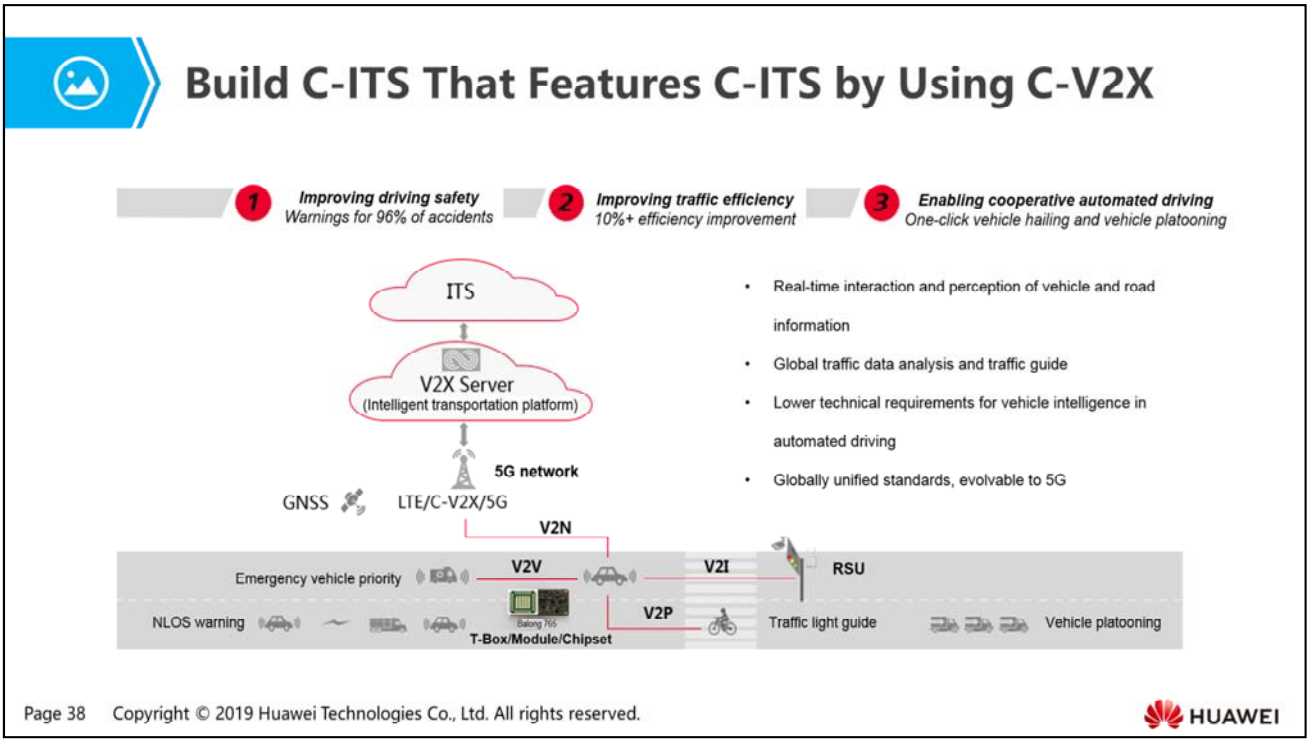



**MDC**
In-vehicle computing platform
Enabling automated driving

**IVI**
Introduction of the mobile phone ecosystem
Providing smart driving experience

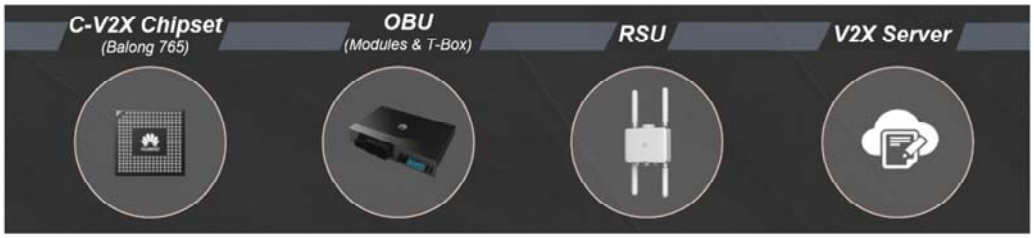
**C-V2X**
C-ITS
Building cooperative intelligent transportation

**IoV Platform**
Vehicle digitization
Enabling automotive enterprises' transformation to service enterprises




- Build a C-ITS to reduce vehicle-road information asymmetry, popularize bidirectional interaction between vehicles and roads, and improve traffic safety and efficiency. Evolution to cooperative automated driving can reduce the cost of making intelligent vehicles.

# Commercially Available Chipset, Vehicle-Side, Road-Side, and Platform Products




**C-V2X features**
- PC5 + Uu concurrency
- Mode3 + Mode4

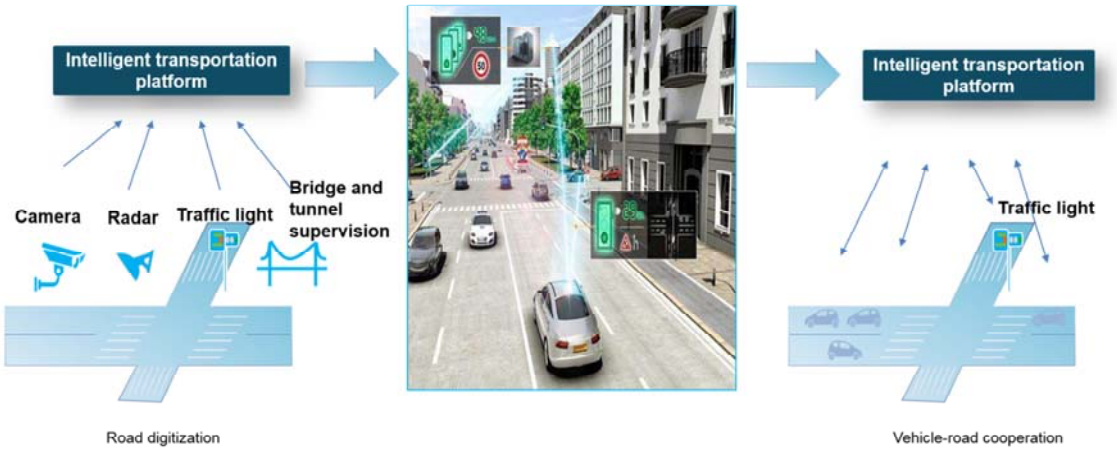
**MBB features**
- 3GPP Rel. 14
- Downlink peak rate: 1.6 Gbit/s
- 4CC CA + 4x4 MIMO
- 2CC CA + 8x8 MIMO
- DL 256QAM

- T-Box recognized by many automotive enterprises
- Advantages of C-V2X and 5G

- World's first RSU that supports Uu + PC5 concurrency
- Uu + PC5 communications encryption
- Dual positioning systems: BDS and GPS
- Wired and wireless deployment modes

- Layered deployment
- Positioning in centimeters
- Third-party algorithm deployment framework
- Evolution to cooperative automated driving

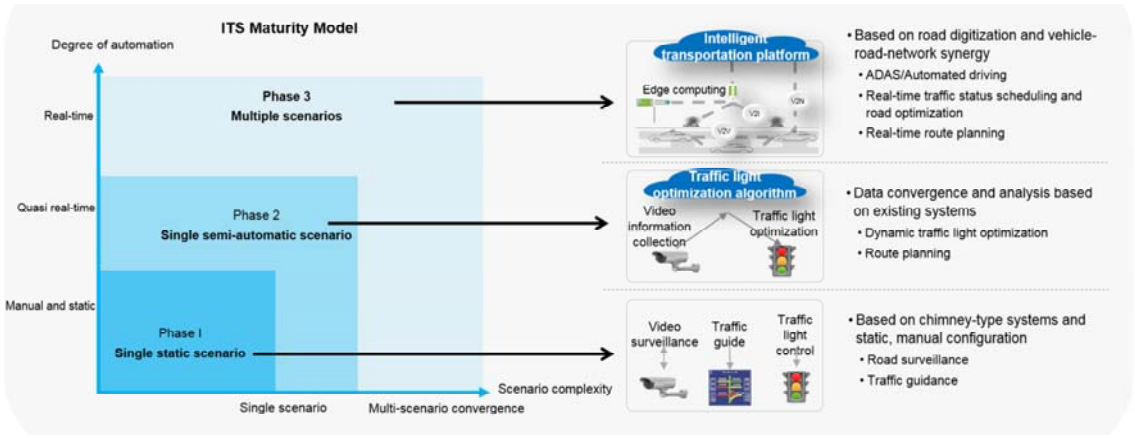
# Intelligent Transportation Platform Provides Road Digitization and Vehicle-Road Cooperation to Enable Traffic Operations




Road digitization

Vehicle-road cooperation

## ITS Develops from Single-Scenario Transportation Management to Multi-Scenario Intelligent Transportation Services



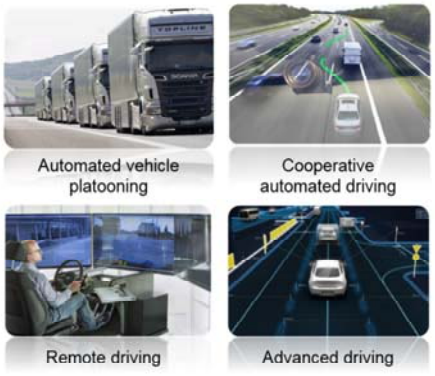
- Network bandwidth and latency requirements in complex scenarios pose the greatest challenge to the current network. The high bandwidth and low latency features of the 5G network can meet these requirements.

# 5G-V2X Connects Vehicles, Roads, and Networks to Achieve Intelligent Transportation


| Seamless connection | Low latency | High reliability | Smart connection |
| --- | --- | --- | --- |
| WAN and direct communications | 20 ms to 2 ms | 99.999% | Real-time C-ITS based on road condition sensing |

# 5G-V2X Defined by 3GPP Meets the Requirements of Advanced Automated Driving

**Application Scenarios of Automated Driving**



Automated vehicle platooning | Cooperative automated driving | Remote driving | Advanced driving

**Automated Driving Requirements Defined by 3GPP SA1 (TS22.186)**

| Case | End-to-End Latency (ms) | Reliability (%) | Throughput (Mbit/s) |
|---|---|---|---|
| Automated vehicle platooning | 10 | 99.99 | 65 |
| Advanced driving | 3 | 99.999 | 53 |
| Cooperative automated driving | 3 | 99.999 | 1000 |
| Remote driving | 5 | 99.999 | Upstream: 25; downstream: 1 |
| | Latitude (m) | Longitude (m) | |
| Positioning accuracy | 0.1 | 0.5 | |

# 5G-V2X Innovations

**Architecture**
- V2X slice
- End-to-end QoS

**Convergence**
- Integrated networking of 5G-V2X and LTE-V
- Integrated networking of 5G-V2X and DSRC

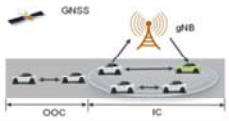
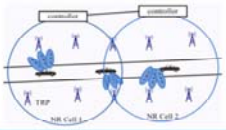
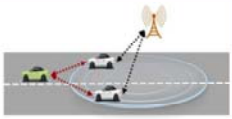
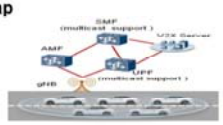
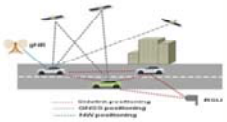
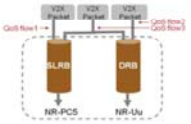
**Uu enhancement**
- Unicast and multicast
- Ultra-reliable and low-latency communication (URLLC)
- User Centric No Cell Radio Access (UCNC)
- Dual connectivity

**Spectrum**
- Sidelink for unlicensed ITS frequency bands
- Sidelink for licensed frequency bands

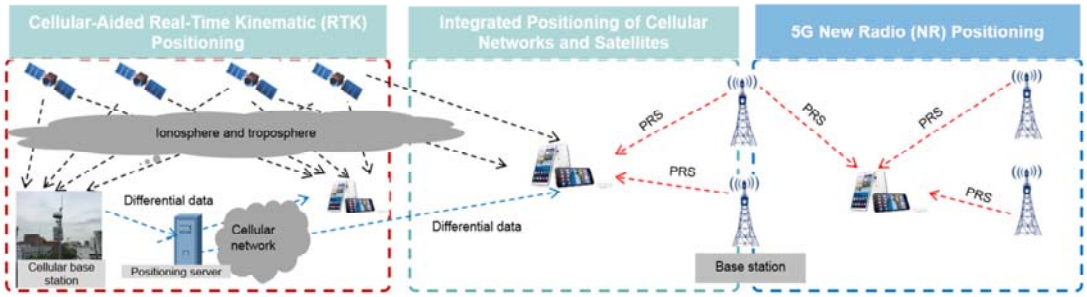
**Positioning**
- Uu-based high-precision positioning
- Sidelink-based positioning

5G-V2X aims to provide lower latency, higher reliability, larger bandwidth, more accurate positioning, and more comprehensive coverage.

# Uu and Sidelink Innovations for 5G-V2X

| 5G Sidelink | Uu Enhancement |
| --- | --- |
| **5G sidelink**<br>• Air interface soft handover<br>• All frequency bands<br>• Unicast and multicast<br>  | **UCNC**<br>• Seamless handover<br>• Dual connectivity<br>  |
| **Communications relay**<br>• Expanding coverage<br>• Improving multi-link reliability<br>  | **Flexible multicast (high-definition map download)**<br>• Higher efficiency<br>• Higher reliability<br>  |
| **Sidelink-based positioning**<br>• Sidelink ranging<br>• Observed Time Difference Of Arrival (OTDOA) and angle of arrival (AOA) sidelink positioning<br>  | **Unified QoS for Uu and sidelink**<br>• Unified QoS for NR-Uu and NR-sidelink<br>  |

# 5G+RTK Achieves Submeter-Level High-Precision Positioning for All Domains




| Cellular-Aided Real-Time Kinematic (RTK) Positioning | Integrated Positioning of Cellular Networks and Satellites | 5G New Radio (NR) Positioning |
|---|---|---|
| Scenario: open areas with few obstacles | Scenario: densely populated urban areas and urban canyons | Scenario: indoor, densely populated urban areas, and places with obstacles |
| Precision: centimeter- to submeter-level | Precision: full domain < 0.5 m; centimeter-level for some scenarios | Precision: < 0.5 m, can evolve to the decimeter level |
| Condition: number of valid satellites > 5 | Condition: 1-2 valid satellites and 1-2 base stations | Condition: LOS signals of three base stations do not rely on satellites. |
| Phase 1: Upgrade base stations and over the top (OTT) services. (Current)<br>Phase 2: 3GPP standard (R15) | Add satellites and 5G base stations. (3GPP R16) | Submeter-level positioning of high-precision synchronization and ultra-bandwidth, which is over 100 MHz. (3GPP R16) |

# Contents

# Case: Live Demo of 5G-V2X Remote Driving in the Xiong'an New Area


Vehicle

Upper-layer vehicle communications suite ← 5G new air interface ← Transmission leased line ← Vehicle control quantity


Remote control

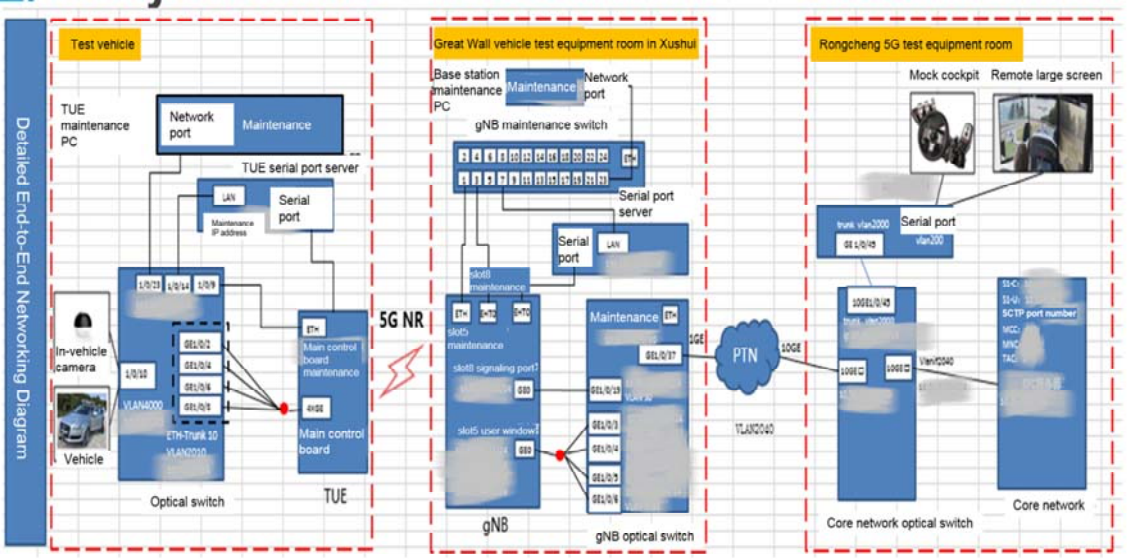

Great Wall WEY test vehicle


In-vehicle 5G test device


5G antenna

**Remotely control the direction, throttle, and brake using the 5G network to realize 5G-V2X remote driving.**

# Networking Solution of the Xiong'an IoV Pilot Project



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# Quiz

1. What are the requirements of the development of IoV on the mobile communications network?
2. What are the advantages of 5G compared with 4G in function implementation?

 

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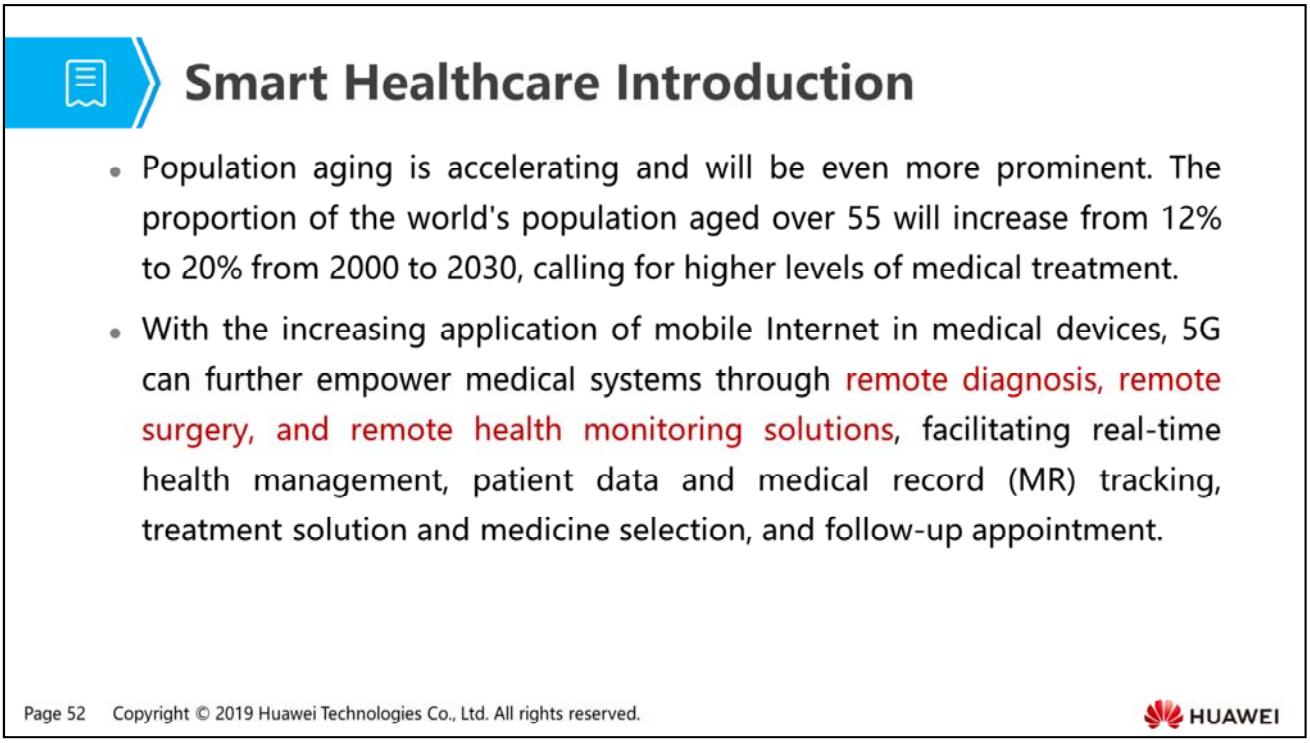
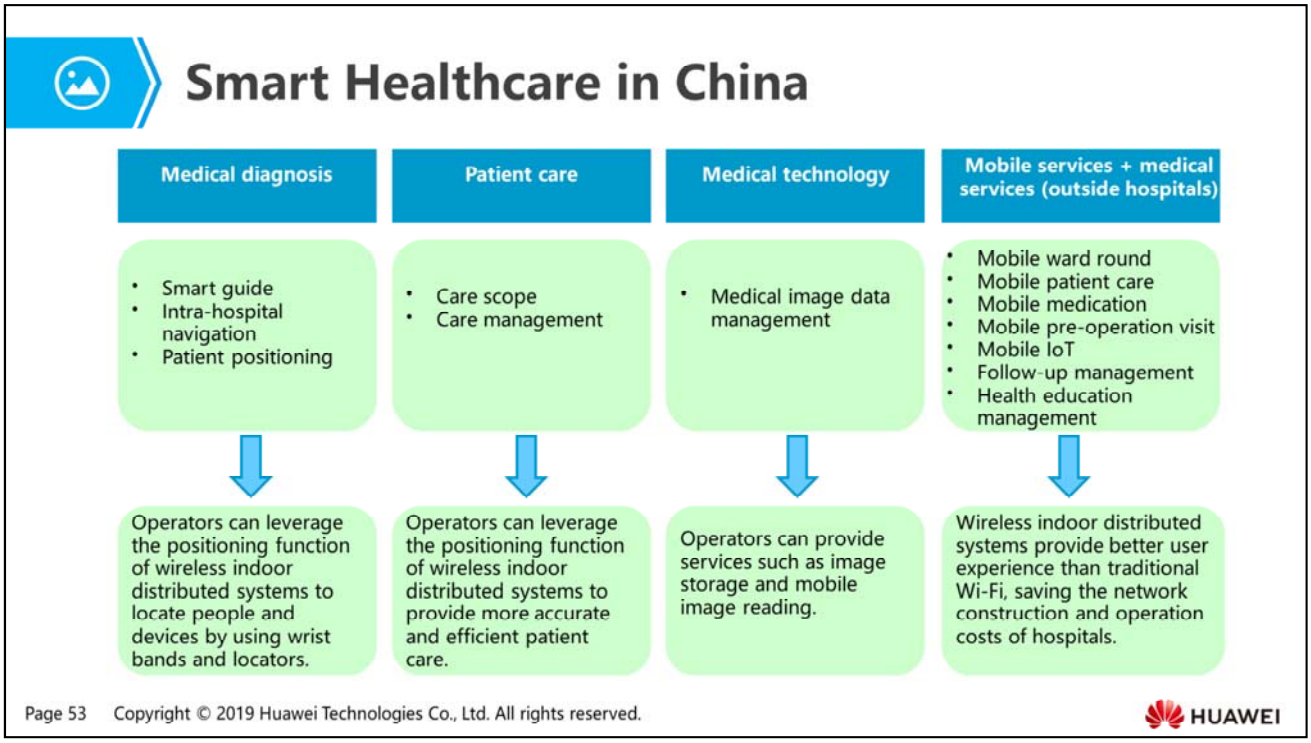
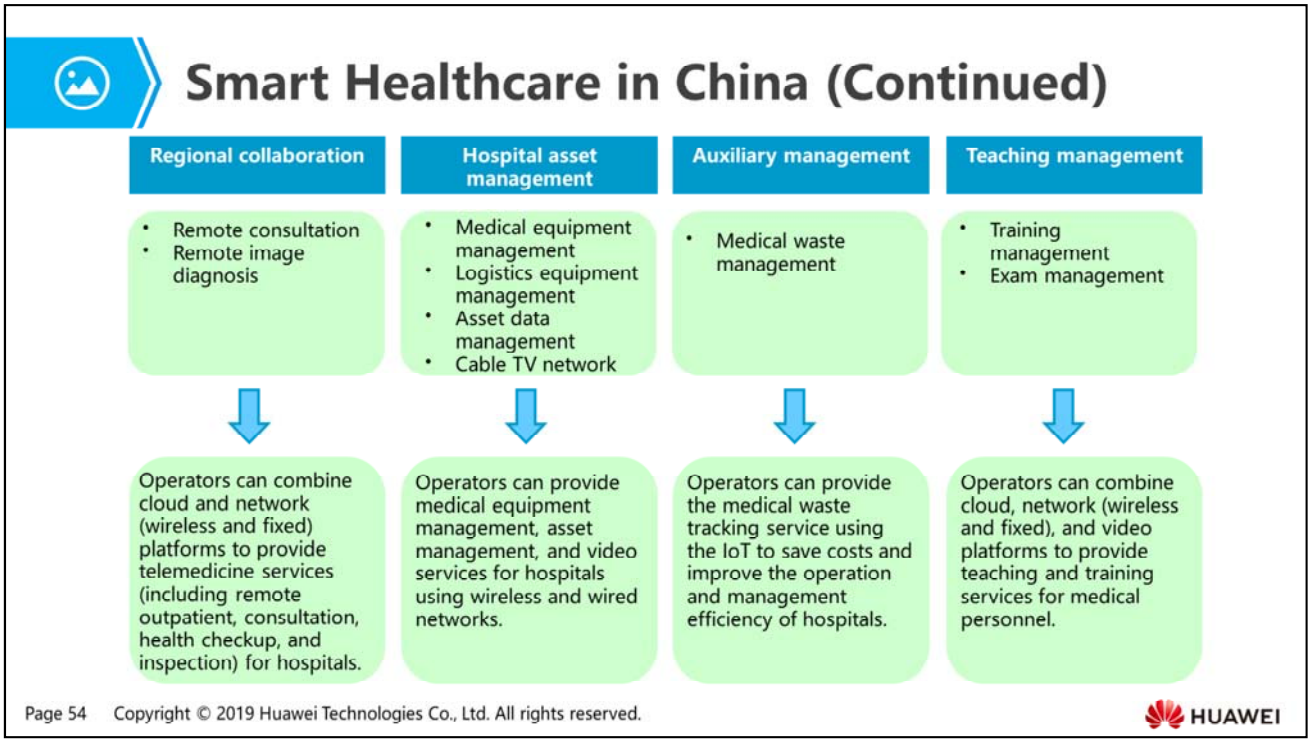



- It is expected that more than US$ 230 billion will be invested in the smart healthcare market by 2025. 5G will provide the connections needed for smart healthcare.
- Remote diagnosis is a special application that particularly relies on the short latency and high QoS features of 5G.
- Belle Île en Mer Hospital (located on a French island off the coast of Brittany) provides remote B-mode ultrasonography and remote access to medical consultation, reducing the cost of medical treatment. This remote B-mode ultrasonic robot is mature enough for commercial use, representing a typical application of force feedback and "tactile Internet". Force feedback allows for more accurate remote operations, alleviating patient pain during health checkups. The force feedback signal requires an E2E latency of 10 ms.




