



5G Use Cases for Verticals China 2020



The GSMA represents the interests of mobile operators worldwide, uniting more than 750 operators and nearly 400 companies in the broader mobile ecosystem, including handset and device makers, software companies, equipment providers and internet companies, as well as organisations in adjacent industry sectors. The GSMA also produces the industry-leading MWC events held annually in Barcelona, Los Angeles and Shanghai, as well as the Mobile 360 Series of regional conferences.

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Founded in 1957, the China Academy of Information and Communications Technology (hereinafter referred to as CAICT) is a scientific research institute directly under the Ministry of Industry and Information Technology (MIIT) of China. It cherishes the cultural philosophy of "boosting prosperity with virtues and expertise" for years while adhering to the development positioning of "a specialized think-tank for the government and an innovation and development platform for the industry". Committed to "the think-tank and enabler for innovation and development in an information society", CAICT has provided strong support for major strategies, plans, policies, standards, tests and certification for the development of the national ICT sector and the IT application, thus proving itself an important facilitator in the leapfrog development and innovation of China's information and communications sector. It has been granted hundreds of scientific and technological awards at both national and provincial levels.

In recent years, with a view to adapting to the new eco-social backdrop and requirements, CAICT has strengthened its efforts in innovation to achieve wider and deeper research landscape. It has conducted in-depth research and foresighted planning in the fields of 4G/5G, industrial Internet, smart manufacturing, mobile Internet, Internet of Things (IoT), Internet of Vehicles (IoV), cloud computing, big data, blockchain, artificial intelligence (AI), future networks, virtual reality/augmented reality (VR/AR), intelligent hardware, and cyber and information security. This enables CAICT to play an important role in strategy and policy study, technological innovation, industrial development, and international cooperation related to the ICT sector and the integration between industrialization and informatization.

Thanks to contributors of report:

- China Telecom
- China Mobile
- China Unicom
- Huawei
- ZTE
- Ericsson
- Nokia Shanghai Bell
- Datang Mobile
- Migu
- Haier

*and other industry partners, not listed one by one here.

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Foreword

The mobile industry in China has made significant progress, with its tireless efforts in the development of 2G, 3G, and 4G technologies, and gone from a follower to a pioneer in 5G. The development of 5G in China and its impact to the global mobile ecosystem are also attracting great attention. According to latest forecast from GSMA Intelligence, by 2025, 411 operators will have launched 5G commercial services for 1.6 billion subscribers in 119 countries and territories. China will account for nearly 45% of the total number of subscribers and become the world's largest 5G market.

A GSMA survey of more than 2,000 member executives suggested that the success of 5G would rest on its comprehensive integration with vertical industries. For mobile operators, the total value of the global addressable 5G-enabled market is forecast to be USD 700 billion in 2030. The key for the mobile industry to capitalise on this tremendous potential will rely on its ability to better serve verticals with 5G and to create new value and innovative services beyond connectivity.

Since China's 5G commercial launch in 2019, mobile operators, verticals, and technology companies have been working even more closely together to explore 5G use cases in vertical industries such as industrial manufacturing, transportation, media, and logistics, and to empower their digital transformation. In conversation with many of our partners, we realised that the development of 5G vertical use cases is likely going to be a long journey that demands varying phases and priorities. Identifying scenarios, establishing standards, and joint innovations are key factors to 5G's success with verticals, but patience and persistence are as important for us in our efforts to better understand their evolving needs and requirements.

The 5G Use Cases for Verticals China 2020 report is comprised of 15 outstanding examples of 5G-empowered applications for verticals, ranging from industrial manufacturing, transportation, electric power, healthcare, education, to content creation, and zooms into the practical scenarios, technical features, and development opportunities for the next generation technology. Every use case represents the relentless efforts of 5G pioneers who are open, cooperative, and innovative. I hope that the scenarios, experiences, and reflections from the report will inspire and enlighten the journey to empower more vertical industries with 5G.

The global economy is embracing new growth drivers as the 4th Industrial Revolution gains momentum. From 1G to 4G, and the mobile industry has now entered the era of 5G. This emerging technology will expand mobile Internet to mobile Internet of Things, closely integrate with society and economy, form critical infrastructure for the comprehensive socio-economic development, nurture new economic drivers, shape new governance models, and improve inclusion for all.

5G converged application is a new concept, and we need to explore new products, models, and forms of business. In 2018 and 2019, China Academy of Information and Communications Technology (CAICT) and IMT-2020 (5G) Promotion Group jointly held two successful "blooming cup" 5G Application Competition targeting innovative 5G applications from both enterprises and individuals to explore talents, facilitate industrial transformation, explore and foster valuable 5G applications. The contest has been well recognised by stakeholders, and in 2019 it received 3,731 entries. It ignited a wave of 5G innovations across the industry that brought many new products and business models.