- In April 2018, China released *National Standards and Specifications for Hospital Informatization*, which specifies the direction of digital transformation in the healthcare industry. The document contains five chapters, 22 categories, and 262 items. It is targeted for the following scenarios: patient positioning, wireless infusion, wireless monitoring, mobile ward round, robotic ward round, emergency medical treatment, remote consultation, remote ultrasonography, and remote surgery. 5G will bring new experience in all scenarios and create new business value.
    - The remote multimedia conference system expands the hospital boundary to benefit more groups.
    - 5G makes remote healthcare workshops, teaching, and surgery demonstration more convenient and intuitive.
    - 5G links up medical consortia and specialist associations, and enables smart interconnection of expert resources and medical devices.
    - 5G provides better technical enablers for remote surgery, a crucial part of telemedicine.
- The information system of hospitals (especially grade-A tertiary hospitals) is evolving from siloed toward **digital, intelligent, efficient, and collaborative industry interconnection** that best taps into service values.




- In April 2018, China released *National Standards and Specifications for Hospital Informatization*, which specifies the direction of digital transformation in the healthcare industry. The document contains five chapters, 22 categories, and 262 items. It is targeted for the following scenarios: patient positioning, wireless infusion, wireless monitoring, mobile ward round, robotic ward round, emergency medical treatment, remote consultation, remote ultrasonography, and remote surgery. 5G will bring new experience in all scenarios and create new business value.
    - The remote multimedia conference system expands the hospital boundary to benefit more groups.
    - 5G makes remote healthcare workshops, teaching, and surgery demonstration more convenient and intuitive.
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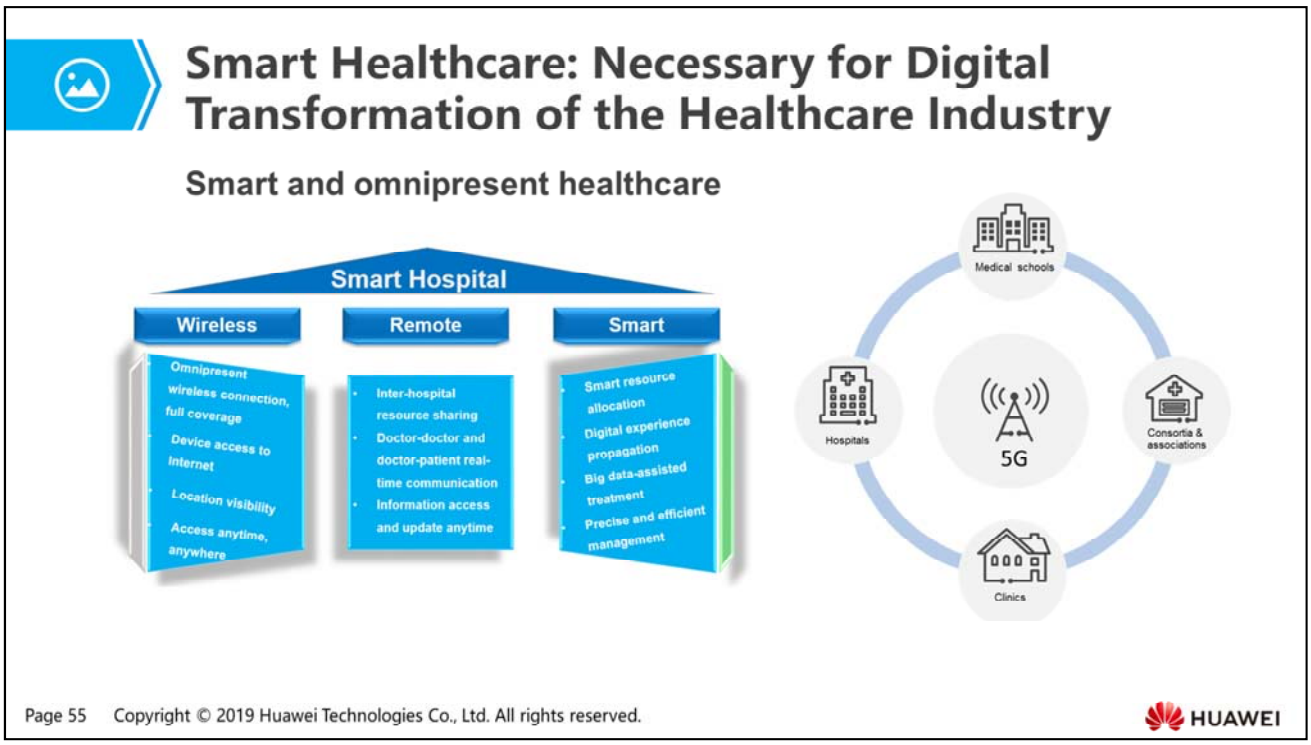


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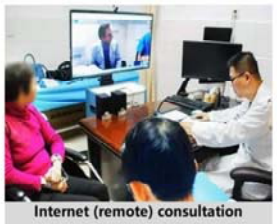
# 5G Application in the Healthcare Industry


Mobile image reading


Pre-hospital (remote) emergency treatment


Internet (remote) consultation


ICU wireless access


AR/VR healthcare


Remote surgery

Indoor value-added service

- 5G will bring new experience in all scenarios and create new business value.
- Wireless application scenarios of 5G in hospitals mainly include: patient **positioning**, wireless infusion, wireless **monitoring**, mobile **ward round**, robotic ward round, emergency medical treatment, remote consultation, **remote ultrasonography**, and **remote surgery**. 5G will bring new experience in all scenarios and create new business value.

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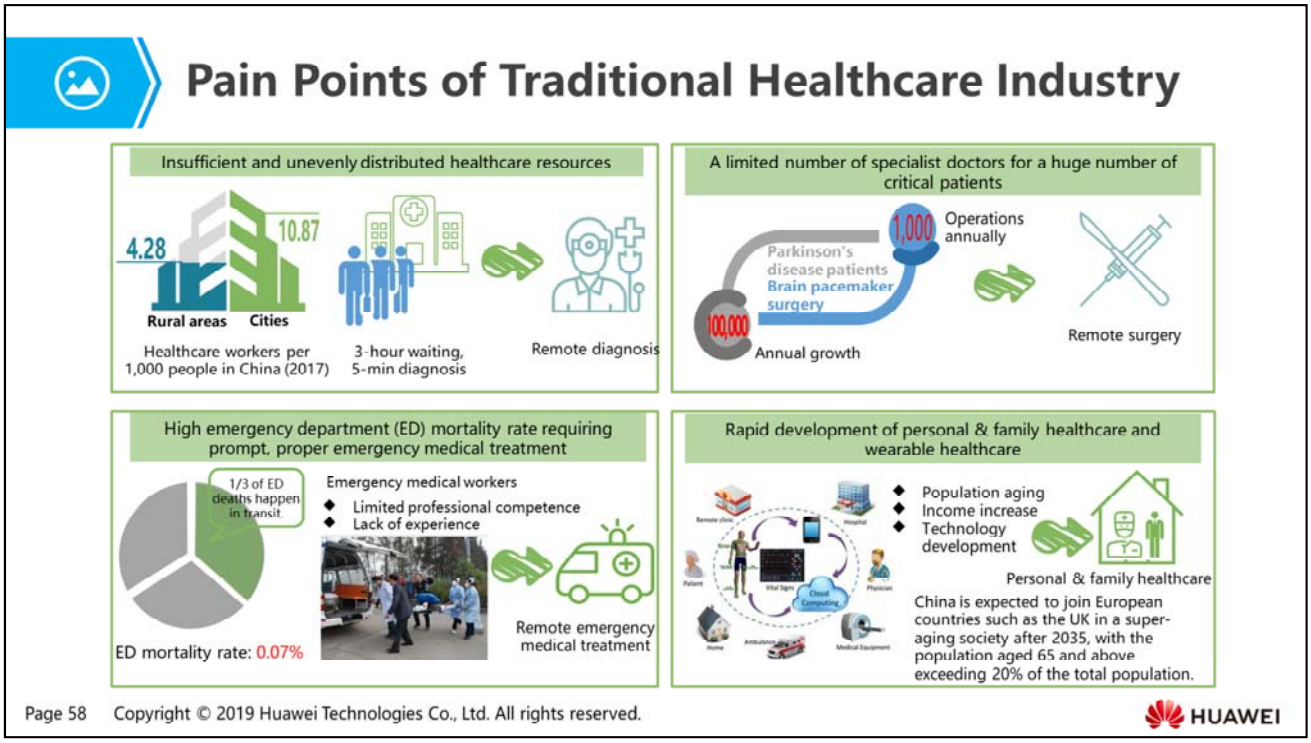
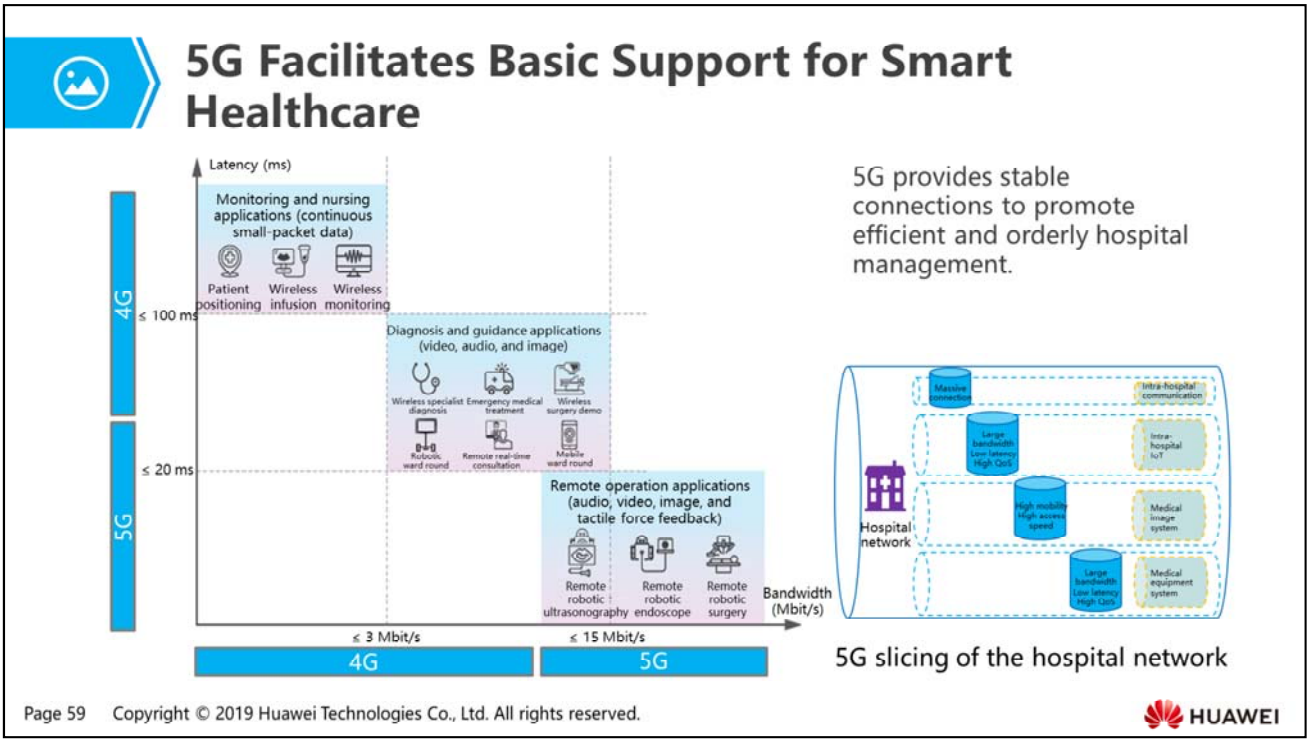



- Hospitals in Beijing urban areas receive 700,000 patients per day, while about 70% of beds are idle in a hospital 30 km away from Beijing.



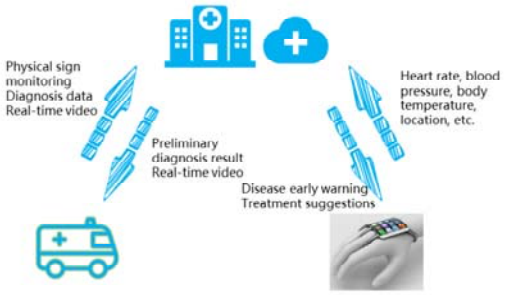

- 5G provides **10 Gbit/s** ultra-high bandwidth**, 20 ms** ultra-low latency, and 1 million massive connections per km2.

| 远程内窥镜 | | | |
|---|---|---|---|
|  | 阶段 | 数据速率 | 时延 |
| | 阶段1：光学内窥镜 | 12 Mbps | 35 ms |
| | 阶段2：360°4K+触觉反馈 | 50 Mbps | 5 ms |

| 远程超声波 | | | |
|---|---|---|---|
|  | 阶段 | 数据速率 | 时延 |
| | 阶段1：半自动，触觉反馈 | 15 Mbps | 10 ms |
| | 阶段2：AI视觉辅助，触觉反馈 | 23 Mbps | 10 ms |

# Smart Healthcare Addresses Industry Pain Points

5G enables healthcare monitoring and medical treatment anytime anywhere.




Time Is Life

Medical imaging requires large bandwidth and medical operation requires low latency.

| Case | Transmission Content at the Patient End | Bandwidth Requirement at the Patient End | E2E Latency |
|---|---|---|---|
| Remote B-mode ultrasonography | Operation and control data (downlink 1 Mbit/s)<br>High-resolution medical images (uplink 10 Mbit/s)<br>Doctor-patient video communication (uplink/downlink 8 Mbit/s) | 18 Mbit/s (uplink)<br>9 Mbit/s (downlink) | 100 ms |
| Remote surgery | Operation and control data (remote desktop: uplink 4 Mbit/s)<br>Surgery footage (uplink 8 Mbit/s)<br>Group consultation video (uplink/downlink 8 Mbit/s) | 20 Mbit/s (uplink)<br>12 Mbit/s (downlink) | 20 ms |
| Remote emergency medical treatment | Remote B-mode ultrasonography (uplink 12 Mbit/s)<br>Interactive video between an ambulance and the emergency center (uplink/downlink 8 Mbit/s) | 20 Mbit/s (uplink)<br>8 Mbit/s (downlink) | 50 ms |

**Video here is at 1080p. For 4K video, a bandwidth of 25 Mbit/s is required.*

# Smart Healthcare Revolutionizes Traditional Medical Treatment


Intelligent infusion


Mobile nursing robot


Real-time vital sign detection and monitoring


Medical assistance system


Mobile doctor working system

| | | | | | |
|---|---|---|---|---|---|
| 5G network capability | Lower power consumption<br>More connections | Indoor contiguous coverage<br>3D high-precision positioning | Wireless ultra-broadband access<br>More connections | Wireless ultra-broadband access | Wireless ultra-broadband access anytime, anywhere |
| Doctor and patient benefits | More efficient<br>More timely nursing | Less manpower<br>More timely nursing | More timely & secure | More efficient, timely, and secure | More economical and timely |

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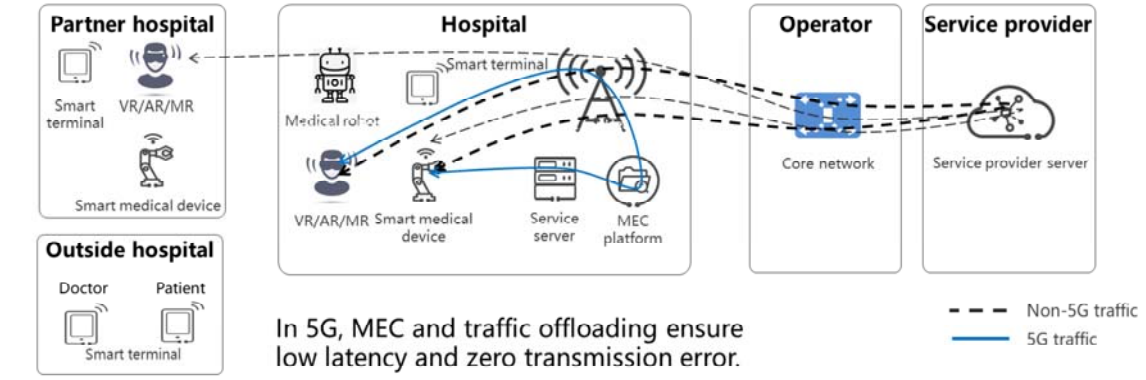
# 5G+MEC Provides Innovative Basic Support for Healthcare Industry

| | | | |
|---|---|---|---|
| 5G Wireless Indoor Distributed System | Healthcare personnel | High-bandwidth, flexible, and reliable wireless connections support medical image services, such as mobile image reading. | Improving efficiency |
| | | High-bandwidth, flexible, and reliable wireless connections support remote outpatient and consultation services. | |
| | Management personnel | High-bandwidth, flexible, and reliable wireless connections and network slicing support wireless networking and medical data collection for devices in, for example, ICUs. | |
| | Management personnel | High-bandwidth, flexible, and reliable wireless connections support wireless video collection in public areas. | Improving operation & management |
| | Healthcare personnel | High-bandwidth, flexible, and reliable wireless connections support professional and collaborative remote emergency medical treatment on ambulances or in emergency centers and partner hospitals. | Business transformation & innovation |
| | | High-bandwidth, flexible, and reliable wireless connections support AR healthcare. | |
| MEC | Healthcare personnel | Service and data distribution support mobile medical services (such as ward round, nursing, medication, pre-operation visit, and logistics). | Improving efficiency |
| | | MEC-based data caching and data convergence support new intelligent medical services (such as image assistant diagnosis and virtual medical assistant). | |
| | Management personnel | Wireless network slicing and edge data distribution support data distribution for various service applications. | Improving operation & management |

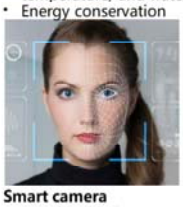
# 5G+MEC Provides Innovative Basic Support for Healthcare Industry (Continued)




Robot for navigation, medicine delivery, disinfection, and ward round | Mobile HD image reading | Smart OR | VR patient condition explanation | AR-assisted diagnosis | MR-assisted surgery

# 5G+IoT Enables the Access of Massive Devices

**Smart lighting, water meter, and electricity meter**
- Smart control of lighting, temperature, and water
- Energy conservation



**Smart camera**
- Facial and behavior recognition from huge crowds
- Effective monitoring of possible suspects


**Vehicle management**
- Orderly dispatch of medical and logistics vehicles
- Emergency location and assistance

**Smart fire control**
- Temperature control by areas and equipment rooms
- Quick alarm generation upon detection of open fires or flames
- Smart fire hydrant activation



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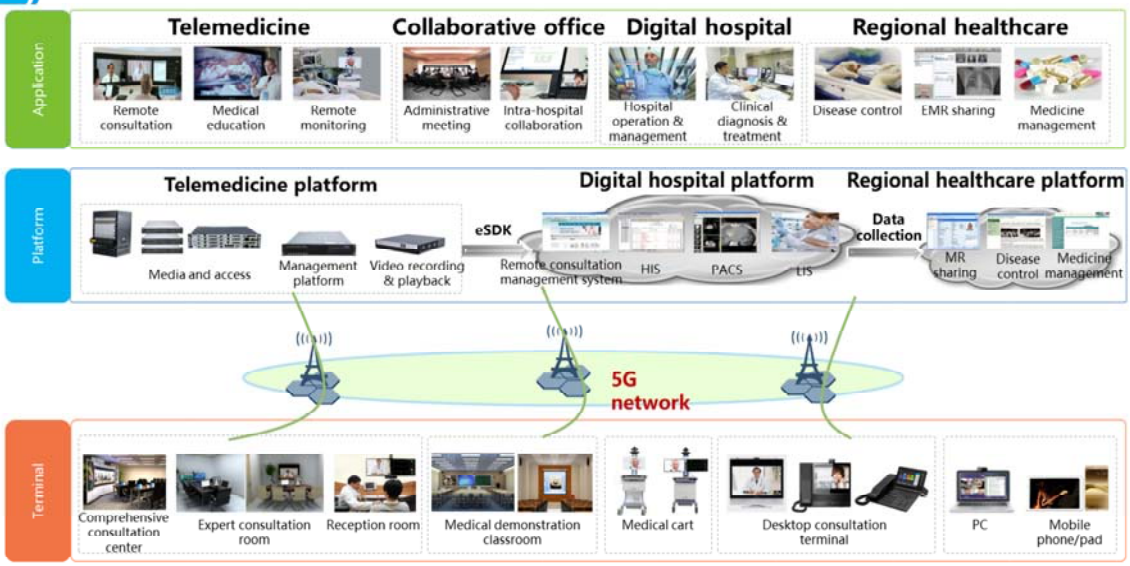
# 5G-enabled E2E Smart Healthcare Solution



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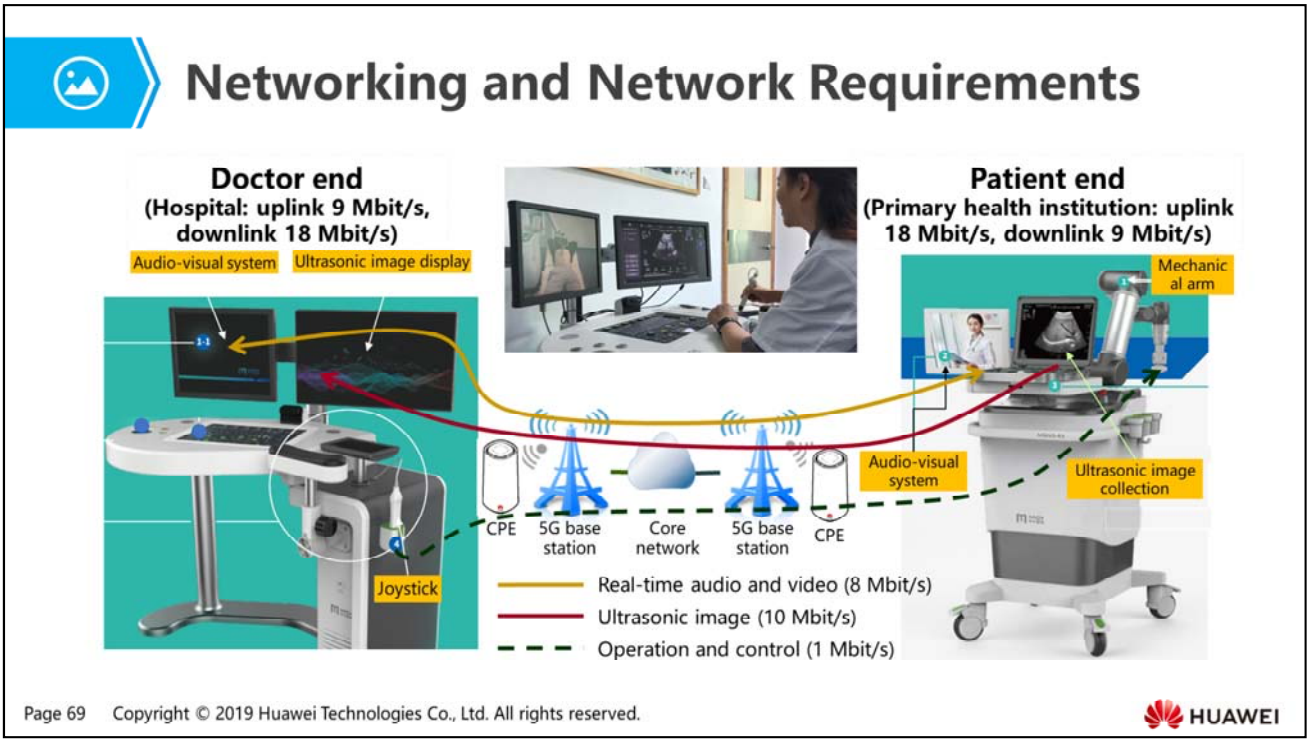
# Case 1: Remote B-mode Ultrasonography

- **[Pain point]:** Ultrasonic diagnosis specialists are insufficient. Healthcare services are geographically constrained, expensive, and difficult to access.
- **[Solution]:** The B-mode ultrasonography equipment has one end deployed in a hospital for doctor access and the other end deployed in a primary healthcare institution for patient access. The two ends can be deployed at one exhibition room for demonstration. Doctors can make diagnosis based on the ultrasonic images collected by the remote ultrasound system, and communicate with patients through real-time audio and video.
- **[Value]:** Higher diagnosis efficiency, lower healthcare costs, and easier healthcare access to reduce poverty

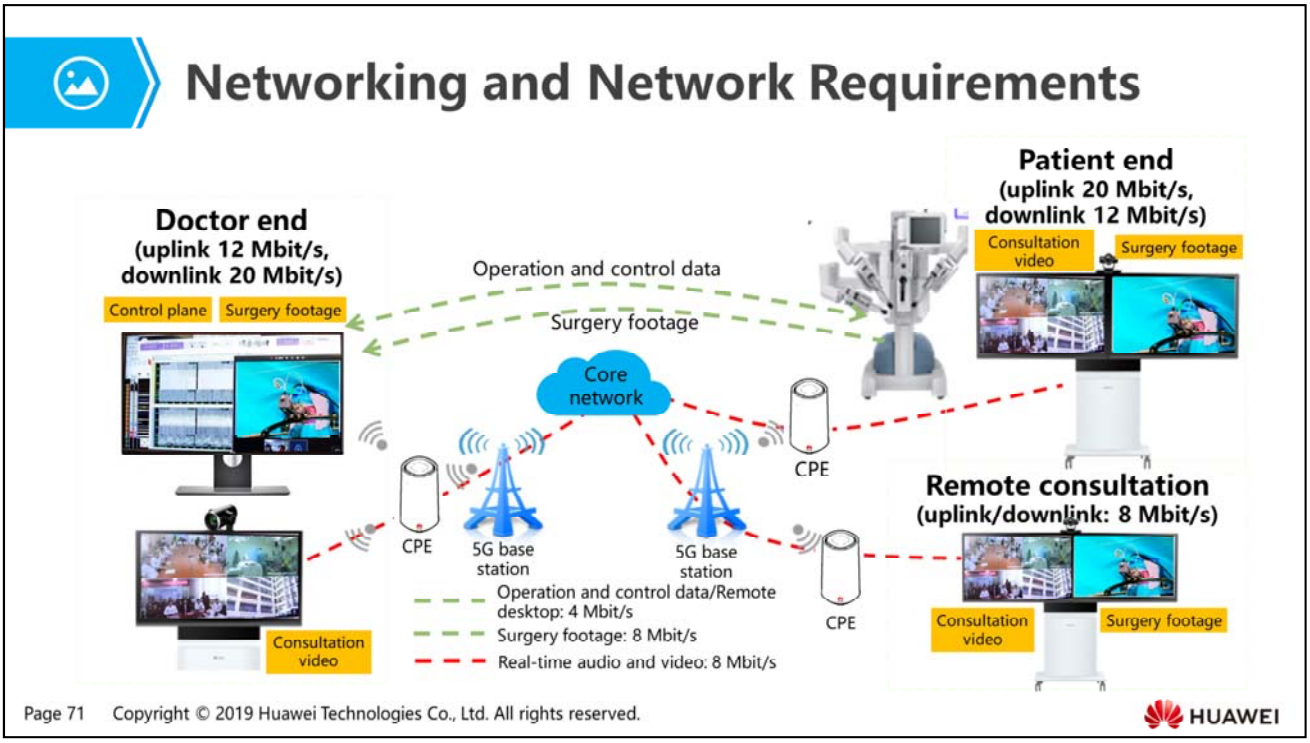
  Patients in district hospitals can receive medical treatment from grade-A tertiary hospitals, saving the need for travel and medical expenses.




- Video download link: http://3ms.huawei.com/mm/docMaintain/mmMaintain.do?method=showMMDetail&f_id=MSS180530213815490

# Case 2: Remote Surgery

- **[Pain point]:** Professional doctors are in a shortage. Take Parkinson's disease as an example. Each year, 100,000 patients are diagnosed, but only 1,000 of them can receive surgeries. In addition, traveling far to specialized hospitals is a big inconvenience for elderly patients.
- **[Solution]:** Doctors can control robotic arms through their remote desktops, and can perform remote consultation based on uploaded videos.
- **[Value]:** Remote surgery clears the barriers in traditional diagnosis and treatment, while saving patients' costs and time. In the future, telemedicine will help evenly distribute high-quality medical resources so that they can be accessible in remote areas.

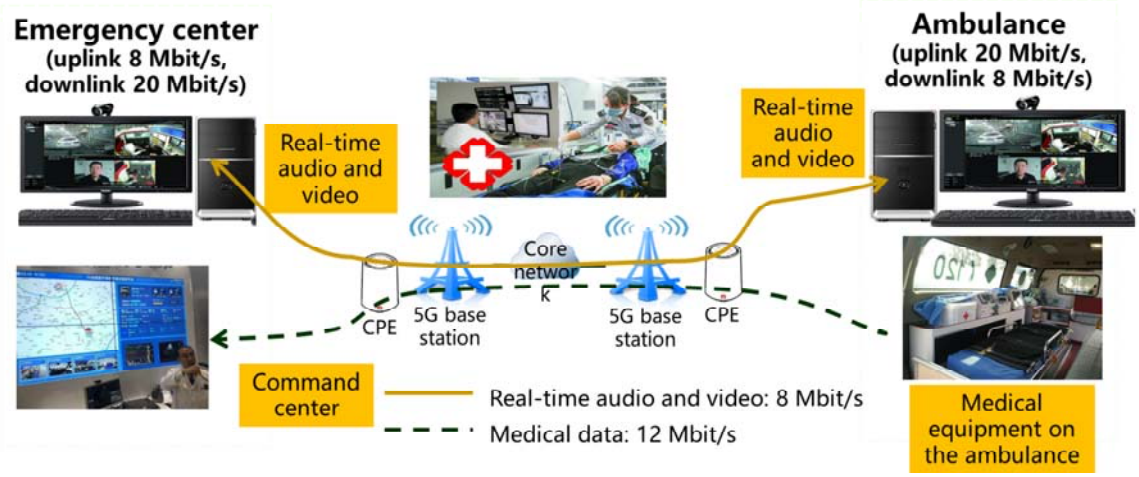



- Remote surgery clears the barriers in traditional diagnosis and treatment. In the future, telemedicine will help evenly distribute high-quality medical resources so that they can be accessible in remote areas.

# Case 3: Remote Emergency Medical Treatment

- **[Pain point]:** There is a lack of professional workers to give emergency medical treatment. For example, in city J, there are 13 districts and 501 ambulances but only 252 first aid specialists, and general medical staffs may not give proper treatment if without guidance.
- **[Solution]:** Real-time data (such as ambulance location, electrocardiograms, ultrasound images, blood pressure, heart rate, oxygen saturation, and body temperature) is synchronized to the 5G remote command center where doctors can guide on-site treatment through real-time audio and video communication.
- **[Value]:** Medical resources are efficiently utilized to improve the overall efficiency of pre-hospital emergency treatment.

# Networking and Network Requirements



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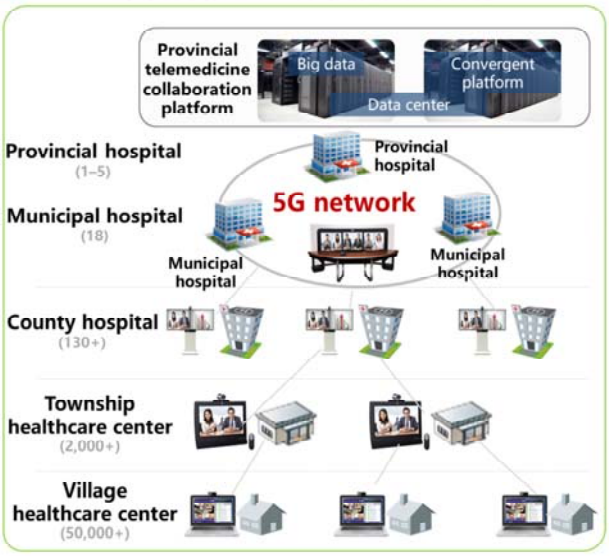
# 5G Helps Build a Telemedicine System for X00 Medical Institutions




**Customer benefits**:

- A hierarchical telemedicine system is built to facilitate medical diagnosis and treatment at all levels.
- More than 120 patients receive remote consultation, meaning 81.2% of patients are treated nearby (which corresponds to a 21% decrease in referral patients). The satisfaction rate of remote healthcare services is improved to at least 97%.
- Through telemedicine, about 300,000 grassroots healthcare personnel can receive further education each year, and healthcare services can be extended to the US, Russia, Uganda, and Italy.


Comprehensive consultation center


Surgical teaching


Remote teaching (observation) room


Remote outpatient room

# Quiz

1. What are the challenges facing the healthcare industry and 5G technologies used to address them?

2. What possibilities can smart healthcare have in the future and based on which technologies?

# Discussion and Sharing

- Group discussion:
  - What are the planning ideas for 5G industry applications, and what are the key 5G technologies used? (20 minutes)
  - Tip: You can discuss from the 3GPP standard progress of 5G, 5G industry chain and policy support in your regions, and existing industry practices of 5G.
- Class sharing:
  - Sharing by group representatives (5 minutes/group)

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# IT Construction: Core Driving Force of Education Modernization

- China has been stressing the importance of IT construction in modernizing the education industry. In April 2018, the Ministry of Education issued Action Plan 2.0 for Education Informatization. In February 2019, the State Council issued China Education Modernization 2035.
- IT-based education is no longer just about information environment construction, software and hardware support. Increasingly, it calls for mining the potential of technologies based on theories in order to pave paths for implementing multiple application scenarios as well as extending practice fields and technology domains. In this process, intelligent technologies (especially big data, AI, and cloud computing) should be leveraged to promote intelligent, popular, and contextual education, and to further revolutionize the education industry.

# Challenges in Current Education Networks

- Resource sharing: Information systems (such as teaching, scientific research, management, technical service, and life service) are siloed, which hinders service and process integration.
- Insufficient capacity to bear new services: New services (such as 4K/8K live classroom, AR/VR classroom, holographic education, 4K HD video surveillance, and mobile patrol vehicles) pose higher requirements on network bandwidth.
- Data security: Data leakage exists in inter-campus resource sharing and parent involvement, and the aggregation of big data makes it worse.
- High construction and O&M costs: Education information systems and multi-network convergence are costly to build, operate, and maintain.

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# Traditional Education Must Follow Digital Transformation of Society

**Simple methods**

- 2D teaching
- Excessive assignments

**Low efficiency**

- Indirect data display
- No reliable supervision

**Uneven resource distribution**

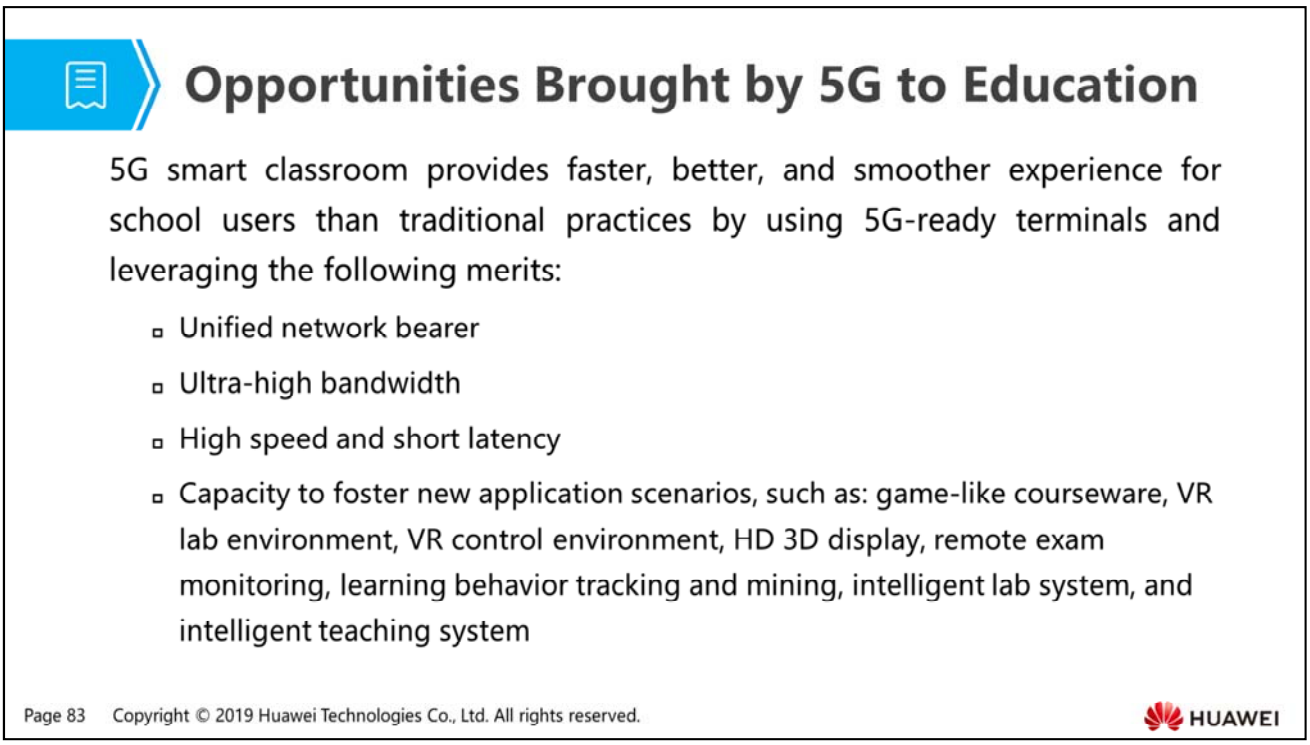
- Most resources in developed areas
- Low start point for students in undeveloped areas

**Traditional education methods are simple, and resources are unevenly distributed.**

# Pain Points of Traditional Smart Classroom

- Intelligent data collection and control are infeasible, regardless of seamless device interconnection.
- Network terminals cannot be effectively managed and controlled.
- Centralized learning and high concurrent network access require network access quality control and edge service caching.




- With the unified network bearer, schools do not need to deploy multiple networks.
- Ultra-high bandwidth ensures that interactive display terminals as well as signal transmission and processing terminals in smart classrooms can perfectly reproduce 4K images, and supports the upcoming 8K interactive terminals.
- High speed and short latency ensure normal streaming in smart classrooms. During distance teaching, school users at remote sites can access 4K or even clearer images without delay.
- New application scenarios in education and teaching can emerge, such as: game-like courseware, VR lab environment, VR control environment, HD 3D display, remote exam monitoring, learning behavior tracking and mining, intelligent lab system, and intelligent teaching system.

# 5G Promotes More Applications of Smart Education

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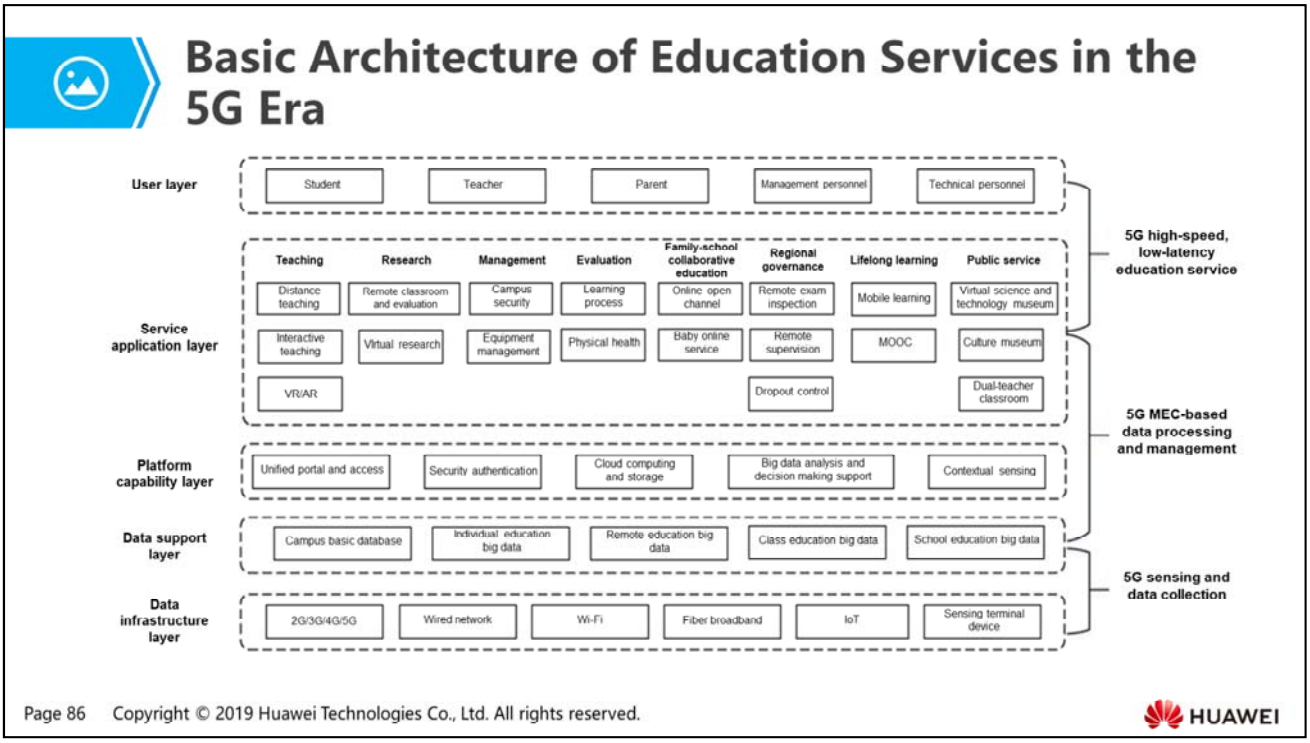
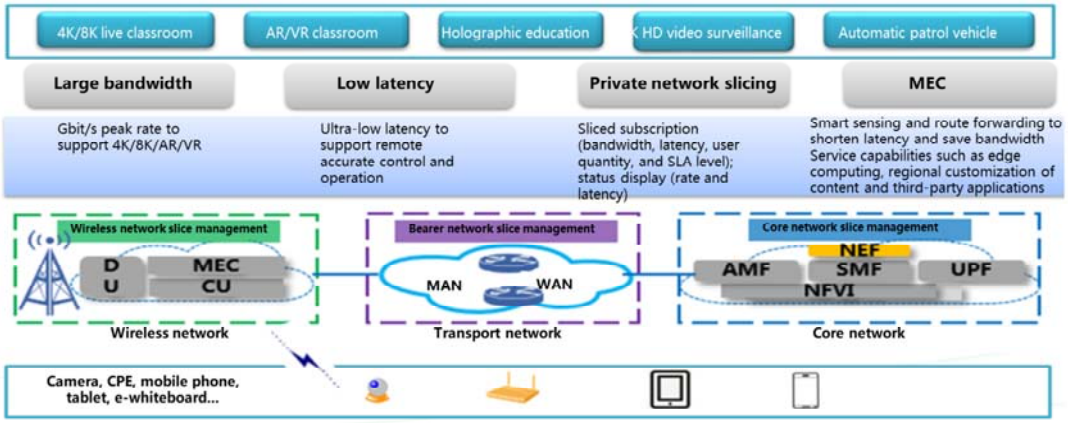
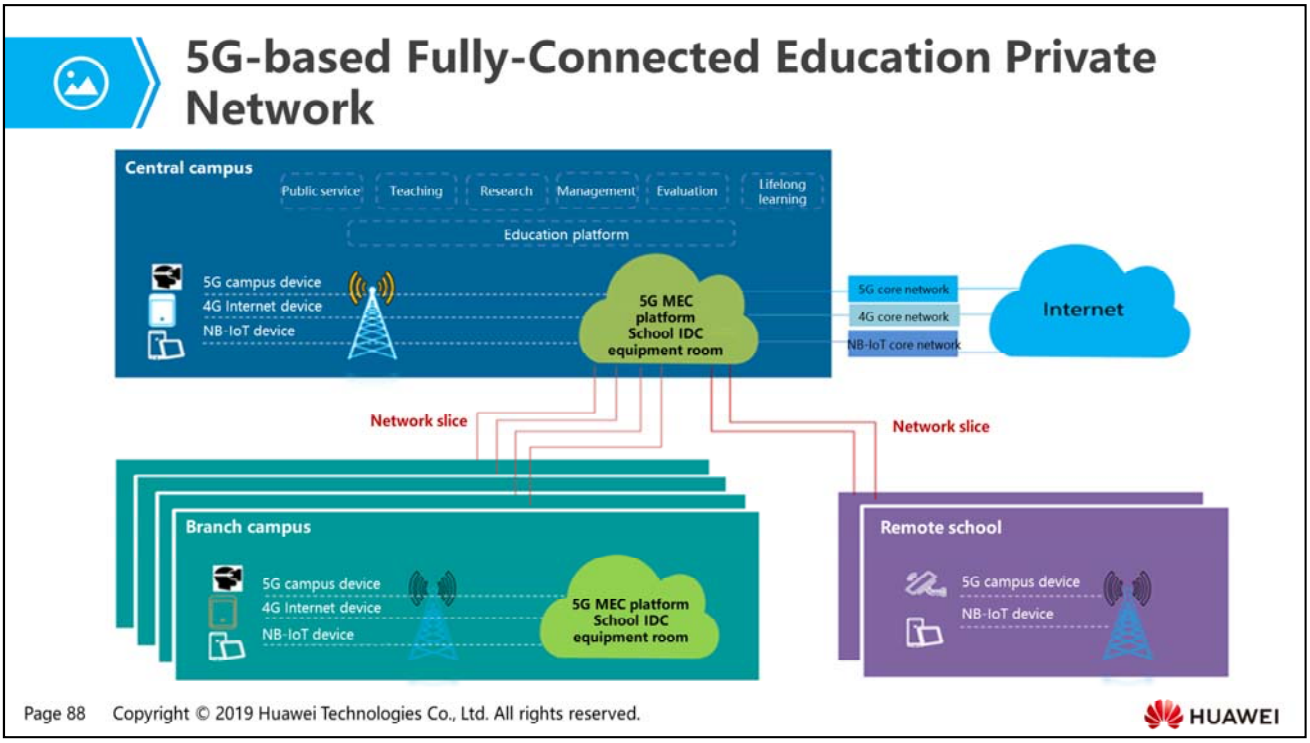



- This section analyzes and explains the teaching activities at the service application layer.
- Intelligent education in the 5G era requires consolidation of various intelligent technologies to establish a five-in-one infrastructure network that consists of the data infrastructure layer, data support layer, platform capability layer, service application layer, and user layer. Students, teachers, parents, management personnel, and technical personnel can access intelligent support services and solutions through:
  - A ubiquitous infrastructure network that is inclusive of multiple technologies and modes
  - An infrastructure layer that is based on the IoT network and sensing terminals
  - A data support layer that aggregates campus basic databases and big data planning
  - A platform capability layer that provides five capabilities
  - A service application layer that covers teaching, research, management, evaluation, family-school collaborative education, regional governance, lifelong learning, and public service

# 5G Smart Campus

- 5G can help build smart campuses and develop diversified education applications based on the service requirements and 5G features. 5G smart campus can provide a fully-connected private network that connects various smart terminals and education equipment, an education edge cloud that integrates computing, storage, AI, and security capabilities, and an application enabling platform with management and security capabilities.