The 5G Use Cases for Verticals China 2020 report brings together 15 excellent 5G use cases, including some outstanding examples from the competition. I hope that these cases can guide and inspire those who are engaged in 5G and its applications, and spark more innovative ideas. Further efforts are needed for the development of 5G converged applications, and the CAICT is willing to collaborate with stakeholders globally to drive an innovative and thriving 5G ecosystem.



Sihan Bo Chen
Head of Greater China, GSMA



Wang Zhiqin
Vice President, CAICT

Flexible Smart Manufacturing with 5G Edge Computing



5G is born for Intelligent Connectivity and “Internet of Things”. Ericsson is an active player in the development of 5G technologies and products, standardisation, and industry promotion. The RoboTechnik project is an innovative joint project among Ericsson, China Mobile Jiangsu branch, and the vertical industry partner, RoboTechnik, in the field of 5G smart manufacturing. We hoped that through our joint efforts, we would be able to identify potential value of 5G for vertical industries, improve our end-to-end 5G products and solutions, cultivate industry partners and explore competitive business models, and improve our service and delivery capabilities for verticals. Significant progress has been made in those areas since the commencement of the project.

Dr. Chen Ming
CTO, Mobile Business, Ericsson China

SOLUTION PARTNERS



OVERVIEW

RoboTechnik is a specialised smart manufacturing solution provider which is committed to making industrial manufacturing more flexible, smarter and more efficient through the use of innovative technologies. It provides smart manufacturing systems for photovoltaic, automotive electronics, electronics and semiconductor, food and pharmaceuticals sectors among others. Their solutions cover smart automation equipment, smart monitoring equipment, smart storage equipment, smart material transfer systems, and smart manufacturing execution systems.

Robotechnik held several discussions with China Mobile

Jiangsu and the Ericsson Industrial Research team, and agreed that transforming smart factories using 5G networks was the way of the future, and that 5G technology can unleash the potential of high-speed wireless connection in the manufacturing industry, and significantly empower smart manufacturing.

On Nov.18th, 2018, China Mobile Jiangsu, Ericsson and RoboTechnik (Suzhou) signed a strategic cooperation agreement to jointly explore collaborations for 5G industrial applications, and to establish a prototype of small-scale discrete manufacturing line at the



Smart material transportation

Providing stable and reliable wireless connection for AGVs and smart docking stations; increasing the stability and reliability of AGV movement and increasing production line deployment flexibility



Automation of precision electronic processing in automobiles

Providing communication links for AGVs in precision electronic processing equipment for automobiles and implementing automated production and production visualization via the real-time data interaction between the Manufacturing Execution System (MES) and Robot Management System(RMS)



Smart image quality inspection

5G networking is used to upload images taken with cameras to the edge cloud. After inspection on the cloud, the results are sent to the control node and the silicon wafers are sorted according to their quality grades



Patrol robot

AGVs are equipped with high-definition cameras and records the factory environment in real-time while moving around. The video is sent back to the monitoring center in real-time so that the factory workshop environment can be monitored remotely. This effectively reduces labor costs and improves management efficiency.

RoboTechnik plant in Suzhou, Jiangsu Province towards a full 5G-enabled smart plant. The prototype plant planned to install a 5G network to replace the fixed lines and WiFi connections at the operational layer to make the equipment more intelligent and facilitate transformation of the industrial applications to the cloud, in order to achieve flexible and smart manufacturing.

The project was implemented in phases. In Phase I, it

completed the technical verification of cellular connectivity alternatives to WiFi and fixed networks; in phase II it deployed a private 5G enterprise network and connected all equipment in the plant; in Phase III, it completed a 5G-enabled flexible production line of solar equipment, and explored innovative applications and services, such as cloud-based AGVs & quality inspections, to further empower downstream photovoltaic manufacturing companies.

CHALLENGES

The manufacturing industry in China recognises the need to upgrade and transform legacy technologies and business models through digital, intelligent, and flexible production techniques. A survey taken by over 100 industrial enterprises identified the following challenges in the transformation of manufacturing companies:

- Connectivity: fragmented network interfaces & protocols, lack of sectoral integration and interoperability
- Flexible production: difficult to increase production flexibility due to fixed networks; lack of reliability and coverage from industrial WiFi; legacy networks couldn't support the required levels of high bandwidth and low latency
- Data collection and control: ineffective data collection, in

situ controls, inefficient interoperation between equipment.

5G serves as an important enabler for smart manufacturing transformation. Combined with cloud computing, big data and artificial intelligence, it can help enterprises achieve smarter production, smarter management and more flexible production, while at the same time connect people, machines and equipment into a unified and interconnected industrial network. With the introduction of new technologies such as 5G edge computing and network slicing, mobile operators can provide industrial customers with a new generation of converged infrastructure that is more flexible and more secure and solutions that are lightweight, easy to deploy, and easy to manage to help them more easily migrate to flexible, automated and intelligent productions.

SOLUTION

A private 5G enterprise network was built by China Mobile Jiangsu and Ericsson for RoboTechnik. Ericsson 5G enterprise-grade mobile communication products can be customised to provide a comprehensive network solution that meets the specific needs of different customers, sectors and levels, and satisfies mobile operators' requirements to simplify network management, optimise investment, and reduce deployment complexity.

The project fully utilised the strengths of 5G technology in the designed scenarios, such as smart AGV scheduling and fault and emergency response which required the end-to-end latency to be maintained at millisecond-level. In this project, the air interface latency in user plane was reduced from 20ms to 4ms and could be further reduced using an edge network to satisfy the needs of critical service such as scheduling. At the same time, the 5G network's high speed capability was utilised to support real-time recognition and processing of high-definition images. Typically, a 20Mbps uplink bandwidth would be needed for real-time video upload from a single camera; an uplink of over 100Mbps for real-time VSLAM 3D map reconstruction; and dozens or hundreds of megabytes per second (depending on the resolution of the CCD) uplink for CCD quality inspection, all of which require highly reliable and stable connections that are difficult to be achieved by existing industrial wireless technologies.

The project is innovative in four aspects:

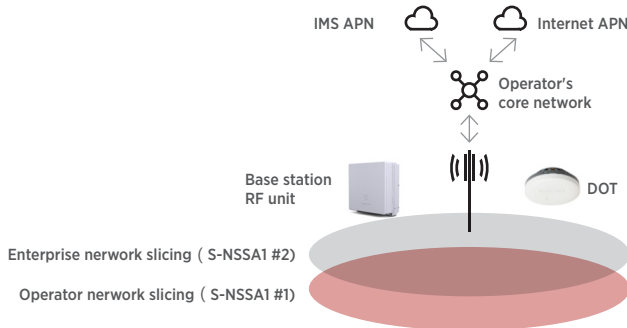
- Convergence of Information Technology, Communications Technology and Operations Technology
- Implementation of 5G edge computing to support lower latency, local data breakout and management
- Decoupling of software and hardware; centralised intelligent industrial control centre and localised mechanical operations
- Interconnected and interoperable applications.

The project not only focussed on innovations on technologies, but also on business and collaboration models. RoboTechnik, as a smart manufacturing solutions provider, is serving customers from electronics, machinery, automotive, new energy and many downstream industries. The three parties could join hands to accelerate the implementation of 5G in manufacturing for other stakeholders. China Mobile Jiangsu also leveraged the opportunity to enhance its service capability in maintenance & operations and value-added data offerings.

Through the pilots conducted with multiple partner companies, this project achieved a 30% increase in production efficiency and a 40% reduction in labour costs. At the same time, it helped companies to effectively improve their yield rate and product quality.

01 Enterprise private network

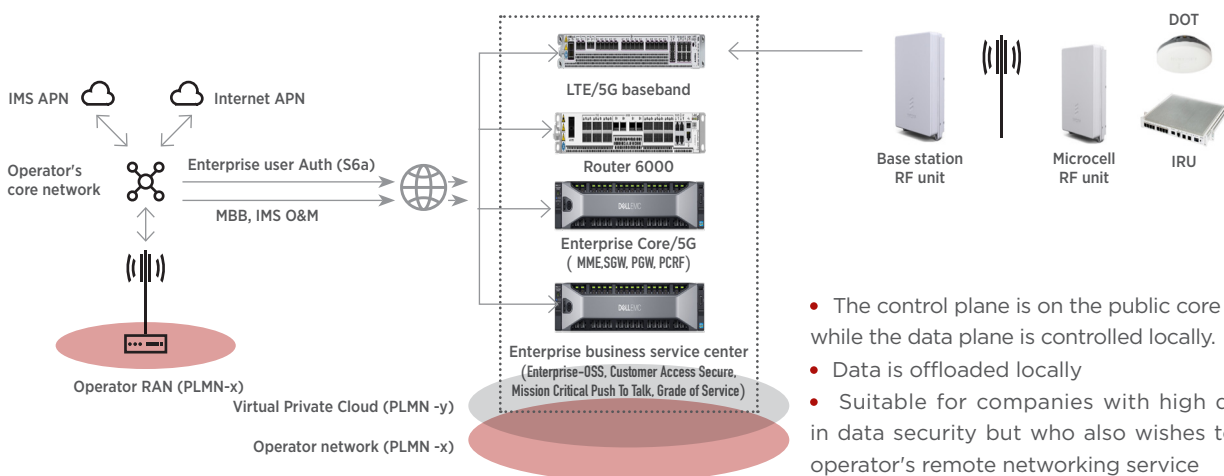
All networks are locally independent



- All network elements are deployed locally in the company. Isolated from operator networks
- Suitable for companies that require complete control and management of data and their own network