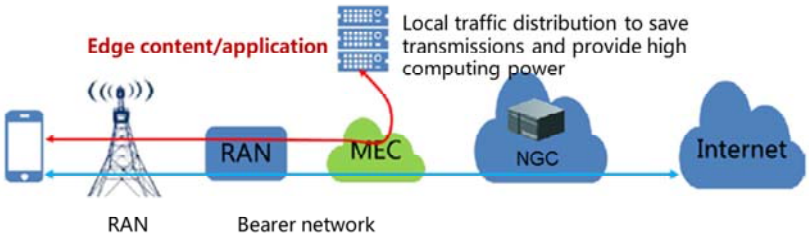

- 5G mobile networks can meet the application requirements of industry users through network slicing and MEC. Education private networks can be built by using network slicing.

# 5G Network Slicing

- Network slicing is the basis of 5G-based education private networks. It constructs multiple dedicated, virtual, isolated, and customized logical networks on a physical network to carry education services, while meeting different requirements of services on network capabilities (such as latency, bandwidth, and connections). Data is shared across 4G, 5G, NB-IoT, and private networks, preventing data silos between networks. In addition, local transmission and storage of private data of teachers, students, and parents ensures user data security.

# 5G MEC

- 5G provides multi-level MEC solutions for universities, K12, and other education scenarios. MEC nodes are deployed on the Radio Access Network (RAN), bearer network, or core network edge to provide multiple intelligent network access and high-bandwidth, low-latency network bearing. Open and reliable network connections as well as computing and storage resources allow for flexible bearing of multiple ecosystem services at the RAN edge.

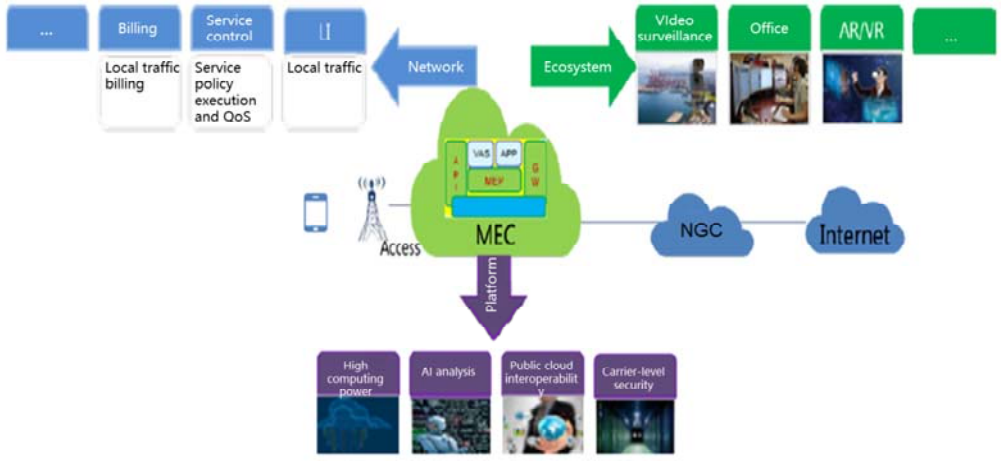



MEC network architecture

- 5G MEC provides basic capabilities such as massive terminal management, high-reliability and low-latency networking, hierarchical QoS, real-time data computing and cache acceleration, application container service, and network capability openness. It also enables a multi-level MEC system to provide real-time, reliable, intelligent, and ubiquitous E2E services for smart education. 5G MEC solutions can be applied in universities, K12, and other education scenarios. MEC nodes are deployed on the RAN, bearer network, or core network edge to provide multiple intelligent network access and high-bandwidth, low-latency network bearing. Open and reliable network connections as well as computing and storage resources allow for flexible bearing of multiple ecosystem services at the RAN edge.

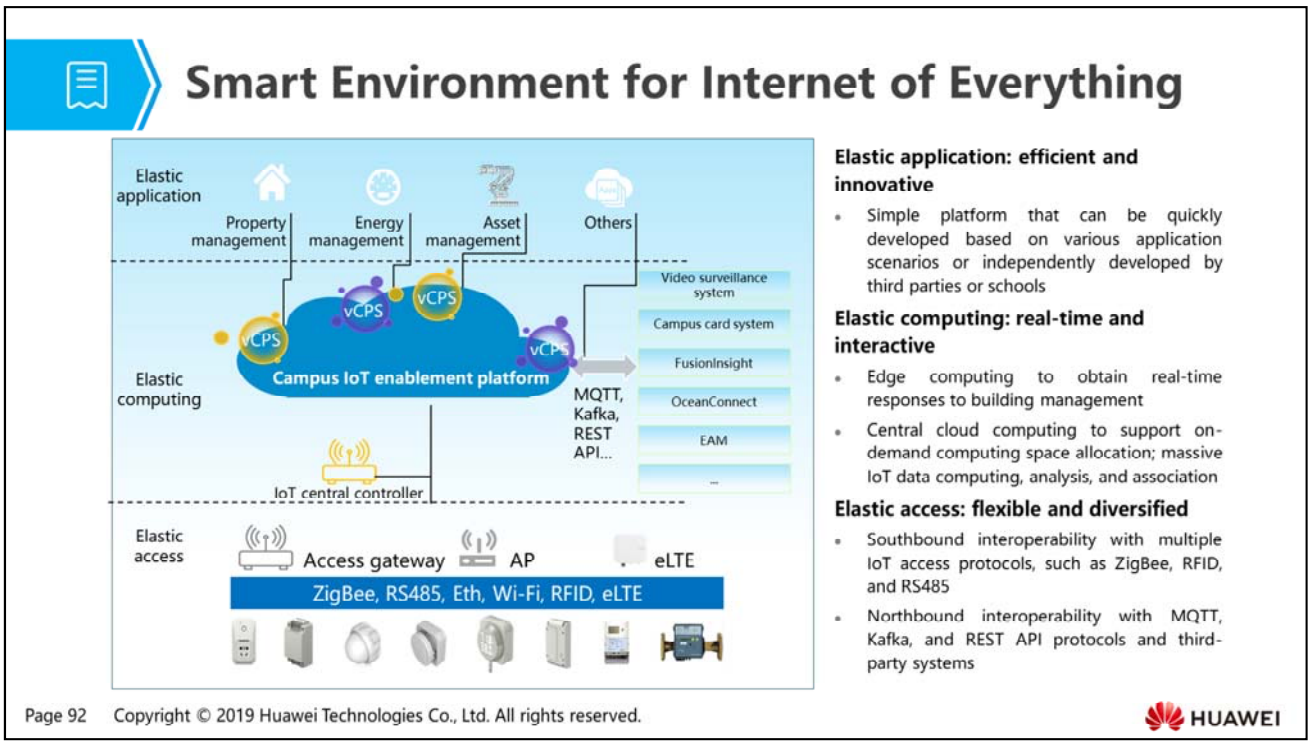
# 5G Mobile Edge Computing (Continued)




5G MEC solution capability overview

- To meet the requirements of new services such as cloud AR/VR teaching, holographic classroom, and cloud intelligent management for ultra-low latency, ultra-large bandwidth, and real-time computing, the existing centralized data processing mode based on cloud computing can provide cloud computing and storage capabilities, but cannot deliver superb experience for many new services. On the one hand, latency and congestion negatively affect service experience as all service flows are processed by the cloud computing center. On the other hand, as the number of terminals increases rapidly, massive data transmission poses a great challenge to the operators' access network and core network, and further reduces the network operating efficiency.




- 5G is like an information superhighway, and IoT is like a typical traffic lane. 5G can deliver a 1 ms E2E latency, 10 Gbit/s throughput, 1 million connections per square kilometer, and high-speed mobility within the network. With the new features of 5G, the IoT can realize "communication of everything" and connect the physical world where sensing is all around, transmission is reliable, and processing is intelligent. The network can connect any object at any time and any place.
- 5G IoT helps education users work flexibly with the campus environment, facilities, terminals, and platforms to achieve more refined and dynamic management of production, learning, and life. The IT capacity of overall teaching management can thereby be enhanced.
- 5G helps build a ubiquitous smart IoT by leveraging intelligent sensing terminals, cloud computing, and MEC. Cloud data computing improves the real-time performance and reliability of IoE and decision making, making IoE intelligent. Eventually, people can live in a software-defined intelligent world propelled by a ubiquitous IoT that enables trusted and controllable people-to-people, people-to-thing, and thing-to-thing communications anytime, anywhere, with anything, anyone, and any device.

# 5G Smart Campus Panorama

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# 5G Teaching

- With the support of 5G technologies and environments, core education services are facing transformation and restructuring. The education industry features diversified users and contexts and accordingly various requirements. Services that meet each requirement are relatively accurate. 5G provides a high speed, high bandwidth, low latency, and fast cache, which are serious issues with traditional education services.
- As the core business of education, teaching transfers content and provides interactive support based on learners' feedback of content and teaching process. 5G can play an important role in the teaching process, for example, improving students' experience through AR, VR, or holography in distance education, improving teachers' efficiency through low-latency and high-speed feedback in interactive teaching, or promoting the immersive experience by simulating experiment environments and processes.

# Distance Education: Dual-Teacher Classroom

1. Scenario description

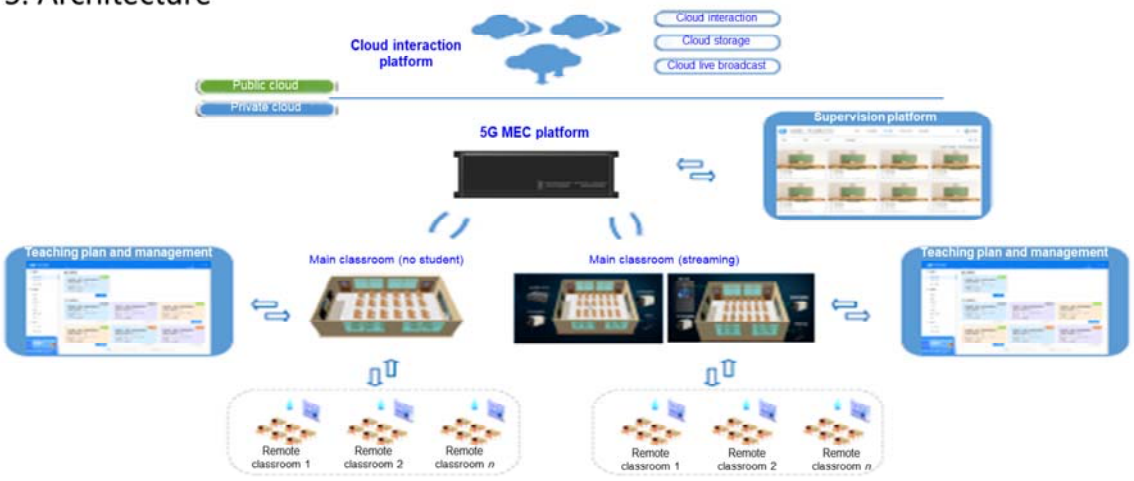
- Dual-teacher classroom is the main scenario of distance education. It solves the problems of insufficient teachers and courses in rural areas, and promotes balanced development of urban and rural education.

2. Benefits

- Wired networks have drawbacks of long construction period, high costs, and poor flexibility, whereas wireless networks such as Wi-Fi are prone to audio and video delay and frame freezing. 5G, however, comes with a high bandwidth and low latency to enable flexible, on-demand, and mobile teaching, 4K HD video transmission, and low-latency immersive interaction. 5G effectively improves the poor experience of interaction in traditional practices to promote the long-term development of dual-teacher classroom.

# Distance Education: Dual-Teacher Classroom (Continued)

3. Architecture



- To further improve the immersive experience and ensure service stability, 5G dual-teacher classroom uses MEC to implement low-latency interaction and network slicing to provide private networks. This way, students attending remote courses can have nearly face-to-face communication with teachers.

# Distance Education: Dual-Teacher Classroom (Continued)

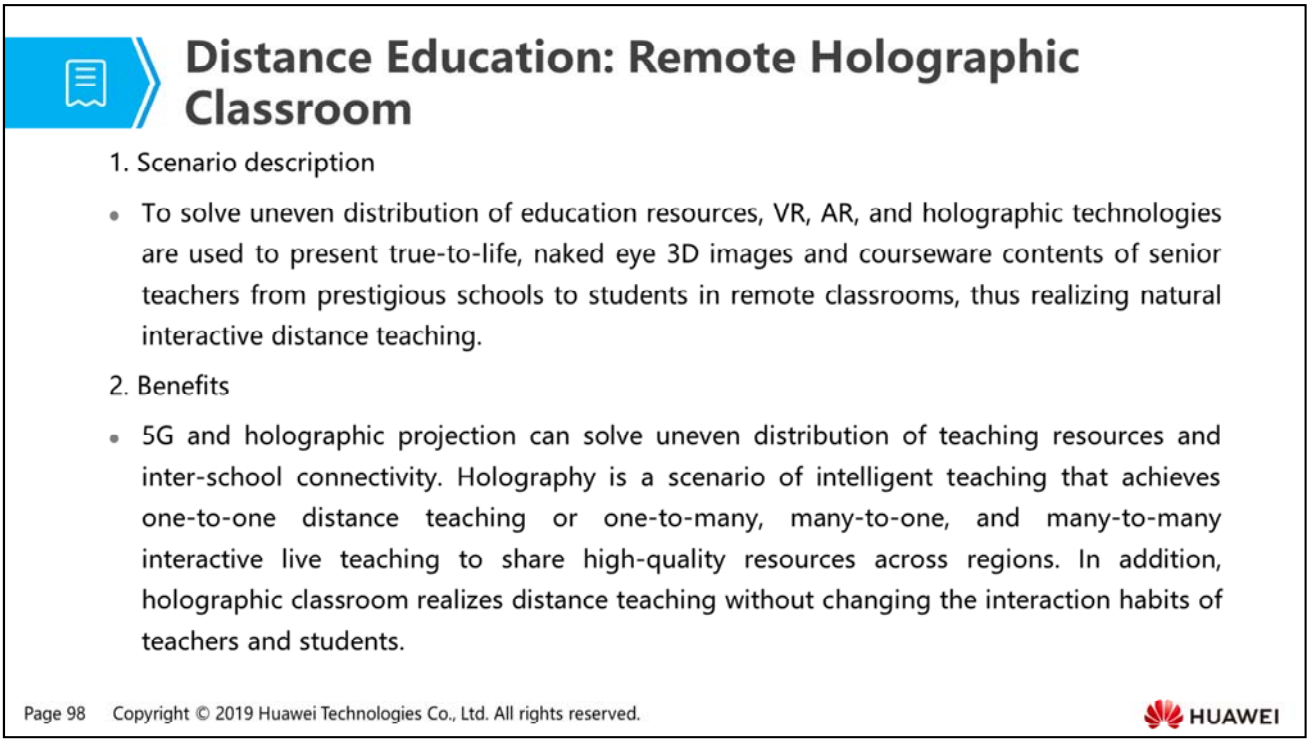
4. Key technologies

• High bandwidth and low latency

| 4K HD Dual-Teacher Classroom (35 Students/Class) | Communications Requirements | | |
|---|---|---|---|
| | Uplink Rate | Downlink Rate | Latency |
| | ≤ 150 Mbit/s | ≤ 430 Mbit/s | ≤ 20 ms |

• Mobility

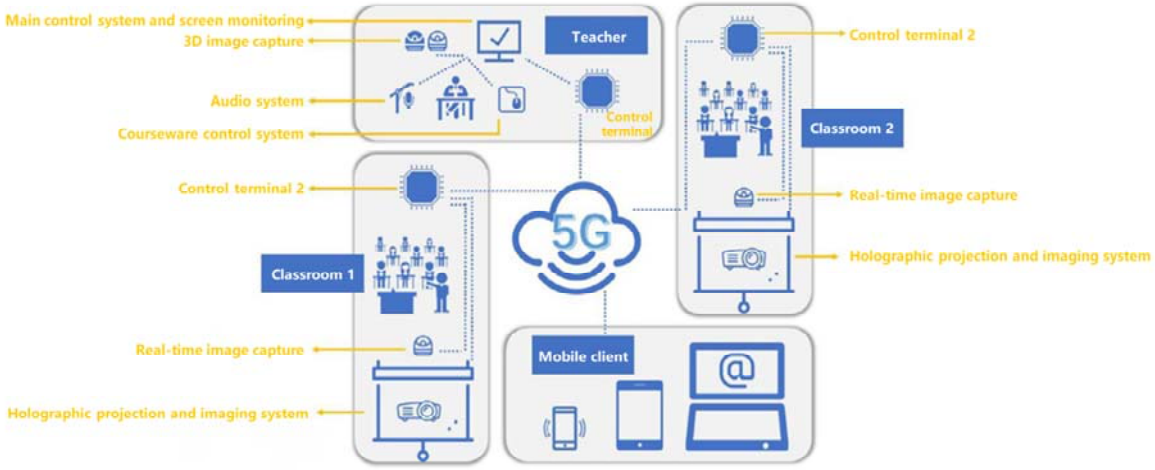
Traditional practices rely on wired or Wi-Fi networks which feature a long construction period and high costs. In the 5G era, 5G communications modules can be embedded into terminals to access the 5G network anytime and anywhere, greatly shortening the service provisioning time.




- 5G delivers data rates of hundreds of Mbit/s (which is about 10–30 times that of 4G) and a 20–40 ms E2E latency. Therefore in 5G, content that requires a high bandwidth (such as audio and video streams and AR applications) can be transmitted at an extremely low latency to support seamless communication between teachers and students in remote classrooms. Holographic AR brings immersive experience and revolutionary interaction modes to students.

# Distance Education: Remote Holographic Classroom (Continued)

3. Architecture



- Holographic classroom provides a holographic teaching platform and a holographic live teaching area, and is mainly used in typical education scenarios such as academic visits and trainings, international culture demonstration, in-class experience, and hands-on skill training.

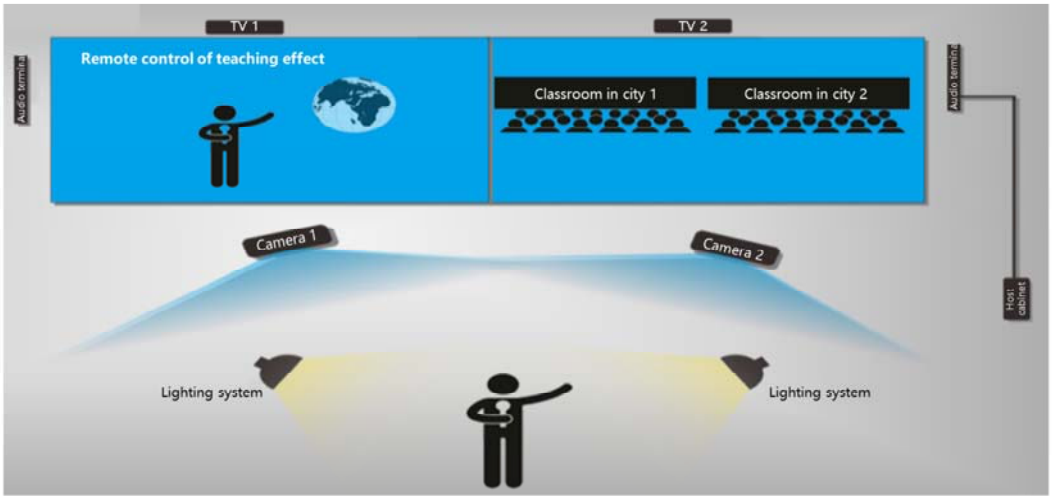
# Distance Education: Remote Holographic Classroom (Continued)

- The holographic teaching platform is deployed in physical classrooms, where a holographic screen displays teachers' image data in the naked eye 3D projection effect. HD cameras and microphones are deployed in the classrooms to facilitate real-time interaction between teachers and students.

Holographic classroom effect

# Distance Education: Remote Holographic Classroom (Continued)




Holographic live teaching area schematic

- Similar to a standard photography studio, the holographic live teaching area is used to collect audio and video data of teachers, and does not require special equipment. Teachers can learn about student status through HD displays and interact with students in real time.

# Distance Education: Remote Holographic Classroom (Continued)

4. Key technologies

• High bandwidth and low latency

| Remote Holographic Classroom (2 4K Video Channels/Class) | Communications Requirements | | |
|---|---|---|---|
| | Uplink Rate | Downlink Rate | Latency |
| | 80 Mbit/s | 80 Mbit/s | 100 ms |

• Mobility

Remote holographic classroom is used for large-scale seminars and public classes. The existing wired networks greatly limit the application scope of holographic classroom, and have problems such as long construction period, high costs, and poor flexibility. 5G lifts geographical constraints to realize on-demand, flexible remote holographic classes.

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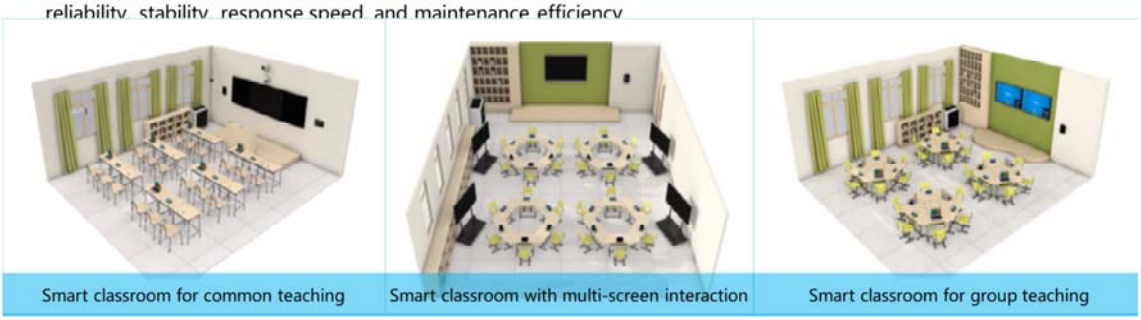
# Interactive Teaching

1. Scenario description

- 5G-based interactive teaching is a process in which software and hardware modules are enabled to implement 5G in traditional smart classrooms of various types and layouts. Large-bandwidth, high-speed, highly secure, and low-latency 5G networks that provide both data transmission and services take the place of wired networks, Wi-Fi, Bluetooth, ZigBee, or NB-IoT. 5G-based interactive teaching delivers a brand new user experience in terms of security, reliability, stability, response speed, and maintenance efficiency.



| Smart classroom for common teaching | Smart classroom with multi-screen interaction | Smart classroom for group teaching |
|---|---|---|

Typical smart classroom scenarios

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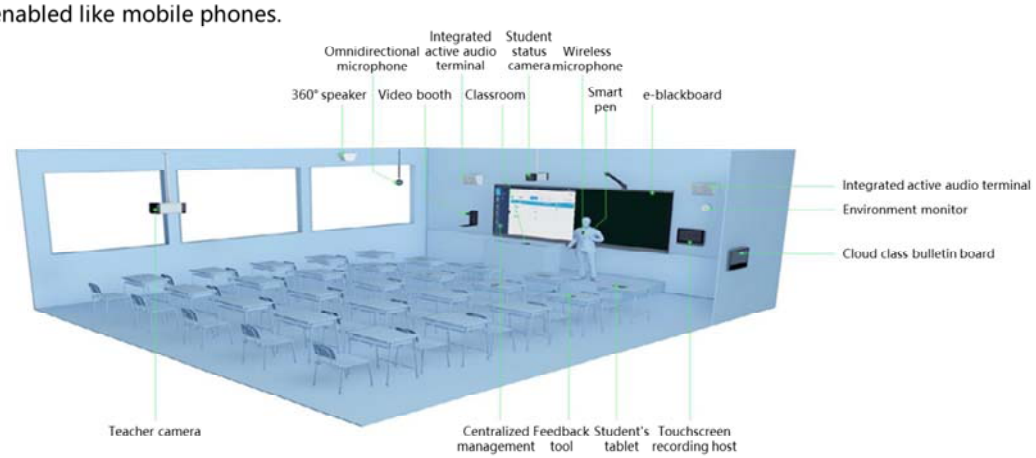
# Interactive Teaching (Continued)

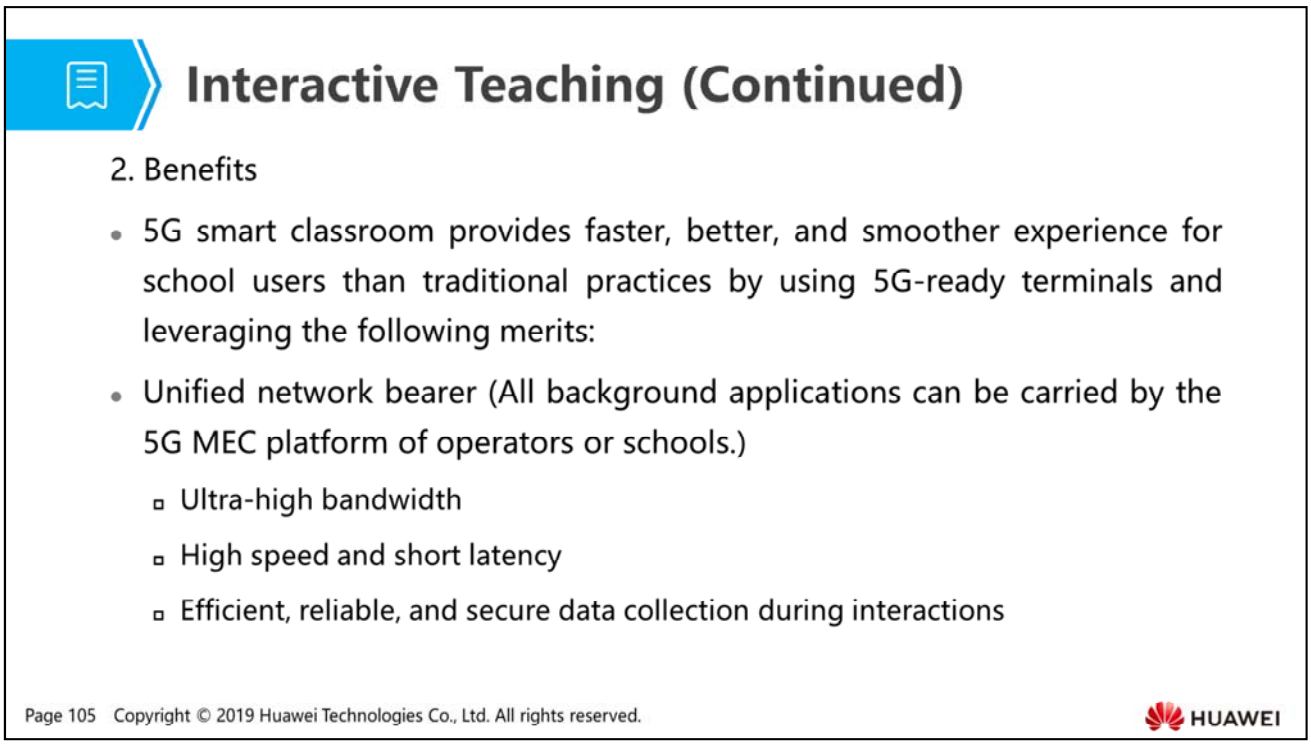
- 5G-based interactive teaching mandates that all necessary hardware modules in smart classrooms are 5G-enabled like mobile phones.