02 Enterprise virtual private network

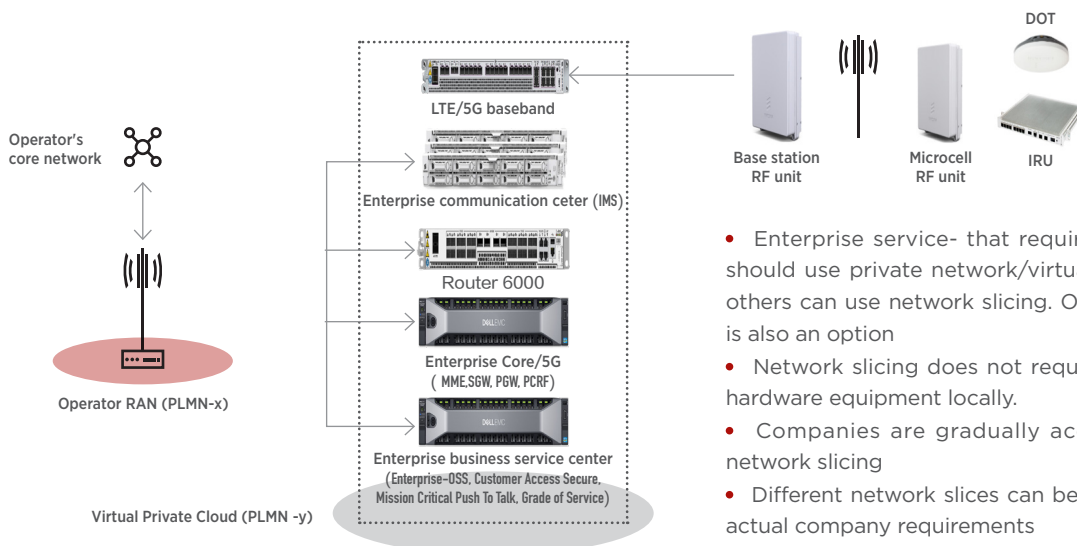
Public and private network use the same base station infrastructure



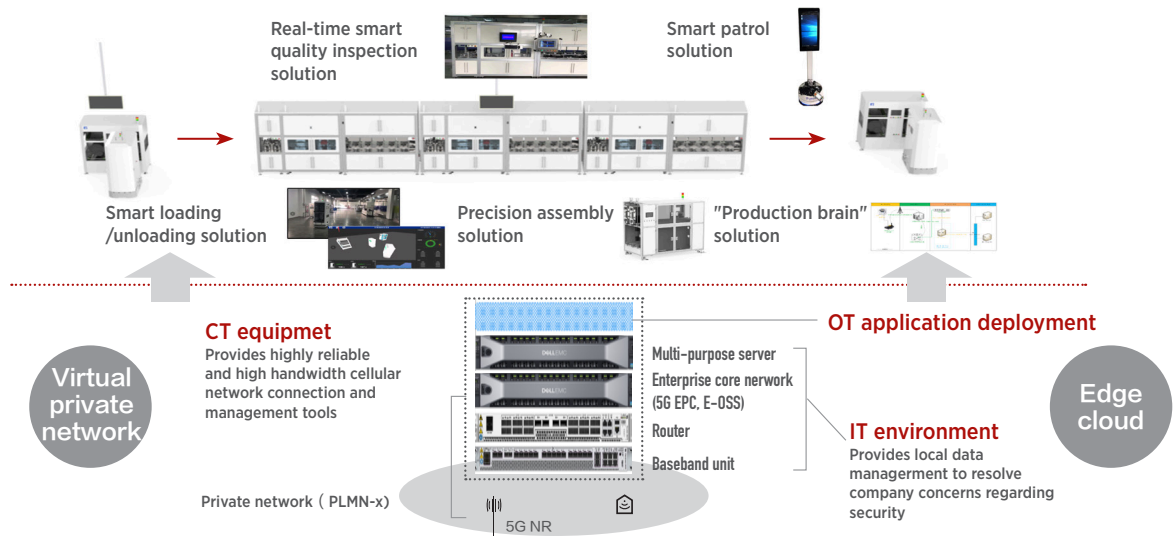
- The control plane is on the public core network, while the data plane is controlled locally.
- Data is offloaded locally
- Suitable for companies with high demands in data security but who also wishes to use an operator's remote networking service

03 Hybrid network

Network slicing + Private network/virtual private network hybrid



- Enterprise service- that require high security services should use private network/virtual private network, while others can use network slicing. Only using network slicing is also an option
- Network slicing does not require companies to deploy hardware equipment locally.
- Companies are gradually accepting the security of network slicing
- Different network slices can be configured according to actual company requirements



REFLECTION

After more than one-year's pilot, we are now very confident that 5G is the best wireless technology that can help manufacturing plants to enhance its intelligent operations in production, management, and control system iteration, as well as the integration of OT & IT systems enabled by its advanced features of high bandwidth, reliability, low latency and mobility. As we now are moving towards Industrial Internet, security and reliability are the most important factors for enterprise. Using enterprise private network as an entry point, we replaced the fixed network with wireless, WiFi with cellular, and took advantage of new technologies including 5G edge computing and network slicing, so that we can build a multi-purpose network, unified infrastructure of cloud and network convergence, and better utilise mobile operators' specialised experiences in communications to provide more tailored and competitive services.

Enterprises can pick and choose operator cloud and network resources on demand to become more flexible, agile in their transformations towards flexible manufacturing, automated productions, and wireless migration:

- Migrated "Fixed Network + WiFi" based Industrial network to a 5G-enabled private industrial network, which mitigated the challenges for the IT department of cable wiring and equipment placement to enable better connectivity for the increased number of IoT devices for flexible productions
- Centralised computing capabilities for some in situ equipment, such as AGVs, computer vision inspection and VSLAM modelling. Achieved coordinated scheduling and faster migration based on 5G edge cloud
- Implemented 5G-enabled industrial AR, factory floor inspections and other scenarios.

We have also learnt the following over the course of the project implementation:

- Training is very crucial for customers to implement 5G in the factories, the more traditional the customer, the longer time is needed. RoboTechnik is responsive to new

technologies and is able to quickly form the partnerships. When we choose the partners for industrial application transformation, it is important to pick those with active attitude and who are more open-minded to new technology

- China Mobile Jiangsu, Ericsson and RoboTechnik worked together on an innovative 5G cloud AGV solution, upgrading from the localised laser inertial guidance to V-SLAM cloud AGVs that used centralised dispatch and navigation guidance using 5G edge computing, making 5G the "internal control bus". AGV development focussed on the cloud side rather than the hardware of the AGV itself, which greatly reduced the difficulties facing AGV development & migration, and significantly enhanced the centralised control capabilities. The cloud AGV solution has been recognised and purchased by other customers
- Factory equipment on the fixed network were segmented based on the types of communication used. The interactions between the PLC and I/O, sensors, actuators etc within each equipment are internal communication which may need extremely low latency and a wide range of protocols. Communication latencies between equipment stations and external systems are controllable and can be scaled up using 5G
- The 5G terminal ecosystem is yet to mature, and impacted project implementation to a great extent. Patience is required for the development of the ecosystem for 5G industrial terminals.

Going forward, as 5G technology and ecosystem continue to mature, they will bring more disruptions and implications:

- Explore the possibility of standalone 5G private network to support the real-time automation scenario;
- Explore network slicing capability of standalone 5G private network to achieve multi-purpose networks and security segmentation for industrial control network, complementary industrial control systems, video surveillance networks, visitor WiFi, and corporate network and etc.

5G Smart Campus in Haier Tianjin Washing Machine Factory



The Haier “Internet of Clothing” washing machine factory is our pilot for smart manufacturing in the 5G era. In homes of the future, we believe that there will be explosive 5G-enabled innovations and practical use cases that will redefine the smart home experience!

Li Yang
Vice President, Haier Smart Home

SOLUTION PARTNERS



OVERVIEW

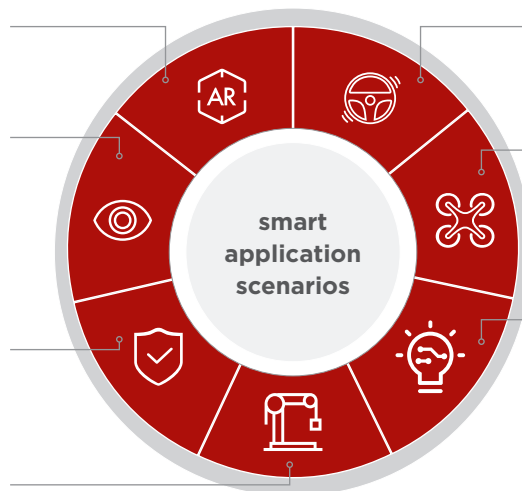
The Haier “Internet of Clothing” Washing Machine Factory is Haier’s 15th “interconnected factory” globally. Based on Haier Group’s innovative “Internet of Clothing” philosophy, latest information and communication technologies such as 5G, artificial intelligence, and cloud computing are integrated into the factory production and field operations to enable a variety of applications, such as in-factory production quality inspection, production safety monitoring, warehouse logistics, and equipment remote control. These innovative efforts are paving the way for a true 5G+cloud enabled smart factory.

AR remote instruction for frontline workers to resolve technical difficulties

AR operations guidance for standardised quality inspection process

Health and safety conformance checks of protective equipment and gear for automated production line workers

Computer vision inspections for raw materials and quality control at every checkpoint of the production line



Unmanned forklifts for transportation of finished products

Unmanned patrol vehicles and drones for security management and comprehensive security coordination on campus

Smart manhole covers, smart trash cans, smart lamp posts, smart parking, and smart smoke detection equipment for campus management.

The aforementioned smart application scenarios are all connected to one cloud-based centralised 5G factory management platform to enable unified access platform, protocols, management and visualisation. The project was initiated by Haier Industrial Intelligence Institution (Qingdao) (China’s first internet-based research institute for industrial intelligence) and in collaboration with China Telecom Tianjin, which signed a strategic cooperation agreement on Sep 26, 2019 together with Haier for the establishment of a new pilot 5G innovation facility focused on smart manufacturing at the Tianjin Haier Washing Machine Co., Ltd.