Smart classroom panorama

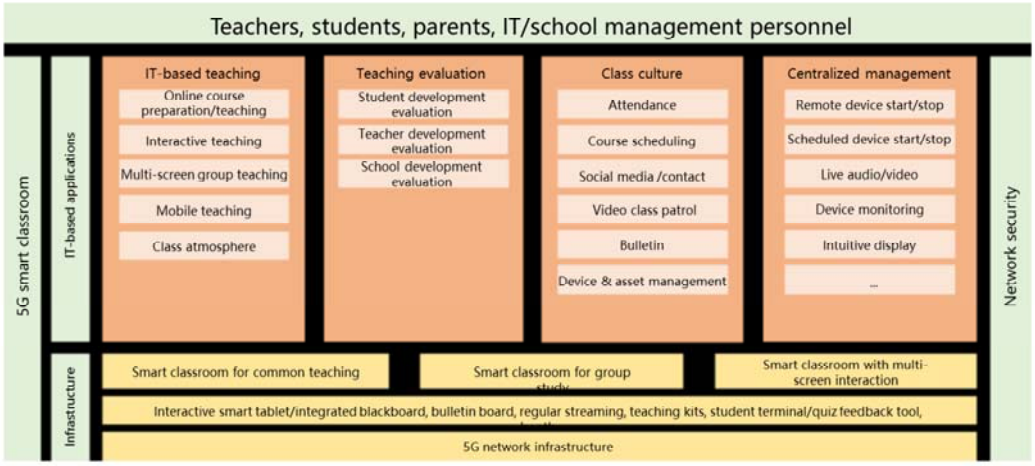
- As shown in the figure, 5G-enabled terminals include:
  - Large-screen interactive terminals used for teaching, such as smart tablets, e-blackboards, and integrated blackboards
  - Smart learning pen
  - Regular recording and playback gear, including recording hosts, cameras, and microphones
  - Class bulletin terminals that display culture values, examination schedules, and class attendance
  - Smart teaching terminals that improve classroom interaction efficiency
  - High-speed document scanner and mobile booth terminals that display teaching materials and assist students' presentations



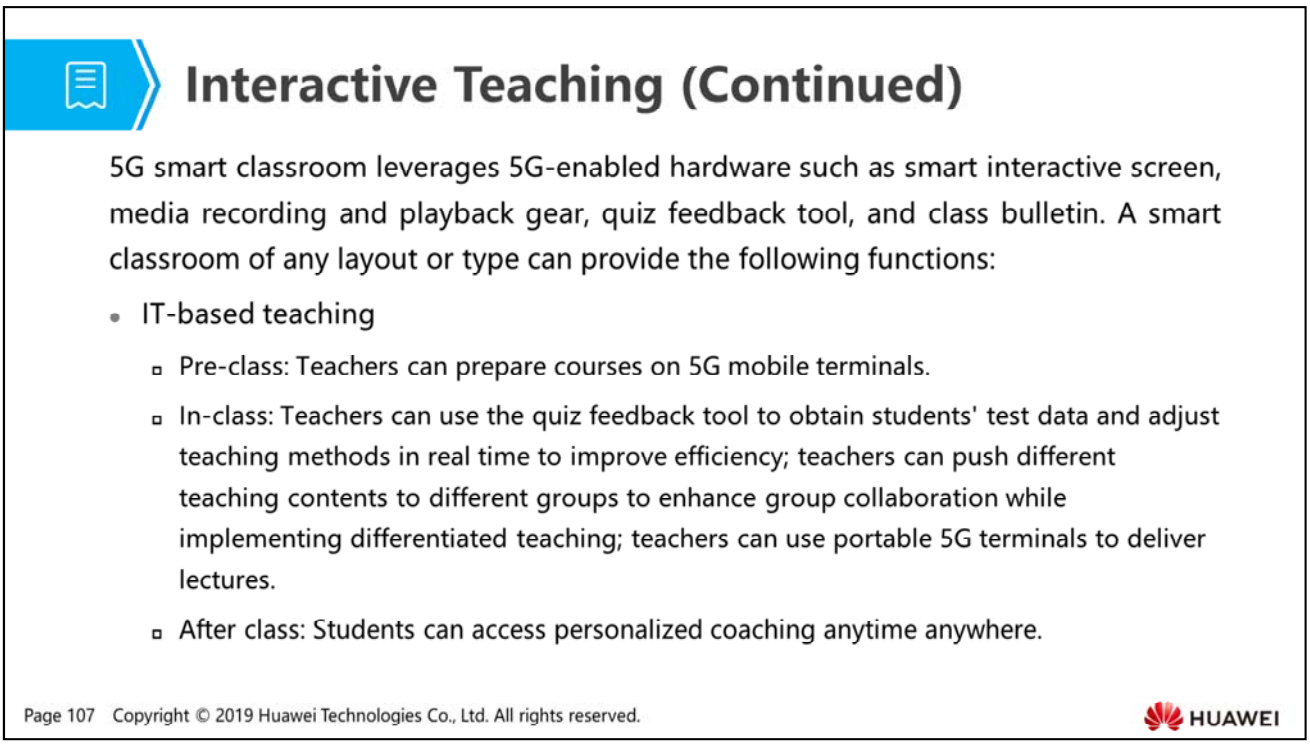

- With the unified network bearer, schools do not need to deploy multiple networks. All terminals are available after they access the 5G network, just like mobile phones. All background applications can be carried by the 5G MEC platform of operators or schools to ensure security and easy management.
- Ultra-high bandwidth ensures that interactive display terminals as well as signal transmission and processing terminals in smart classrooms can perfectly reproduce 4K images, and supports the upcoming 8K interactive terminals. Apart from superb user experience, this feature also ensures technological edge of smart classroom.
- High speed and short latency ensure normal streaming in smart classrooms. During distance teaching, school users at remote sites can access 4K or even clearer images without delay.
- Efficient, reliable, and secure data collection during interactions helps teachers learn students' status through the low latency, high speed, and high reliability features.

# Interactive Teaching (Continued)

- 3. Architecture






- During a class, teachers can use the quiz feedback tool to obtain students' test data and adjust teaching methods in real time to improve efficiency. In addition, teachers can push different teaching contents to different groups to facilitate group discussions and enhance group collaboration while implementing differentiated teaching. Teachers can also use portable 5G terminals to deliver lectures. Teachers can attract students' attention through knowledge contest, classification comparison, random selection, and many other tools deployed on the 5G MEC platform.

# Interactive Teaching (Continued)

- Streamlined teaching evaluation

With 5G, data generated by students throughout a class are recorded and transmitted to the 5G MEC platform for big data and AI analysis to output more comprehensive and objective analysis results for different users (including students, parents, teachers, school administrators, and education authorities). This way, targeted teaching and scientific policies can be provided for students based on impersonal evaluation, thereby ensuring education equality.

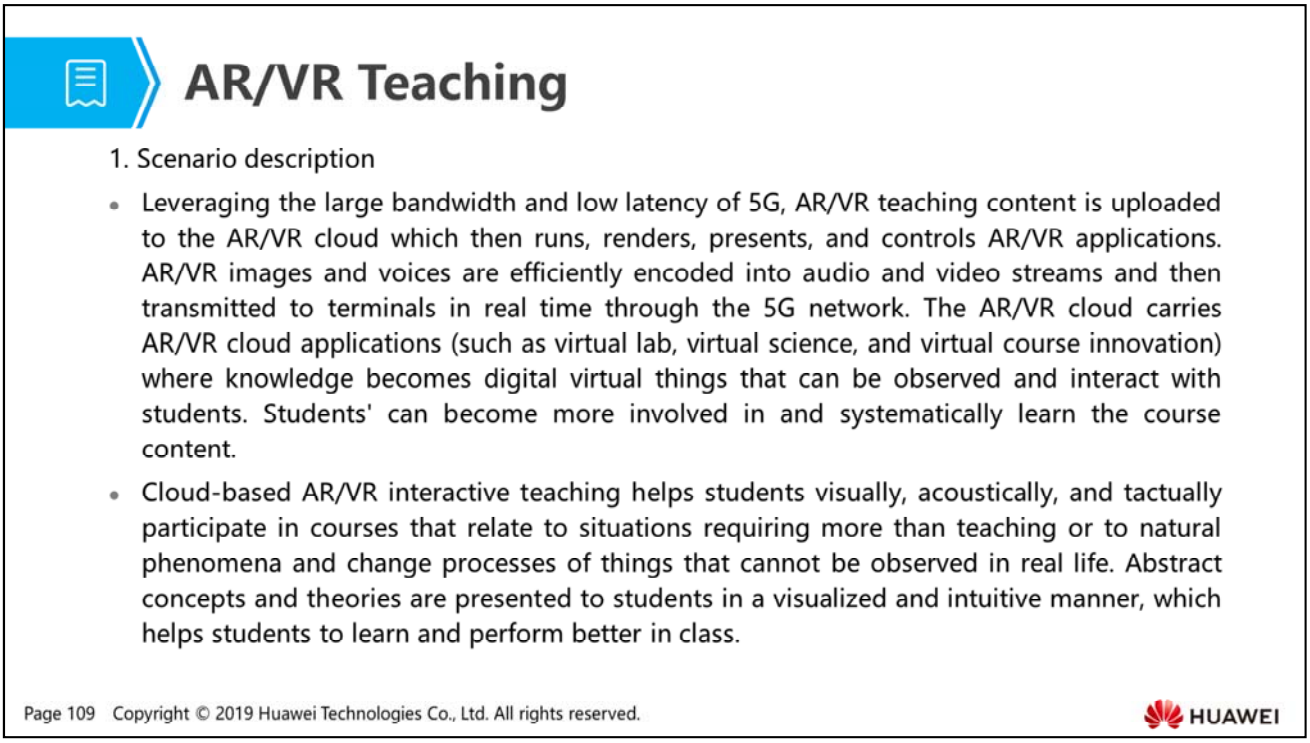
- Centralized access control

A smart classroom with cloud, pipe, and device capabilities implements unified access control for all 5G terminals, centrally manages device status, service applications, and log data, and intuitively displays data to achieve stable, secure, and efficient operation.

4. Key technologies

Everything is connected, smart, quick, and easy-to-use in the teaching environment with the large bandwidth, low latency, and massive connection features of 5G. Data related to teaching activities and students are stored on the 5G MEC platform to eliminate security risks.




- Compared with traditional classes, AR/VR teaching have the following benefits:
  - Classrooms change from 2D where there are only books and blackboards to 3D where the content becomes vivid. Real-life objects such as animals, plants, and daily supplies as well as abstract or invisible contents such as radio waves, magnetic fields, atoms, and geometry are intuitively displayed in front of students to help them better understand the target.
  - Students interact and participate more in classes, and can associate the AR/VR practices with previous experiences or knowledge to establish better understanding. AR/VR education realizes learning as an experience of a real situation, allowing students to see, hear, think, and act accordingly, and become more involved in learning.
  - Students interact while they study. They can pause or repeat a process at any time without interrupting or bothering teachers.
  - The teaching process is like a game. Many studies have proved that in many learning scenarios, games are a fast and effective learning method. Attractive AR/VR game-like courseware can be designed to arouse students' interest and thereby improve their efficiency.
  - Risks in teaching activities, such as chemistry, physics, and electromechanics can be eliminated in AR/VR teaching where the effects are the same as real-life environments.
  - Education resources can be evenly distributed. Teachers and students from different places can join the same virtual classroom, while students in remote areas can have access to senior teachers.
- Cloud-based AR/VR interactive teaching helps students visually, acoustically, and tactually participate in courses that relate to situations requiring more than teaching or to natural phenomena and change processes of things that cannot be observed in real life. Abstract concepts and theories are presented to students in a visualized and intuitive manner, which helps students to learn more and improve the teaching efficiency.

# AR/VR Teaching

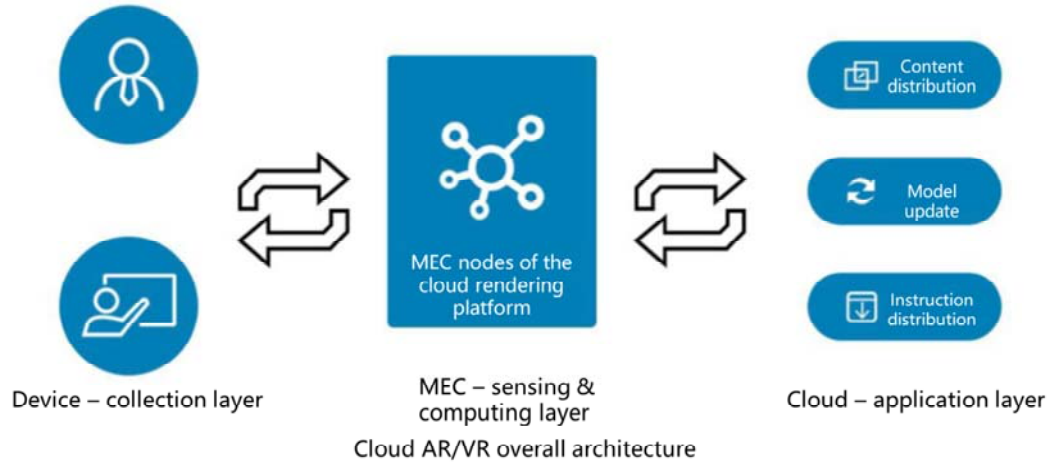
2. Benefits

AR/VR teaching content is uploaded to the AR/VR cloud which then runs, renders, presents, and controls AR/VR applications. AR/VR images and voices are efficiently encoded into audio and video streams and then transmitted to terminals in real time through the 5G network. The MEC architecture allows the rendering function requiring a low latency to be deployed close to users so that service data is directly processed on the edge rendering platform and then transmitted to users without passing through the core network. The 5G MEC solution effectively solves insufficient connections, low speed, and high latency of cloud services common with traditional networks.

# AR/VR Teaching (Continued)

- 3. Architecture



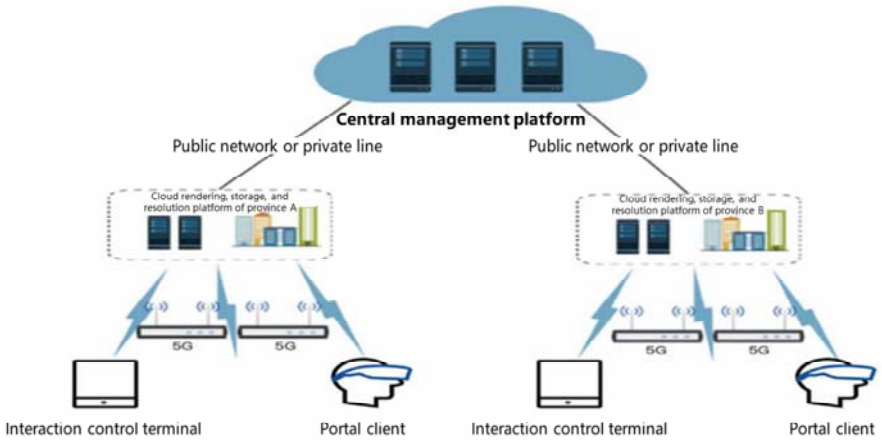

Cloud AR/VR overall architecture

- At the collection layer, interactive terminals collect original videos and transmit the videos to nearby MEC nodes from where terminals directly obtain rendered content through the network.
- At the sensing & computing layer, the MEC aggregation node is pre-configured with the AR/VR rendering model and parameters delivered from the cloud, completes aggregation and model calculation of the original AR/VR streams, and obtains structured feature information.
- At the application layer, the central control platform comprehensively plans and makes decisions based on the feature information reported by MEC nodes, obtains original AR/VR streams in real time to perform model training and optimization, and distributes content and instructions so that MEC nodes can obtain the model and original materials required for rendering.

# AR/VR Teaching (Continued)

- Network architecture




Cloud AR/VR architecture based on the edge cloud

- The overall network architecture provides E2E cloud-pipe-device collaboration. It distributes and controls network, storage, computing, and intelligent data analysis on different devices, reducing response latency, cloud load, and bandwidth costs. It also provides cloud services such as network-wide scheduling and computing power distribution.

# AR/VR Teaching (Continued)

- 4. Key technologies

5G-based edge cloud rendering of AR/VR content is a key technology of AR/VR teaching. AR/VR content is rendered on an edge cloud server. When a user terminal accesses a resource by using web software or a local program over a 5G network, the user terminal sends an instruction to the edge cloud server. The edge cloud server executes the corresponding rendering task according to the instruction, and then sends the rendered image back to the user terminal.

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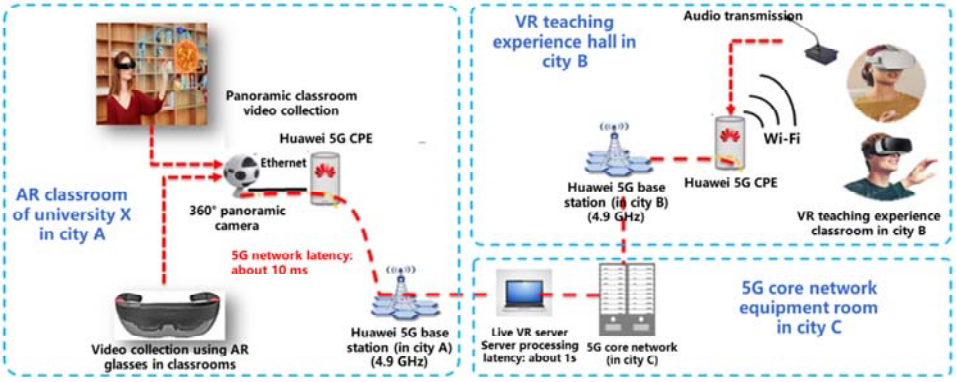
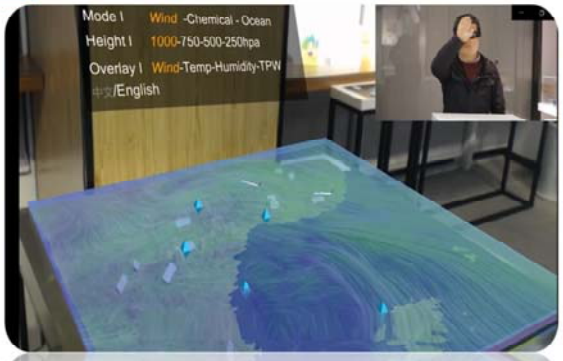
# 5G High Bandwidth and Low Latency Enable VR Remote Classroom




- Scenario (university X): The teacher wears AR glasses for onsite teaching. AR courseware is imaged in the glasses and projected to the large screen. The 360° panoramic camera collects images in real time.
- Communications network (E2E 5G network): Real-time images are transmitted to the server equipment room through the 5G network for VR image rendering and pushed to the remote access side.
- Remote learning (an experience hall): Students wear 5G-enabled VR glasses to have an immersive experience and watch teaching content provided by the teacher and AR images.

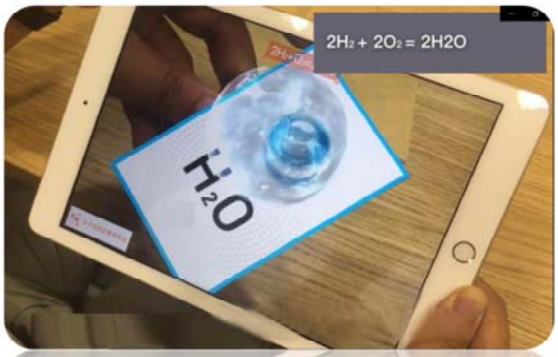
 

# AR+VR Distance Learning




**AR geographic system**

**Sea level and atmosphere changes are controlled by voice so the geographic model can display corresponding virtual scenarios.**




**Virtual chemistry equation**

**The chemical elements are virtualized to vividly simulate the chemical reaction process.**

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# Contents



 

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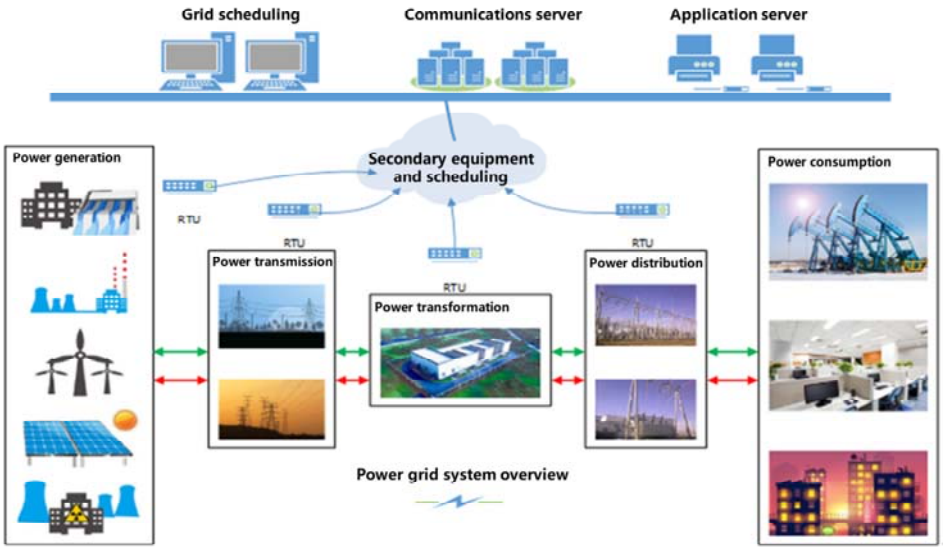
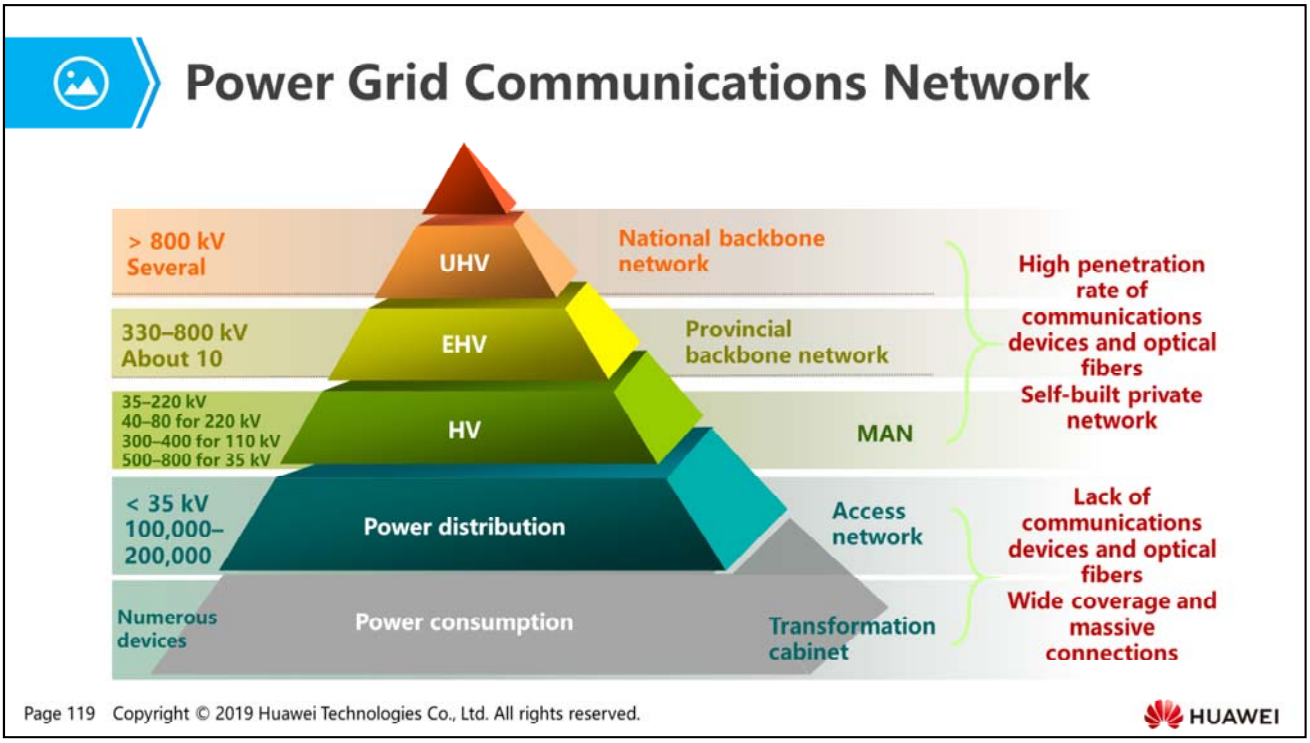
# Composition of a Typical Power System



- A typical power system consists of power generation, transmission, transformation, distribution, and consumption.




- How to meet the requirements of intelligent power distribution and consumption in the last few kilometers is a top priority.

# Power Grid Communications Network (Continued)

| Department | Service | Optical Fiber | Operator GPRS | Operator 4G |
|---|---|---|---|---|
| Operation inspection | Power distribution automation | Δ | Δ | |
| | Power distribution environment status and security monitoring | Δ | | |
| | Robotic patrol | Δ | | |
| | Power transmission and transformation status monitoring | | Δ | |
| | Mobile patrol | | | Δ |
| Marketing | Power consumption data collection | | Δ | |
| | Charging station/post video monitoring | Δ | | Δ |
| | Mobile service expansion and meter installation | | | Δ |
| Materials | Material storage management and monitoring | Δ | | |
| Infrastructure | Construction site image and data collection | | | Δ |

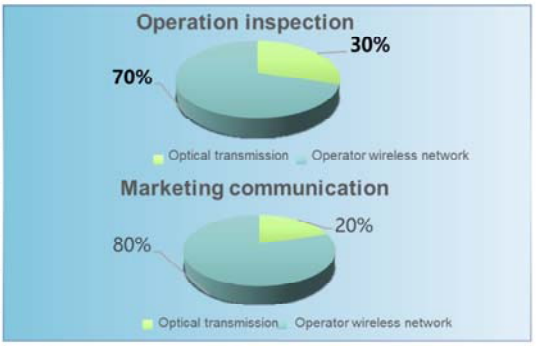
Cable pit buried

Located on traffic artery

Construction not allowed in residential areas

Difficult construction in old urban areas

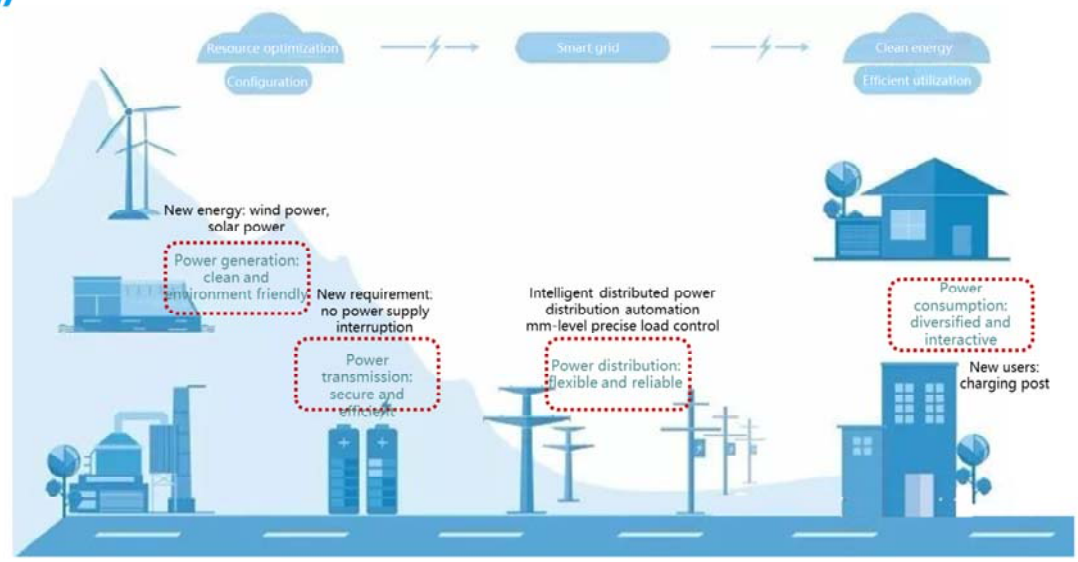
Optical communications for power distribution networks below 10 kV is difficult.




- Power services carried on public networks are not secure and reliable.
- Due to a low online rate and long latency, the public network GPRS cannot provide remote monitoring, remote communication, and remote control. Therefore, fault locating is slow.
- Service monitoring using operators' 4G networks is costly.

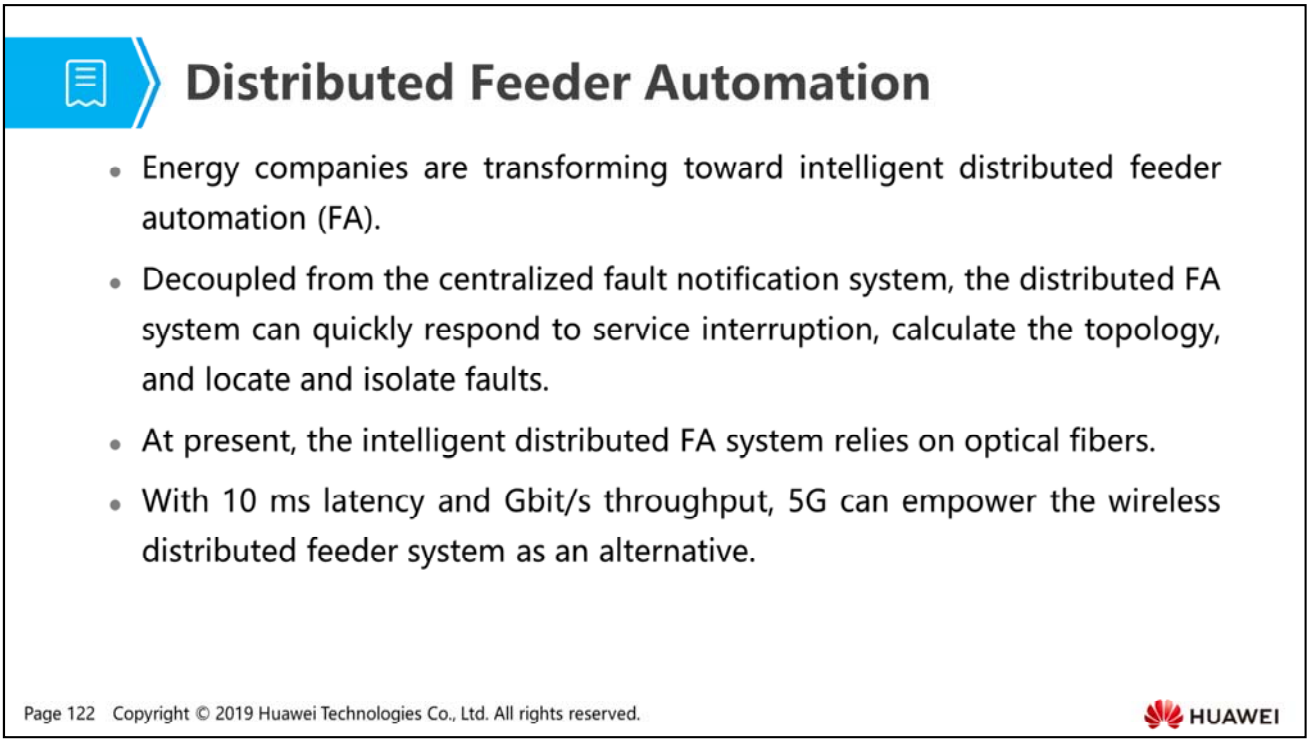
Heavy involvement of operators' wireless networks poses security risks.

# Traditional Power Grid on the Road to Smart Grid



- A smart grid is built on an integrated high-speed and bidirectional communications network. Advanced sensing and measurement technologies, device technologies, control methods, energy storage technologies, and decision support system technologies are used to ensure reliable, secure, economical, efficient, and environmentally friendly grid operation.
- Building on traditional power systems, a smart grid also integrates new energy sources, materials, and devices to deliver a high IT capacity ratio, automation level, and interaction capability.
- With the rapid development of new technologies in various fields, smart grids are facing new challenges and opportunities.
    - New energy: To cope with global warming and achieve sustainable development, renewable energy is urgently needed to generate electricity. A large number of renewable energy sources will bring new challenges to grid operation and management. The intermittent and random nature of renewable energy makes power balance and operation control difficult. On the other hand, the deep penetration of distributed energy resources (DERs) means that the distribution network has to change from passive one-way power flow to active two-way power flow.
    - New users: With the rapid development of electric vehicles, the demand for charging capacity is increasing. To better manage the requirement (for example, balanced power supply), new power consumption management modes are required. For example, users can charge their vehicles interactively at any time instead of only when the vehicles are connected to the power supply.
    - New requirements: New devices and scenarios pose higher requirements on power quality. For example, some high-tech digital devices do not tolerate interruption of power supply. In addition, grid operation places high requirements for asset utilization, for example, higher equipment utilization, smaller capacity ratio, and less line loss. Therefore, the load and power supply of the grid need to be adjusted more accurately.




- The FA system is of great value for integrating renewable energy into power grids to reduce O&M costs and improve reliability.
- In developed and emerging markets, many energy companies have already begun to deploy distributed FA systems. In developed markets, the reliability of power supply is estimated to be 99.999%, which means that the annual outage time must be controlled to less than 5 minutes. The solar energy, wind turbine, and hydropower in emerging energy microgrids will bring different loads to power grids. This means that the current centralized power supply system may not be able to meet the requirements, because fault location and isolation may take about two minutes. The FA system requires a communications network with ultra-low latency, such as 5G.
- Mobile operators can provide dedicated network slices for the intelligent distributed FA system for energy suppliers, so that energy suppliers can perform intelligent analysis and respond to analogies in real time, thereby implementing faster and more accurate grid control.

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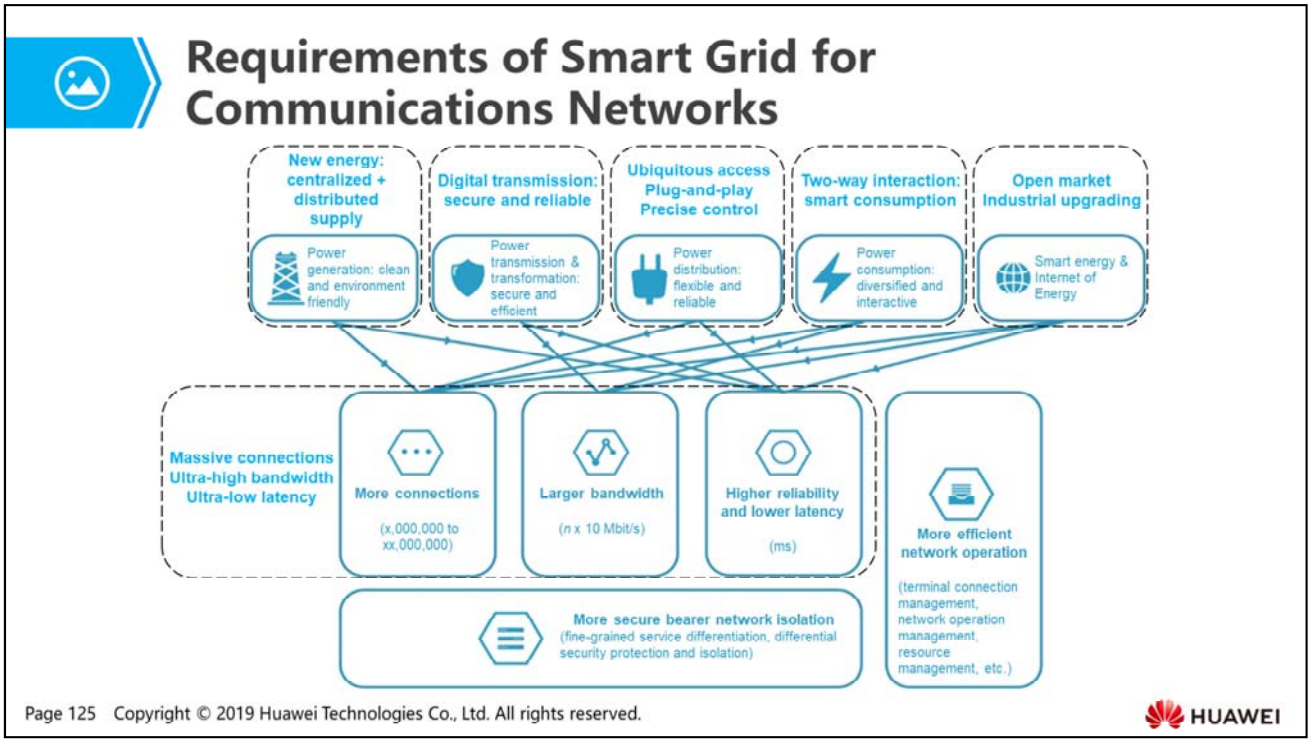
# Opportunities and Challenges Faced by Smart Grid

- New energy:
  - The intermittent and random nature of renewable energy makes power balance and operation control difficult.
  - The deep penetration of distributed energy resources (DERs) due to wide distribution of new energy means that the distribution network has to change from passive one-way flow to active two-way flow.
- New users: With the rapid development of electric vehicles and similar industries, the demand for charging capacity is increasing. To better manage the requirement (for example, balanced power supply), new power consumption management modes are required. For example, users can charge their vehicles interactively at any time instead of only when the vehicles are connected to the power supply.
- New requirements: New devices and scenarios pose higher requirements on power quality (for example, some high-tech digital devices do not tolerate interruption of power supply). In addition, grid operation requires high asset utilization, for example, efficient equipment utilization, small capacity ratio, and small line loss, calling for more accurate adjustment of the grid load and capacity.




- **Protection**: The highest level of protection for power grids is differential protection, which is equipped on all main grids using optical fiber solutions but not on a large number of live grids. State Grid Corporation of China, mobile operators, and Huawei have submitted seven industry standards to 3GPP and formulated 5G wireless standards for differential protection on distribution networks. The purpose is to make three improvements using the 5G low latency feature. First, reduce the construction cost by saving optical fibers. Second, use the CPE timing function to implement differential protection and narrow the impact scope of power outages. Third, let operators run wireless networks to save costs. Currently, the first-phase test has been successfully conducted in Shenzhen.
- **Security**: Power grid communications has high requirements on security and traditionally relies on private networks. Currently on operators' networks, power grid communication must be physically and logically isolated from other services to ensure security. Huawei E2E slicing implements logical isolation and flexible scheduling of the core network, and FlexE-based transmission enables hard pipe isolation. Currently, this solution is being piloted on live power grids in Shenzhen.
- **Inspection and monitoring**: With the 5G large bandwidth feature, power grid lines and equipment rooms can be inspected using 360° cameras, UAVs, and robots. Robotic inspection can be experienced on MR glasses.
- **Metering**: Electricity meters are read once every five minutes, which is much higher than that in the 2G or NB-IoT era. This efficiently eliminates electricity thefts and leakage.

# Connection Requirements for Power Distribution and Consumption of Smart Grid

**Grid**

| Generation | Transmission | Transformation | Distribution | Consumption |
|---|---|---|---|---|

**Mostly wired, partially wireless**
- Low cost requirement due to a small number of nodes
- 100% fiber to the site
- Substation robotic patrol and mobile video surveillance

**Wireless + wired**
- High cost concern due to tens of millions of distribution nodes; < 10% global average fiber-to-the-site ratio; wireless deployment to save 70% E2E cost
- Wireless coverage preferred due to mesh wide distribution

**Mainly wireless**
- The wired advanced metering infrastructure (AMI) technology is mature but cannot support inter-transformer distribution. Therefore, it is suitable for ultra-densely populated areas with large transformers.
- Wireless AMI supports several transformers on a single site, and is suitable for sparsely populated areas with small transformers.

**Service**

Video surveillance | Trunking voice dispatching | Distribution automation | Smart metering/Charging post management

| Name | E2E Latency | Communication Latency | Single-Link Bandwidth | 5G Service |
|---|---|---|---|---|
| Distribution network protection and control | < 100 ms | < 10 ms | < 2 kbit/s | URLLC |
| Timing | < 100 μs | < 10 μs | < 2 kbit/s | URLLC |
| Trunking voice dispatching | Seconds | Seconds | < 4 kbit/s | eMBB |
| Smart metering | Seconds | Seconds | < 10 kbit/s | mMTC |
| Online monitoring | Seconds | Seconds | x00 kbit/s | mMTC |
| Video surveillance | Seconds | 100 ms | 100 Mbit/s | eMBB |
| Mobile operation | Seconds | 100 ms | 100 Mbit/s | eMBB |

## 5G Smart Grid Has Huge Potential for Connections

**2020 China**

Electrical power cable (camera/2.5 km)

**20 million**

Power distribution terminal

**20 million**

Electricity meter

**500 million**

Charging post

**4 million**

- **State Grid & China Southern Power Grid**: 5G will become the main solution for power distribution networks and terminals.
- **Europe subnet of America Movil**: The 5G plan for smart grids had been proposed.
- **Vodafone Italy**: Smart grid is an important part of VDF 5G applications in Italy.
- **Germany**: Operators plan to expand the smart grid market through slicing.



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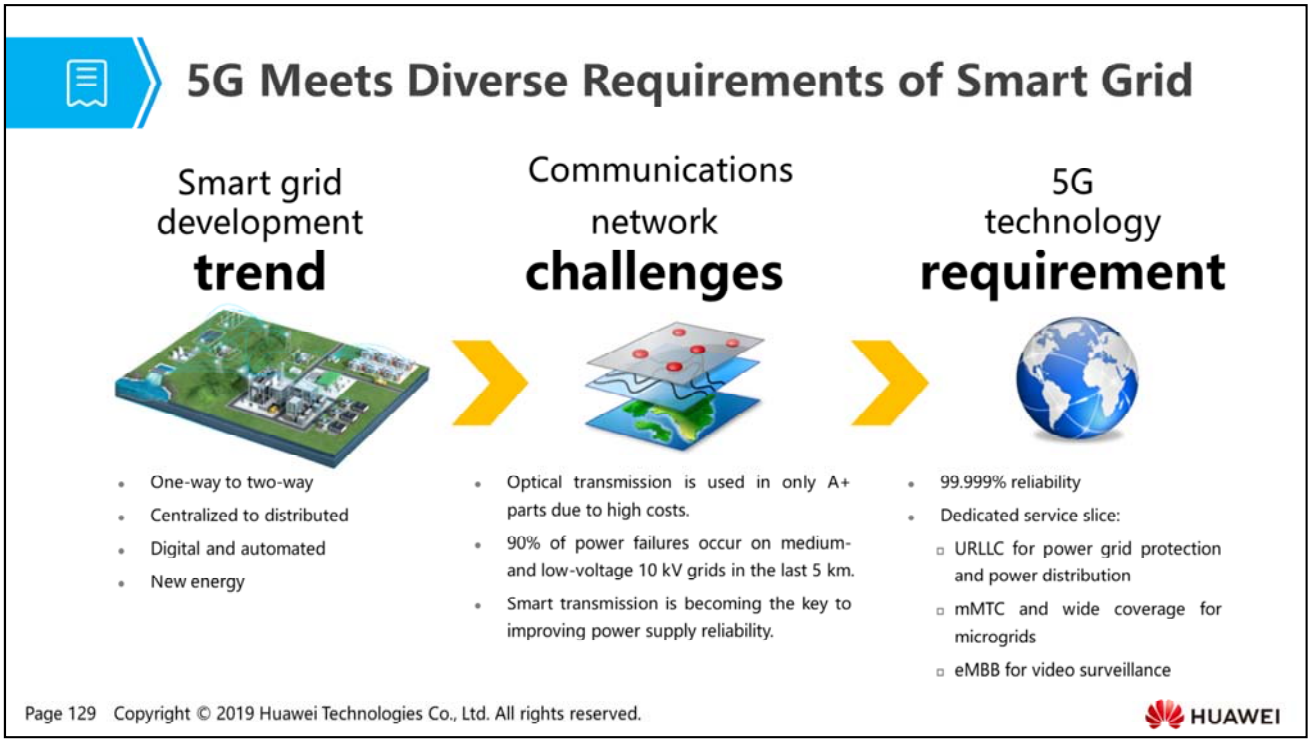
- As an industrial leader in 5G, Huawei is actively exploring and incubating 5G applications in the electric power industry in the early stage. Once the 3GPP Release 16 standard is finalized, wireless private network products for power grids must be adapted accordingly to match the grid spectrum characteristics. It is estimated that it will take at least 2 to 3 years until large-scale commercial use after the products are initially put into commercial use, piloted, and then developed into the enterprise standard.
- Key 5G technologies such as air interface fragmentation and grant-free low-latency scheduling are introduced to the eLTE-G solution in advance to fully meet the requirements for frequency isolation and low latency of current services such as precise load control and power distribution automation in the electric power industry. In addition, key features such as discrete carrier aggregation and interference control, and low power consumption are also available. Further evolution to 5G is expected to introduce more key technologies in order to meet new requirements of electric power services in the future. The deployment of wireless private networks for power networks is irreversible.

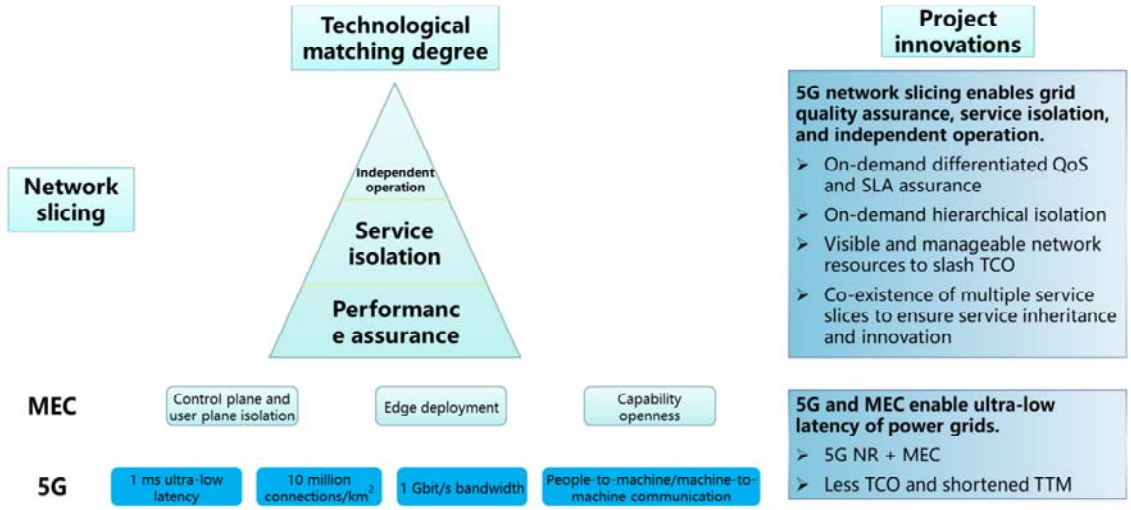
# Smart Grid Communications Requirements

| Service Type | Service Name | Requirements | | | | |
|---|---|---|---|---|---|---|
| | | Latency | Bandwidth | Reliability | Security Isolation | Connections |
| Control | Intelligent distributed power distribution automation | ≤ 12 ms | ≥ 2 Mbit/s | 99.999% | Secure production part I | X x 10/km$^2$ |
| | Response to power load requirements | ≤ 50 ms | 10 kbit/s to 2 Mbit/s | | Secure production part I | |
| | DER adjustment and control | Collection: ≤ 3s<br>Control: ≤ 1s | ≥ 2 Mbit/s | | Services in parts I, II, and III | x,000,000 to x0,000,000 |
| Collection | AMI | ≤ 3s | 1–2 Mbit/s | 99.9% | Management information part III | Centralized metering: X x 100/km$^2$<br>50–100 times at the user level |
| | Substation robotic patrol | ≤ 200 ms | 4–10 Mbit/s | | Management information part III | Concentrated in 1–2 local areas |
| | Transmission line UAV patrol | | | | | |
| | Comprehensive video surveillance in the distribution room | | | | | |
| | Mobile onsite construction management and control | | 20–100 Mbit/s | | | 5–10 in a local area |
| | Comprehensive application of SON for site emergency | | | | | |




- Wireless private networks for power grids are still in the early stage of construction and therefore do not provide wide coverage. In areas covered by private networks, private networks carry power services. In areas not covered by private networks, the public network continues to carry non-control power services which can be progressively migrated to private networks with the increase of the private network coverage.
- The 230 MHz band for power grids is a discrete narrowband spectrum and not within the 5G frequency range defined by 3GPP. According to 3GPP, at least 5 MHz continuous bandwidth is required for 5G deployment. This means the 230 MHz band cannot be directly used for 5G rollout. The prospect of applying for 5G private network spectrum for power grids is unclear. Currently, Radio Association of China authorizes only 5G spectrum to operators for network deployment.
- With the maturity and large-scale deployment of the eMBB network on 5G public networks, the single-terminal bandwidth is greatly increased to carry non-key high-bandwidth services, such as HD video and VR services. The 230 MHz private network cannot adequately support high-bandwidth services due to limited available frequency resources, and therefore is used to construct a full-coverage power IoT infrastructure network.