SOLUTION

01 5G network coverage of production line for flexible manufacturing

Manufacturing enterprises increasingly need to modernise their existing production methods in order to better satisfy diversified and bespoke requirements from different markets globally, which is evident of a global trend to move towards flexible manufacturing techniques.

5G presents unparalleled advantages for a manufacturing factory, which allow unconstrained movement of robots, their uninterrupted operations and smooth provisioning under highly reliable contiguous network coverage while reducing cable costs between machines. In a factory setting, different production scenarios require different network requirements, and 5G end-to-end network slicing technology can support different QoS levels within the same core network and be adjusted based on varying needs. 5G can also support a comprehensive information ecosystem connecting people and machines inside and outside of the factory towards an ultimate goal of seamless information sharing between people

and machines anytime and anywhere. Production scenarios often involve inter-factory and cross-regional maintenance of equipment and remote troubleshooting. The application of 5G technology in these areas can help improve efficiencies in operations and maintenance, and reduce costs.

China Telecom provided 5G coverage on campus to satisfy specific network needs across different areas of the campus. The 5G coverage planning took into account both indoor and outdoor requirements, whereby outdoor coverage was mainly focussed on exposed areas while indoor coverage on internal-drum production, lab areas, and packaging areas.

Four 5G coverage sectors are planned for the outdoor area with the actual downlink at 1Gbps and uplink at 100Mbps which are sufficient for the needs of UAV and AGV transportation within the factory.

Coverage solution for the indoor laboratory zone

A distributed PRRU network was used to achieve desired coverage. As the walls were clad in metal sheets, PRRUs were deployed indoors to satisfy the laboratory's needs for high-speed data transmission;

Coverage solution for the indoor packaging zone

The area is mostly open space, and a distributed PRRU network was deployed with reference to legacy WiFi AP installations. This solution enables the unmanned forklifts to automatically pick up the finished washing machine products from the inventory and subsequently place them in the designated areas using visual analysis.

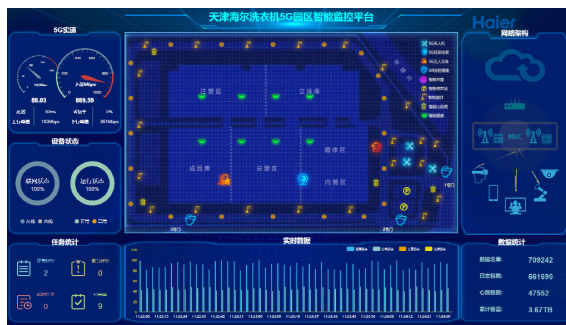
Coverage solution for the indoor machine drum production zone

Four AAU equipment were deployed along both sides of the production line to ensure coverage. This helps to meet factory maintenance workers' needs to communicate with foreign experts at any time using AR glasses as well as to quickly conduct visual inspection of stamped steel plates.

02 Establishing a central monitoring platform

The big data platform for aggregation of business data is deployed on China Telecom's E Cloud, comprised of 14 servers in total.

The platform has been designed to show relevant information from respective 5G applications in the interconnected Haier washing machine factory, and to achieve comprehensive smart monitoring and supervision. It is capable of real-time tracking and detection, image comparison analysis, big data, statistical analysis, and alert & warning using a large installation of IoT and video devices. It ensures system reliability by adopting mature open-source SSH technology with frontend-backend separation and integrating open-source technologies including Spring, SpringMVC and Hibernate with the backend JAVA.



03 Modification of unmanned forklifts

Home appliances don't typically have bottom plates and the movement of which are performed using pick-up clamps on the sides. However, most unmanned forklifts on the market today only come with forks to lift from the bottom of products. The interconnected Haier washing machine factory modified the normal unmanned forklifts by integrating side clamps with the traditional unmanned forklift. The modified forklifts, together with normal ones, greatly improved safety management and efficiency for the storage and transportation of finished goods within the factory. This is an excellent example of how the use of logistics automation and smart logistics can help a factory modify its existing forklifts to meet new needs.

04 5G+AR Use Cases

The interconnected Haier washing machine factory in Tianjin piloted 5G + AR technologies widely in multiple scenarios such as security inspection, remote instruction, and task guidance, thus providing a practical test bed for scaled use of the technologies in the future and the verification of innovation pilots in real operating environment.

REFLECTION

01 Expand integration of edge computing and establish an coordinated cloud-edge-terminal architecture

Edge computing architecture will be integrated into cloud platform in the future to achieve provisioning, monitoring and management of edge nodes. This can mitigate the challenges from the lack of responsiveness and bandwidth, and high energy consumption in traditional cloud platform.