# 5G Service Slicing Drives Technological Innovation



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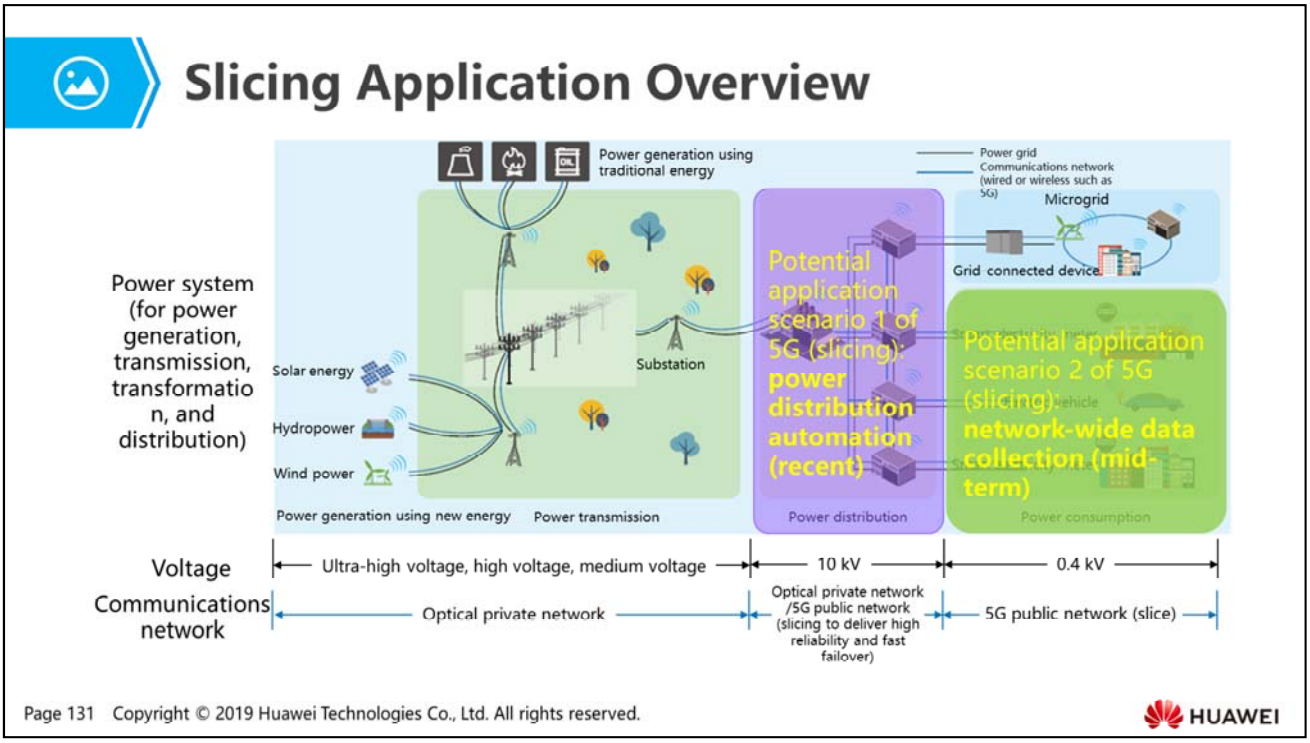
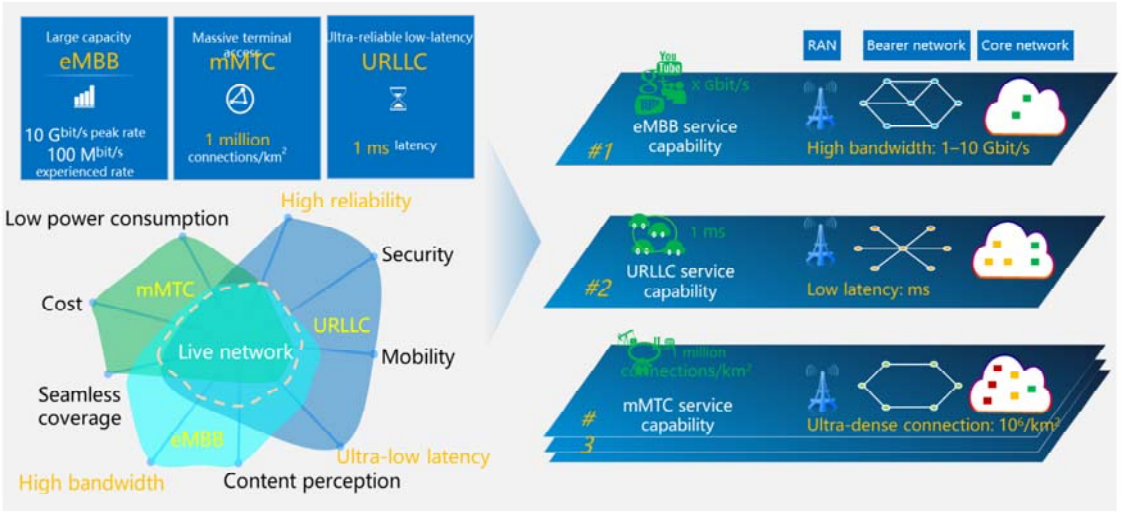


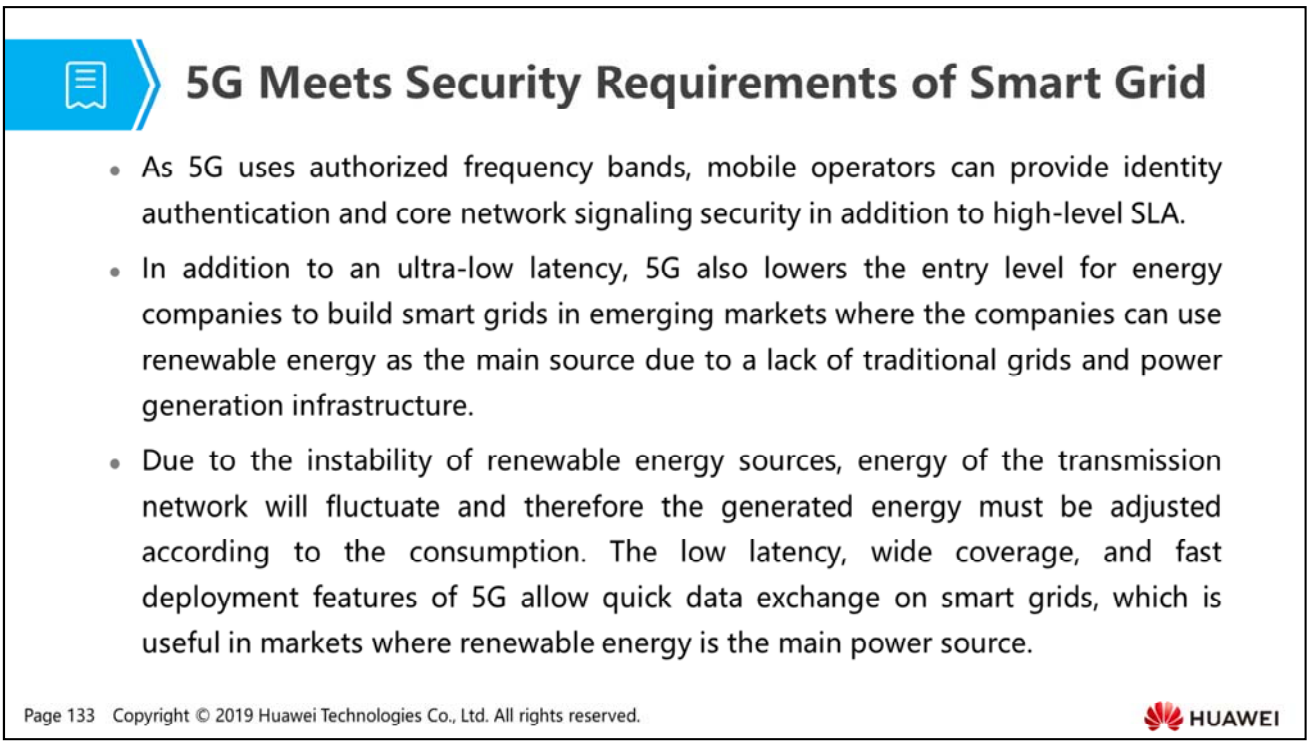

- Smart grid construction mandates fiber deployment and requires high network reliability and low latency, and primarily concerns the last mile. Currently, smart grid construction has market opportunities in Europe and China.
- The potential opportunities of 5G mainly lie in power distribution and consumption. Power generation, transmission, and transformation are the core of a power grid and must use private networks, which means there is no room for wireless networks.
- **Power distribution automation, 1 ms failover, and short power outage duration**: 22 V grids require that faults must be removed within 100 to 120 ms to ensure stability and security, and the requirement is between 200 ms and 500 ms for 110 V grids.

# 5G Slicing for Power Grids



- Base station coverage of operators and the slicing technology are used to isolate services, ensuring security, low latency, and large connections.




- NARI has deployed multiple intelligent distributed FA terminals in China by using the fiber-based solution in Pudong, Shanghai. The power supply reliability is improved from 99.99% to 99.999%. Companies such as GE and Eaton are also promoting intelligent distributed FA terminals and showing preference for wireless solutions to reduce communication costs.
- According to ABI Research, the global market potential of distribution automation will increase from US$ 13 billion in 2015 to US$ 36 billion in 2025.
- 5G can replace the existing fiber infrastructure in distribution automation and deliver a network latency smaller than 10 ms and gigabit throughput to implement wireless distributed control.
- 5G will also lift the barriers for energy suppliers in the emerging market.

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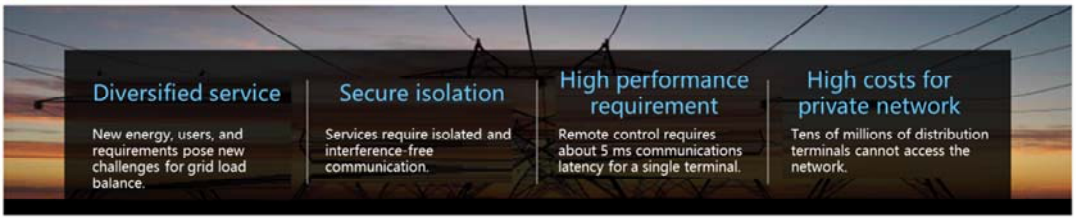
# 5G Network Slicing Enables Smart Grid




**On-demand deployment**
Customize network functions based on service requirements.

**E2E SLA assurance**
5G network slicing ensures millisecond-level E2E latency.


**Network slicing**

**Isolation**
Build logically isolated private communications network on shared telecom infrastructure.

**Automation**
Shared infrastructure, automated deployment and O&M save costs.

Distribution automation | Power consumption data collection | New energy vehicle | Distributed power supply | Precise load control

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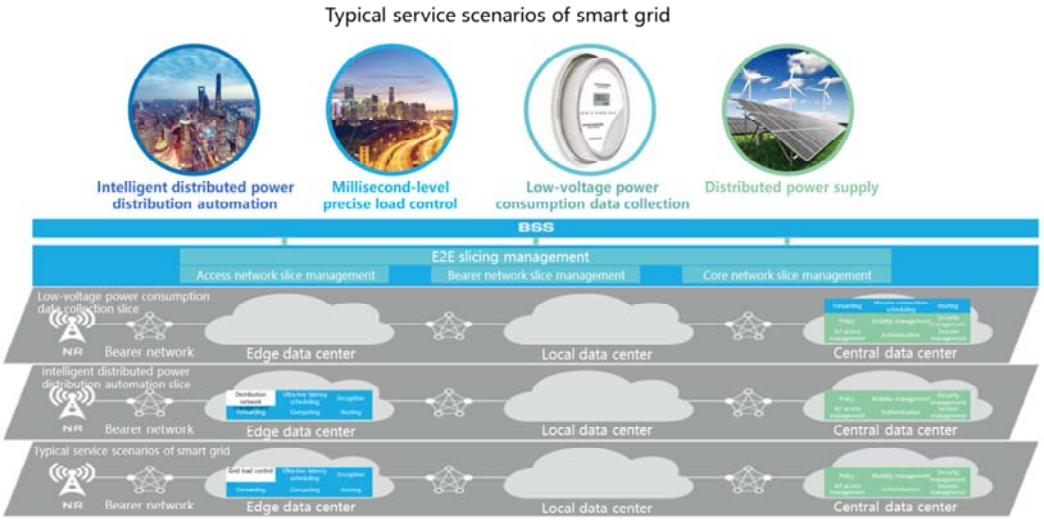
# 5G Network Slicing Architecture of Smart Grid



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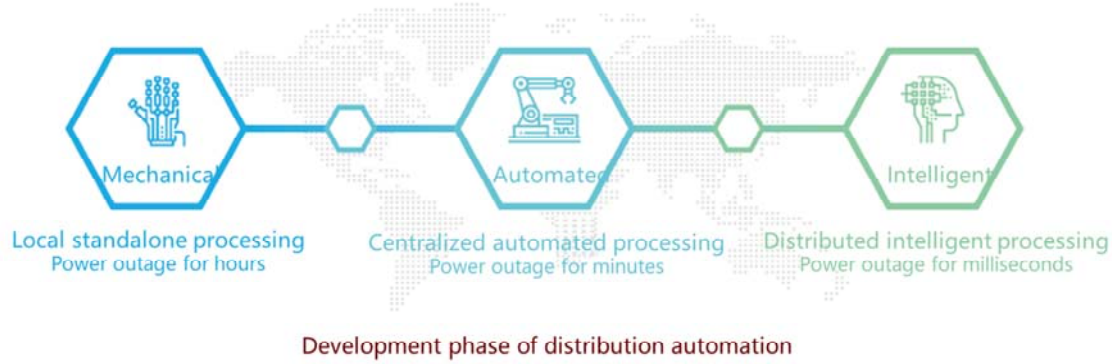
# Typical Scenario 1: Intelligent Distributed Power Distribution Automation

- Power distribution automation is an integrated information management system that integrates computer technologies, data transmission, control technologies, modern equipment, and management. It aims to improve power supply reliability and power quality, provide high-quality services for users, reduce operating costs, and alleviate labor input.




Development phase of distribution automation

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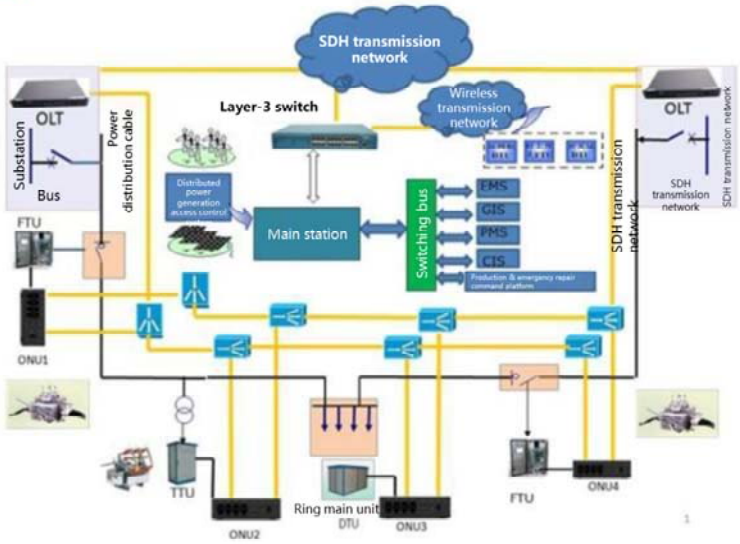
- The development of distribution automation includes three phases:
  - The first phase heavily relies on automatic switch equipment to implement fault isolation and power supply recovery in fault-free areas, mainly including the automatic circuit recloser, sectionalizer, and backup power automatic switching device. The communications network and the computer system are not required. Distribution automation systems at this phase feature a low automation level and are still widely used.
  - The second phase relies on the communications network, feeder terminal unit, and background computer network. The distribution network running status can be monitored and the running mode can be changed through remote control when the network is running properly. In this way, faults can be detected in time and then remotely isolated so that the power supply in fault-free areas can be restored.
  - In the third phase, the automatic control function is added based on the second phase of distribution automation.

## Typical Scenario 1: Intelligent Distributed Power Distribution Automation (Continued)

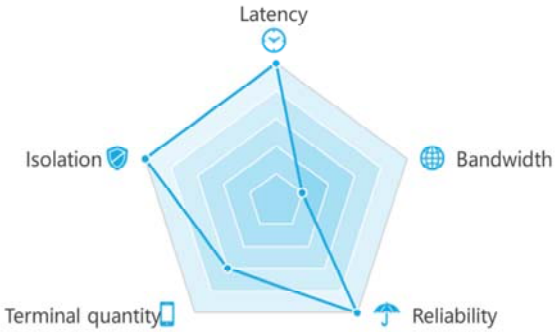



The new management system integrates computer, data transmission, and control technologies to improve power supply reliability and power quality, reduce operation costs, and improve O&M efficiency.

- The main station is centrally deployed in cities, and intelligent power distribution terminals are distributed to the edges. The communications system mainly transmits data services, including: telemetry and remote sensing data collected by terminals and uploaded to the main station (in the uplink), general instructions delivered from the main station to terminals (in the downlink), line fault location (lines and sections), and remote control commands for fault isolation and recovery. Uplink traffic volumes are greater than downlink traffic volumes.
- The processing logic of the main station is distributed to the intelligent power distribution terminals. The peer-to-peer communication between terminals enables intelligent judgment, analysis, fault location, fault isolation, and power supply recovery in fault-free areas. Automatic troubleshooting in milliseconds is realized, and the power outage time and range are minimized.

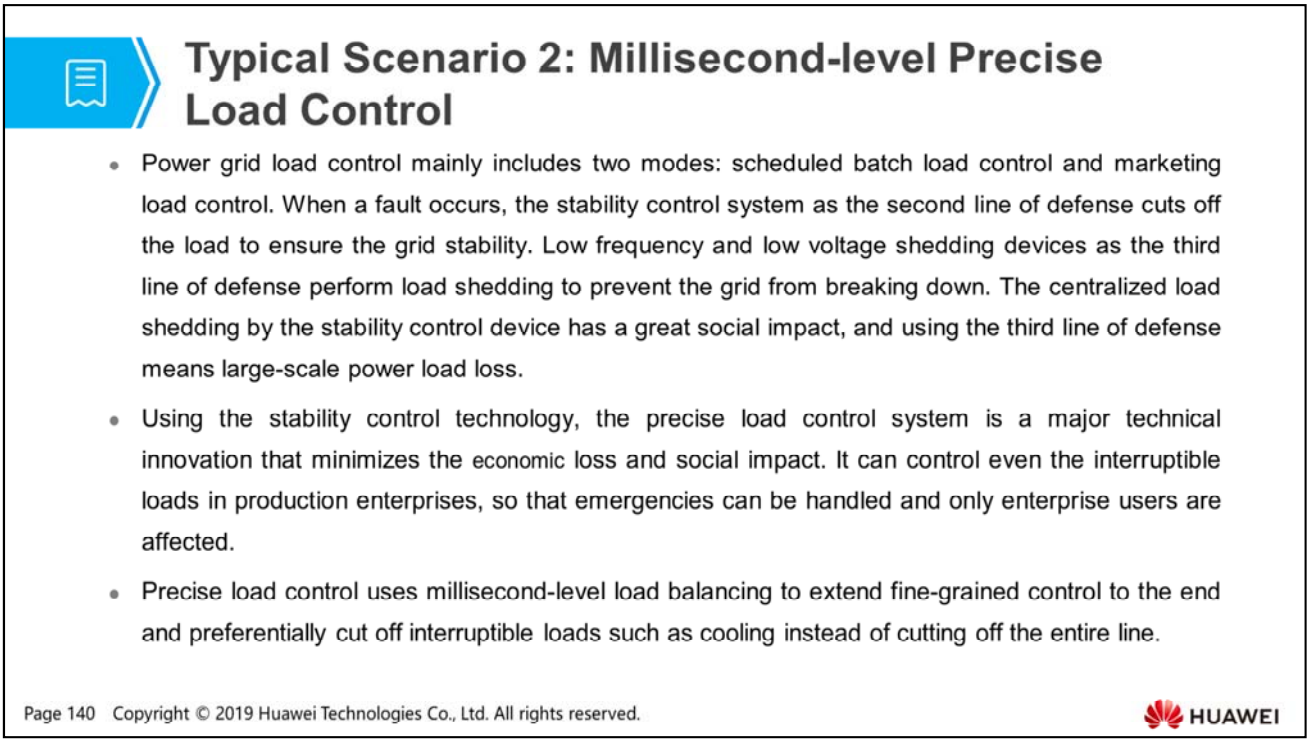
# Key Requirements for Communications Network




Key requirements:

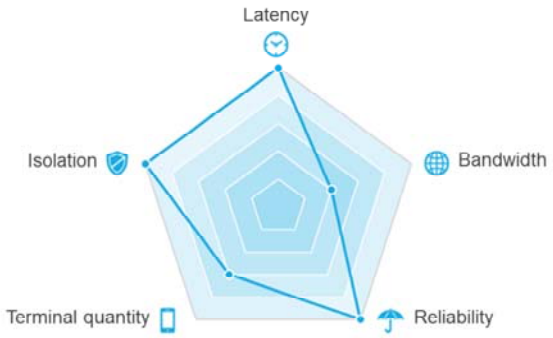
- Millisecond ultra-low latency
- High isolation
- High reliability

| Downlink Rate (Mbit/s) | Uplink Rate (Mbit/s) | Service Latency (RTT, ms) | Network Latency (RTT, ms) | Reliability | Remarks |
|---|---|---|---|---|---|
| 0.2 | 1.5 | 8 | < 8 | 99.999% | Power distribution automation belongs to I and II production parts of power grids and must be completely isolated from other III and IV management parts. Therefore, this scenario has high requirements on network reliability. |




- At present, the safety and stability control system is still an important means to guarantee the security of UHV AC and DC power grids in emergency. If bipolar block faults occur in a UHV DC input, the power loss of the receiving-end grid exceeds a certain limit. As a result, the frequency of the power grid drops seriously and even the system frequency may be lost. To ensure secure and stable operation of the power grid after a DC fault occurs, measures such as multi-DC boost and pump switching of pumped storage power stations are taken so that the power shortage is balanced. However, these measures cannot prevent the frequency drop of the power grid in the case of a serious DC fault. Therefore, emergency load switching is still necessary. When serious faults such as DC bipolar block occurs, the traditional method of centrally cutting off loads on 110 kV lines will trigger power accidents specified in the State Council Order 599, which will cause great social impact.

# Key Requirements for Communications Network



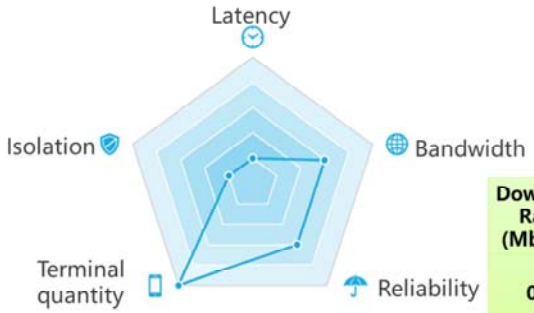

Key requirements:

- Massive access of tens of millions of terminals
- High frequency and high concurrency
- Quasi-real-time data reporting in seconds

| Downlink Rate (Mbit/s) | Uplink Rate (Mbit/s) | Service Latency (RTT, ms) | Network Latency (RTT, ms) | Reliability | Remarks |
|---|---|---|---|---|---|
| 1.0 | 1.13 | 200 | 50 | 99.999% | Precise load control belongs to I and II production parts of power grids and must be completely isolated from other III and IV management parts. |

## Sub-scenario 1: Low-Voltage Power Consumption Data Collection

- Low-voltage power consumption data collection is a system that collects, processes, and monitors in real time the power consumption data of users. It implements the following functions: automatic collection of power consumption data, metering exception monitoring, power quality monitoring, power consumption analysis and management, related data release, DER monitoring, and data exchange of intelligent power-consuming equipment.
- Key requirements on the communications network:
  - Massive access of tens of millions of terminals
  - High frequency and high concurrency
  - Quasi-real-time data reporting in seconds




| Downlink Rate (Mbit/s) | Uplink Rate (Mbit/s) | Service Latency (RTT, ms) | Network Latency (RTT, ms) | Reliability | Connections |
|---|---|---|---|---|---|
| 0.2 | 1.5 | Seconds | Seconds | 99.9% | x,000,000 to x0,000,000 per km$^2$ |



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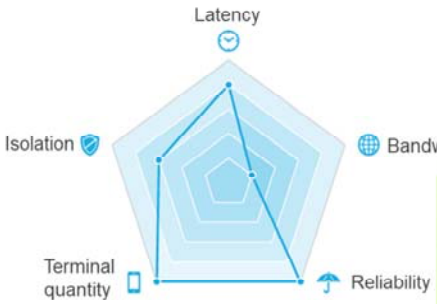
- Power consumption data collection is mainly used for metering and mostly about data service transmission, including the status data collected by terminals and uploaded to the main station and the general commands delivered by the main station to terminals (in the downlink). The traffic volume is large in the uplink but small in the downlink. Currently the communication modes include 230 MHz network, wireless public network, and optical transmission. User terminals are deployed in concentrator mode, and the main station is deployed in a centralized manner by provincial companies. In the early stage, data is collected at 24 metering points in a day. Currently, data is collected every 5 or 15 minutes. Data at 00:00 is collected in a unified manner.
- New services in the future will require real-time (or quasi-real-time) reporting of power consumption data. In addition, the number of terminals is increasing, and power consumption data collection will be extended to homes. This way, the load data of all power-consuming terminals can be obtained to achieve refined balance between supply and demand. For example, in Europe and America, the tiered pricing mechanism for power consumption has been implemented. Users need to be notified of electricity prices in real time so that users can purchase as required.

## Sub-scenario 2: Distributed Power System

- New types of distributed power supply, such as wind/solar power generation, electric vehicle charging station, energy storage device, and microgrid, are built at the user end and can run independently or connect to the grid.
- Energy transformation requires power grid enterprises to quickly apply clean energy on power grids.
- Key requirements on the communications network:
  - Massive access of millions to tens of millions of terminals
  - Low latency (especially in the downlink)
  - High reliability




| Downlink Rate (Mbit/s) | Uplink Rate (Mbit/s) | Service Latency (RTT, ms) | Network Latency (RTT, ms) | Reliability | Connections |
|---|---|---|---|---|---|
| 0.2 | 1.5 | Downlink: seconds | Seconds | 99.999% | x,000,000 to x0,000,000 per km$^2$ |



- New types of distributed power supply, such as wind/solar power generation, electric vehicle charging station, energy storage device, and new distributed microgrid increase by 1% annually, and will account for 9.1% of the total installed devices by 2020 in China.
- The introduction of distributed power grids brings new technical problems and challenges to the safe and stable operation of distribution networks. The access of distributed power supplies has not been considered during the design of traditional distribution networks. Once distributed power supplies are added, the network structure changes from a single power source to two or more sources, making the power flow mode on distribution networks more complex. Users both consume and generate power, and current flows bidirectionally and changes dynamically in real time.

# 5G Network Slicing Meets Requirements of Different Service Scenarios of Smart Grid

- Technology: 5G network slicing to meet the connection requirements of core industrial control services
- Typical slice type for industrial control services: URLLC
- Typical slice type for data collection services: mMTC

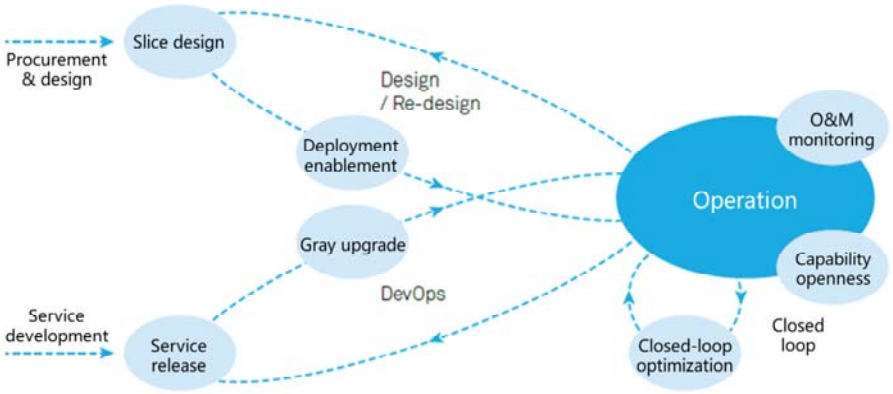
| Service Scenario | Latency | Reliability | Bandwidth | Terminal Quantity | Service Isolation | Service Priority | Slice Type |
|---|---|---|---|---|---|---|---|
| Intelligent distributed power distribution automation | High | High | Low | Medium | High | High | URLLC |
| Millisecond-level precise load control | High | High | Medium and low | Medium | High | Medium and high | URLLC |
| Low-voltage power consumption data collection | Low | Medium | Medium | High | Low | Medium | mMTC |
| Distributed power supply | Medium and high | High | Low | High | Medium | Medium and low | mMTC (uplink) + URLLC (downlink) |

- In addition to the preceding two typical types of slices, the power industry may also require eMBB and voice slices. The typical service scenario of the eMBB slice is remote UAV patrol, and that of the voice slice is manual maintenance and inspection.

# Smart Grid Lifecycle Management

- The lifecycle management of a 5G network slice includes slice design, deployment enablement, slice running, closed-loop optimization, O&M, and capability openness.



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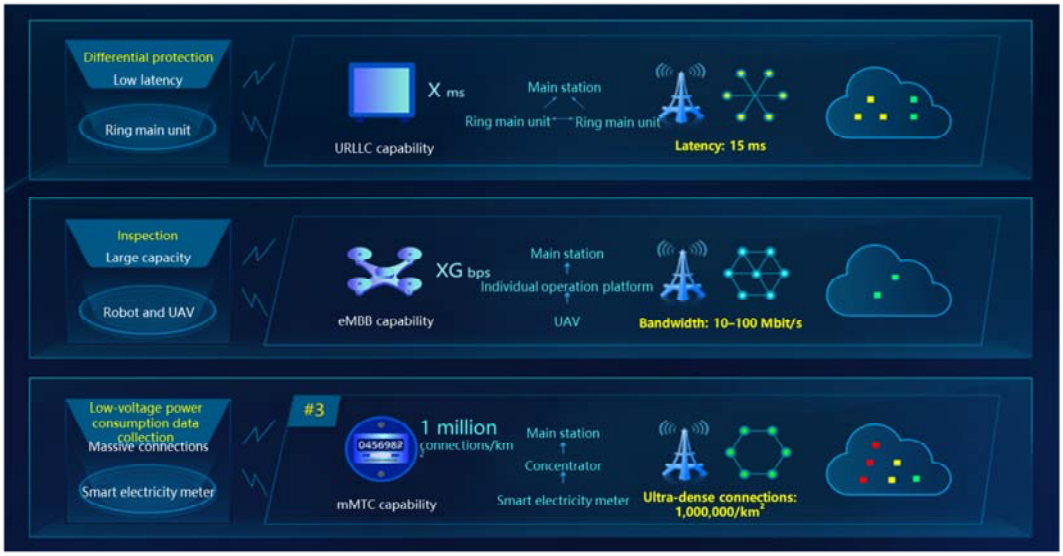
# 5G Network Slicing Solutions for Smart Grid



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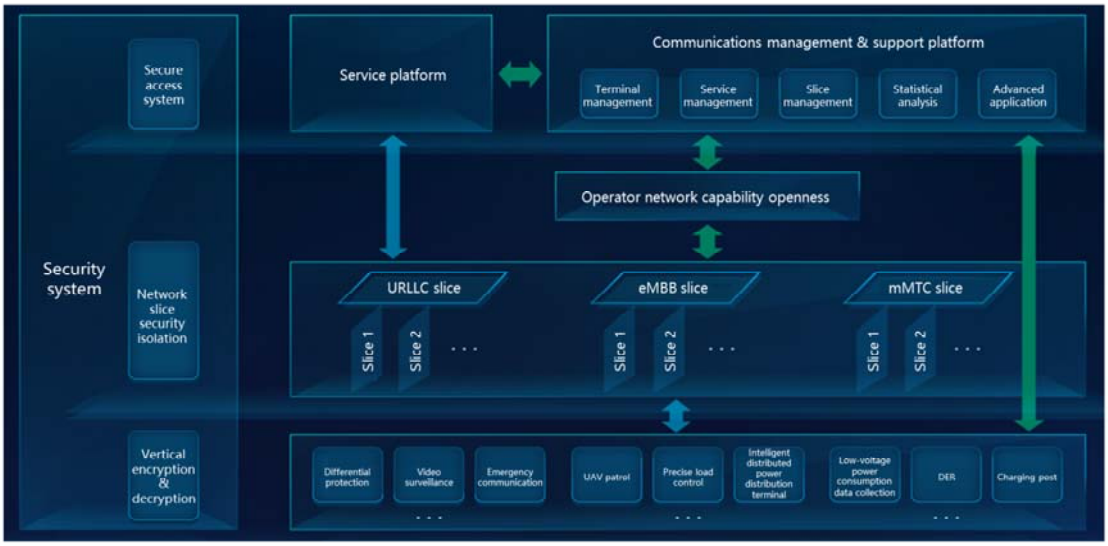
# 5G Network Security System for Smart Grid



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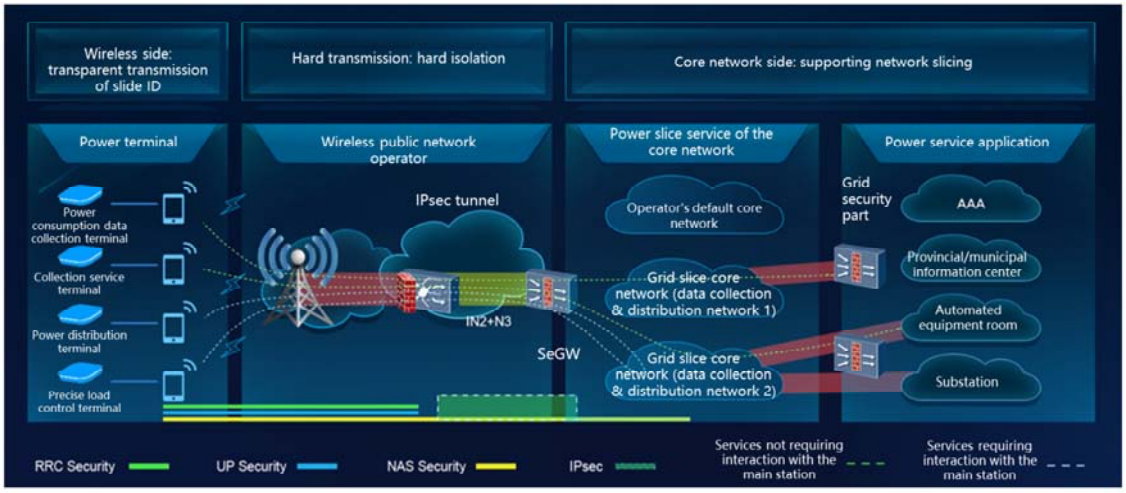
# 5G Network E2E Service Isolation for Smart Grid



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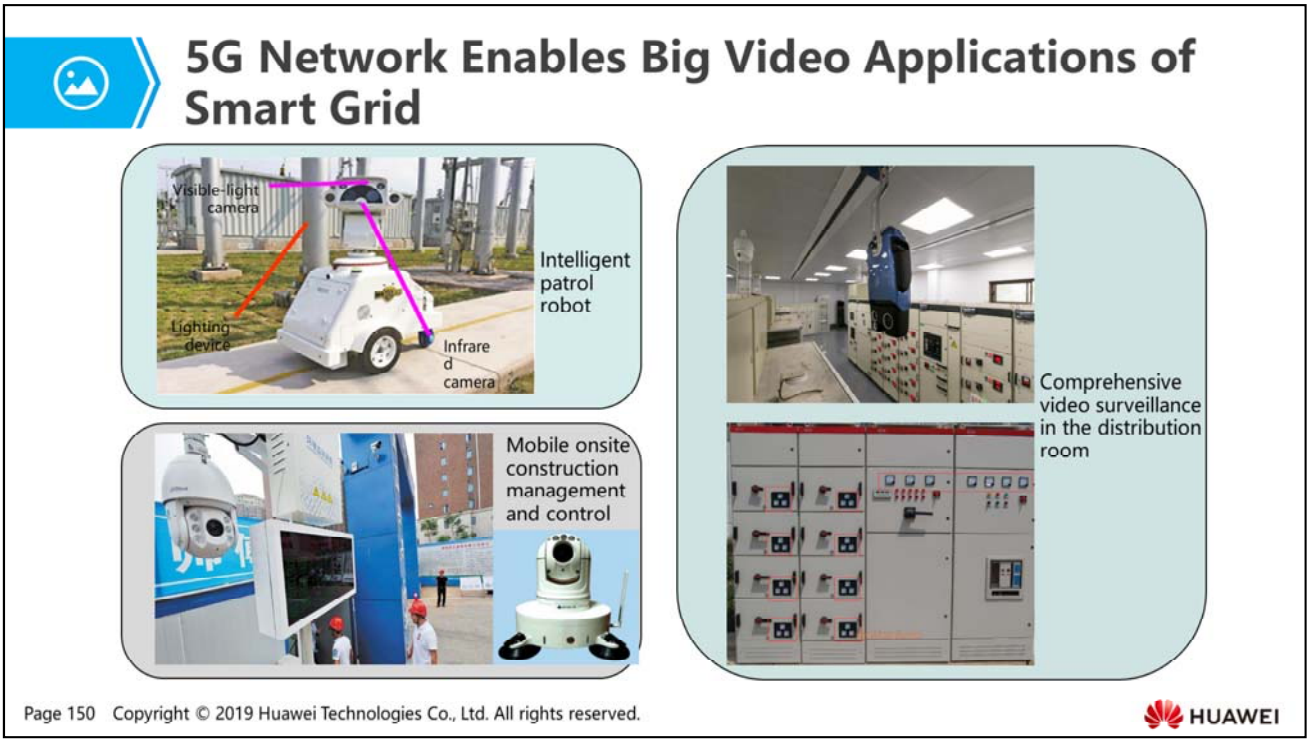
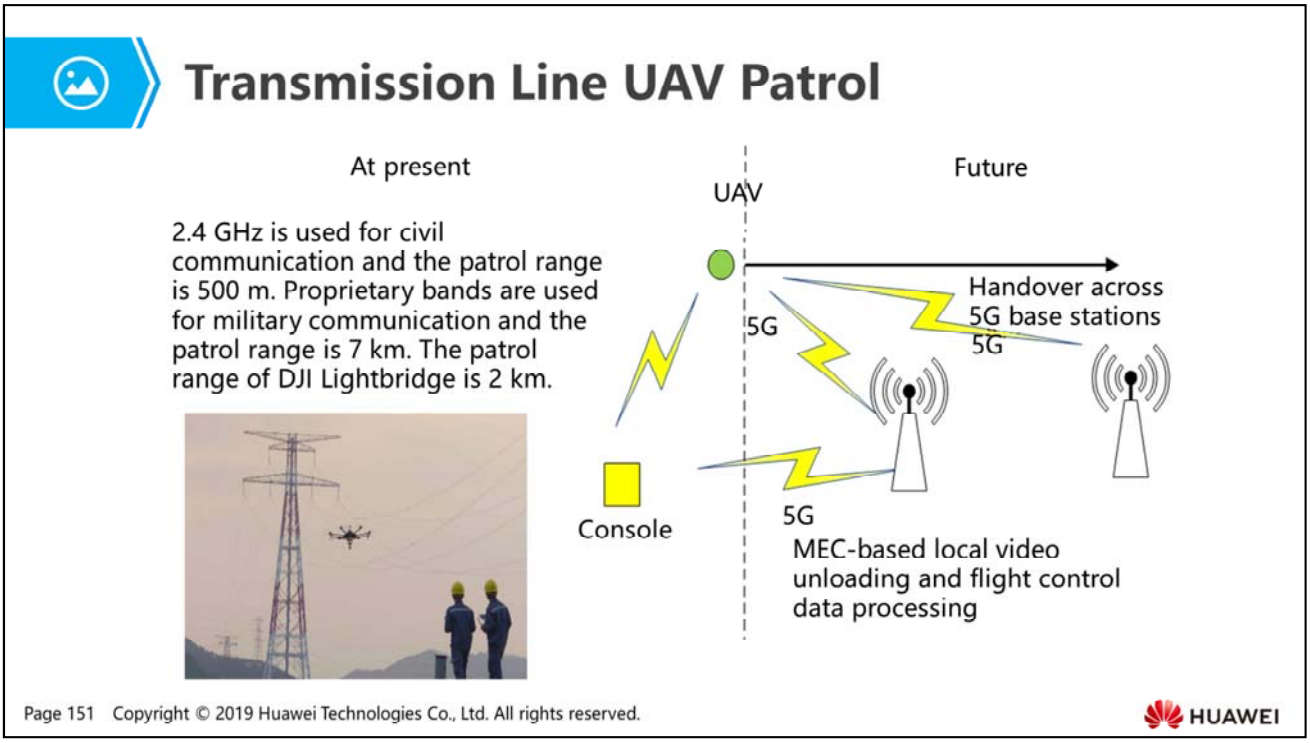



- **Substation patrol robot**: This service is designed to meet the requirements of comprehensive status monitoring and security inspection of primary power supply equipment in 110 kV and above substations. Currently, patrol robots are mainly connected through Wi-Fi, and most of the generated videos are stored in local stations and not uploaded to the remote monitoring center in real time. In the future, patrol robots at substations will be equipped with multiple HD video cameras or environment monitoring sensors to transmit detection data to the remote monitoring center in real time. In some cases, patrol robots can even perform simple live-line working, such as gate switch control.
- **Mobile onsite construction management and control**: In the electric power industry, strong-current operations require high construction security, calling for all-around monitoring of personnel, procedures, and quality at the construction site. In addition, this service also provides remote and real-time decision-making support for emergency situations such as solution changes, as well as fault source tracing and troubleshooting.
- **Comprehensive video surveillance in the power distribution room**: The running status and resources of important nodes (switch stations) in the distribution network are monitored. This service is usually used for power distribution rooms or public places that are relatively concealed. It features centralized and real-time, with service video data collected by terminals in each power distribution room and then centrally uploaded to the video surveillance platform of the power distribution network.




- **UAV patrol of power transmission line**: This service is to check the physical characteristics of power transmission lines across grids, such as bending, deformation, and damage. It is applicable to scenarios with open space and long transmission distances. Generally, the length of a transmission line between two tower poles is from 200 to 500 m, but the patrol range covers several tower poles spanning several kilometers. Typical applications include forest monitoring, ice-endurance monitoring, mountain fire monitoring, and external damage warning.
- **At present**, the detection devices at two ends of a transmission line calculate and determine the line state based on complex monitoring data of cable characteristics, and the data must be confirmed onsite manually. UAV-based patrols are already in use today, but the console must communicate with UAVs using 2.4 GHz Wi-Fi or proprietary protocols, and the patrol is effective only within a 2 km range.
- **In the future**, UAVs can run for a longer period of time and 5G communications modules will become more capable to support MEC-based applications as well as 5G-enabled UAV flight control and image and video communication. UAVs and the console communicate with the nearby 5G base station. MEC services are deployed on the 5G base station side so that videos, pictures, and control data are unloaded locally and then directly transmitted to the console, **ensuring millisecond-level latency and Mbit/s bandwidth**. In addition, the high-speed mobility feature of 5G ensures timely handover when UAVs communicate between adjacent base stations to guarantee service continuity. **The patrol range thereby extends to several kilometers**, and the patrol efficiency greatly improves.

# Quiz

1. In the future, is it possible for the electric power industry to build its own 5G private network to provide wireless signal coverage?

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# Practice

- Design and discuss the strategy of your group within 15 minutes, and then practice it.
- The practice of each scenario lasts for about 30 minutes. After your practice, the observation team and mentor will have about 5 and 10 minutes, respectively, to make comments.


**Role definition**


**Operation group:** Acts as operator X to design and introduce a solution based on customer requirements and persuade the customer to choose the solution.


**Customer group**: Acts as the customer and questions whether the solution meets the requirements or solves the pain points.


**Observation team**: Observes and comments on the performance of the other two groups, and provides constructive suggestions.

 

# Practice 1: Public Safety

| | |
|---|---|
| **Project Background** | Province X lacks police resources and plans to deploy the smart police project. On one hand, the project aims to improve mobile law enforcement efficiency through UAV/AR patrol and 4K video upload from police cars. On the other hand, an integrated command system is to be built with the capabilities of AI facial recognition, AI license plate recognition, and AI video surveillance analysis of the command and video surveillance center.<br>The ultimate purposes include: 1) integrated ground and air patrol in target areas to make up for the shortage and improve efficiency of police resources; 2) change from traditional fixed-point video surveillance to mobile 3D seamless surveillance to better combat crimes; 3) real-time and efficient collaboration of law enforcement actions, real-time report and quick location of suspects through AI facial recognition and comprehensive intelligence command to improve the overall law enforcement efficiency. |
| **Customer Requirement** | 1.<br>2.<br>3. |
| **Practice Scenario** | The operator group learned the preceding requirements from the customer and accordingly designed a 5G solution for the security industry. |
| **Practice Requirements** | Develop a strategy within about 15 minutes based on the case background and customer requirements, and then practice your strategy. You can refer to the content of this course for information. |

 

# Practice 2: Smart Household

| | |
|---|---|
| **Project Background** | The commercial use of 5G will have a far-reaching impact on the smart household industry, considering its strong correlation with the IoT. Functions such as smart household appliances and data transmission for household security accelerate industry privatization. However, the increasing number and types of access devices pose new requirements in aspects such as network response speed, unified device management, and data exchange. Take intelligent security control as an example. Intelligent locks, door status sensors, and cameras play an important role in protecting household security and preventing crimes. They put isolated data together by using multiple sensors through the intelligent household control system. However, households vary in space, residential area, and space layout which often affect network coverage and signal transmission, causing various problems in the use of smart security devices. |
| **Customer Requirement** | 1.<br>2.<br>3. |
| **Practice Scenario** | The operator group learned the preceding requirements from the customer and accordingly designed a 5G solution for household security. |
| **Practice Requirements** | Develop a strategy within about 15 minutes based on the case background and customer requirements, and then practice your strategy. You can refer to the content of this course for information. |

 

# Practice 3: Smart Logistics

| | |
|---|---|
| **Project Background** | In recent years, driven by economic globalization and e-commerce, traditional logistics is rapidly modernizing and becoming a future mainstream. Smart logistics is a key factor that drives the transformation and upgrade of modern logistics. With the promotion and application of 5G technologies, the domestic logistics industry will embrace new development opportunities, and smart logistics presents a positive market outlook. The Chinese government attaches great importance to and encourages innovations in the logistics industry. *Guiding Opinions of the General Office of the State Council on Advancing the Collaborative Development of E-commerce and Express Delivery Logistics* encourages: improvement in science and technology application, use of advanced and applicable technologies and equipment, improvement in automation and specialization of express logistics equipment, and technological innovation and application in drones, UAVs, and unmanned warehouse.<br>In this context, province X plans to deploy the smart logistics project which will encourage logistics enterprises and operators to improve the efficiency of the logistics industry and reduce costs through the low latency, large bandwidth, and massive connection features of 5G. |
| **Customer Requirement** | 1.<br>2.<br>3. |
| **Practice Scenario** | The operator group learned the preceding requirements from the customer and accordingly designed a 5G solution for smart logistics. |
| **Practice Requirements** | Develop a strategy within about 15 minutes based on the case background and customer requirements, and then practice your strategy. You can refer to the content of this course for information. |

 


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