02 Increase modularisation of equipment trigger-response framework to enable customisable configuration

Different scenarios present different requirements for communication between equipment. At the same time, the diversity of devices, complexity of data involved, and varying downlink protocols mean that there is no common framework for the complex logics between trigger conditions and responses.

More efforts should be made to modularise equipment data structures for different scenarios and equipment to allow more easily customisable configurations for trigger-response requirements.

03 Configurable user interface for easy customisation

The system is capable of accommodating multiple smart systems, but users' preferences to the dimensions of data, types of information, and format of displays vary from scenario to scenario. There is already a comprehensive

set of API documentation to allow customisation of UI displays, but that would need specialised front-end development and is unable to allow flexible mix-and-match configurations.

In the future, easily configurable US displays for monitoring centre will be developed together with a data display module "warehouse". APIs will be further opened up so that a user will be able create various combinations of smart systems quickly and easily.

04 Evolution of usage scenarios and innovation in technologies

We will continue to develop new scenarios for quality inspection and production safety, connect various application scenarios through a consolidated platform, and standardise solutions. These efforts will provide best practices and experiences for industry colleagues in their transformation to intelligent productions. We continue to optimise machine learning and autonomous driving algorithms towards industrial grade performance which will reduce response time into the seconds range

Practical scenarios are key to the implementation of 5G for industries. We should not innovate simply for the sake of new technologies. We have learnt that it is an effective way to implement 5G in a phased approach. Start with small problems, extrapolate to more general issues, and then promote to wider industry for their benefits is our mission.

Aircraft Surface Inspection with 5G and 8K at Commercial Aircraft Corporation of China



Commercial Aircraft Corporation of China (COMAC) is committed to develop 5G-based smart large-aircraft manufacturing system and demonstration plant that would reshape processes, production, quality control, and logistics by 2021.

WANG Shunli

Deputy Secretary of the General Party Committee Branch of COMAC Shanghai Aircraft Design and Research Institute and Head of the Smart Plant department

SOLUTION PARTNERS



CHALLENGES

Surface quality inspection is required in the manufacturing of aircrafts, trial flights, and routine operational maintenance. Typical inspection scenarios include surface feature position inspection, surface defects detection, and critical component installation status check during aircraft assembly; inspection of defects such as blisters, wrinkling, drips, and missing paint surface during painting; and routine surface maintenance inspections during operations.

Manual inspection

inefficient and reliant on experts

At present, most inspections are carried out by manual visual inspection, which are inefficient and prone to inaccuracies. However, due to the large size of the aircraft, heavy inspection workload, complex aircraft exteriors, stringent accuracy requirements, and complex inspection environments, as well as various technical problems such as the inconvenience of cabling, difficulty in image transmission, low inspection efficiency, and lack of accuracy, machine vision inspection has not been widely used in the inspection of aircraft surface.

Wiring

hard to implement while slow in transmission

The emergence and application of 8K ultra-high resolution industrial cameras have been an answer to the challenges of large inspection areas and high accuracy. However, with a large volume of data involved, tens of meters of wiring are required for data transmission during inspection or for offline storage, which makes it difficult to upload this data to the cloud for analysis, and eventually leads to inefficiency and slow response time.

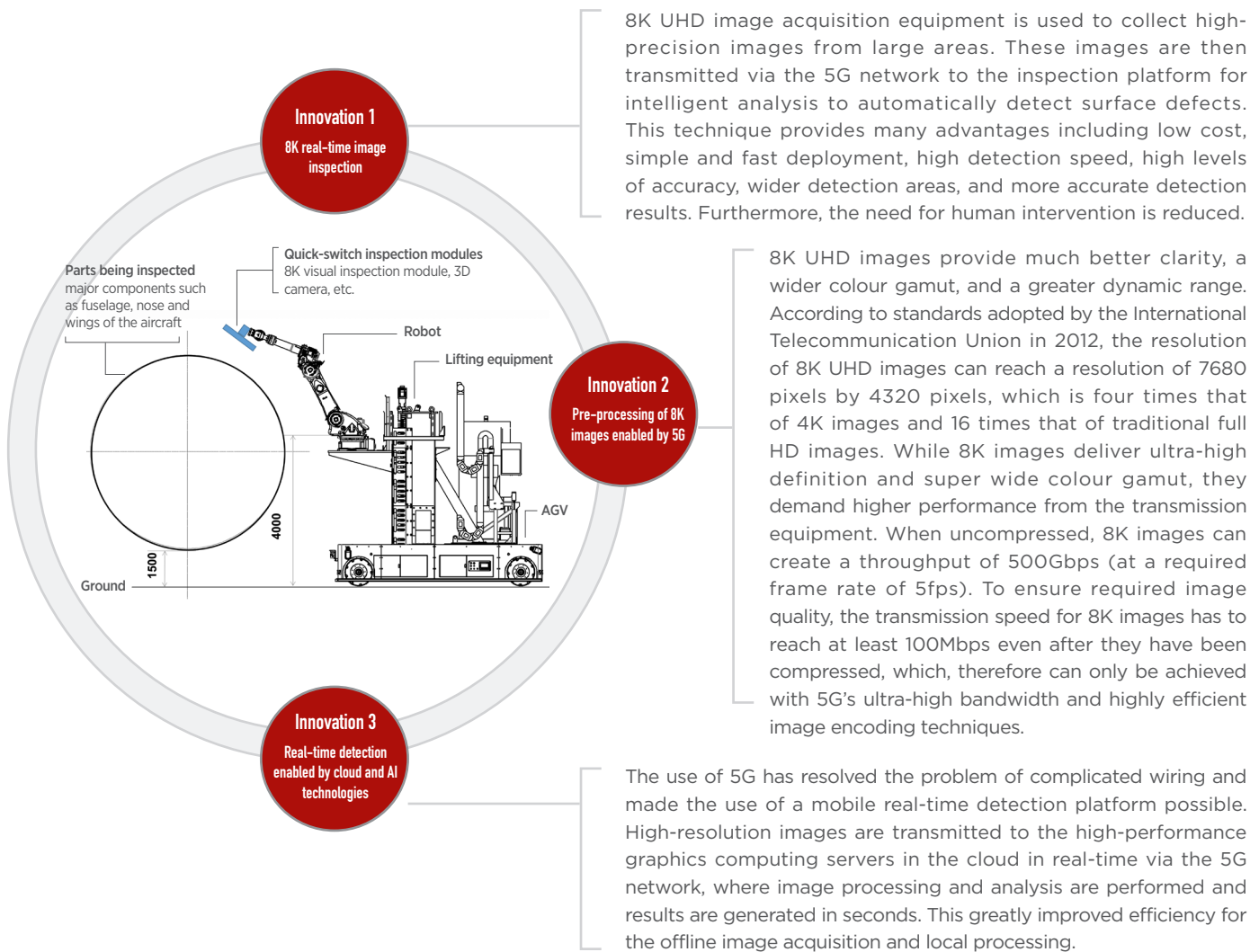
SOLUTION

In response to the pain points and difficulties encountered during the process of aircraft surface inspection, COMAC combined the capabilities of 8K ultra-high resolution imaging, high precision machine vision with high-speed 5G technology to create a 8K ultra-high resolution aircraft surface quality inspection system. It is mobile, flexible, highly precise, highly efficient, and tailored to the needs of aircraft surface inspection.

The system team focused its innovation efforts on the

following few areas:

- 8K ultra-high resolution image encoding and decoding technology; deep concurrent optimisation, quality optimisation, and concurrent bitrate control techniques for real-time ultra-high-definition (UHD) image encoding algorithms
- 8K image transmission techniques using 5G
- Defects detection techniques using artificial intelligence



REFLECTION

8K ultra-high resolution aircraft surface quality inspection system based on 5G has the potential to be adopted more widely, such as for surface inspection in all stages of aircraft manufacturing and operation, which could bring significant benefits to the global aviation industry:



Improved manufacturing efficiency

As there is no longer a need to ready and use industrial climbing equipment for inspection during the manufacturing process, it can increase inspection efficiency by over 3 times with reduced inspection time and automated inspection process. It also brings valuable improvements to passenger operations, including significantly reduced maintenance periods, increased aircraft turnaround, more efficient utilisation of airport space, and overall efficiency gains for airlines, airports and the aviation industry.



Cost reduction

Labour costs are reduced as the system could be operated by only 1 person, saving at least 2 quality inspectors from each production line. Furthermore, production efficiencies are improved by the reduction of time needed for acceptance inspections, which lead to better economics for aircrafts.



Improved inspection quality

All inspection results are objective, quantifiable and traceable, and the inspection coverage rate can reach over 90%. For the manufacturing process, it can reduce points of failures at delivery, improve product safety and user satisfaction; for passenger operations, it can improve the quality of scheduled inspections.

Xinfengming Group's Smart Factory Based on MEC Technology



In the first year of the 5G era, we have been fortunate enough to become a pioneer for China Mobile's 5G applications. We have been able to verify the strengths of 5G in areas such as data acquisition, connectivity, and computing performance. We look forward to further development of 5G applications, which will in turn drive deeper integration of "Business + Management + Technology" and demonstrate successes in digital transformation and high-quality development for the synthetic fibre industry.

WANG Huicheng
CIO, Xinfengming Group

SOLUTION PARTNERS



OVERVIEW

Xinfengming Group is a large-scale business focussing on polyester manufacturing, spinning, fibre texturizing, import and export. It ranks the second in the global polyester filament industry.

In 2019, ZTE and China Mobile Jiaying teamed up to provide Xinfengming Group with a comprehensive digital solution for the Group's filament production operations, taking advantage of large bandwidth, low latency and "Big Connection" features of 5G. It includes applications such as unmanned IGV, 8K high-definition smart monitoring for factory floor, machine vision + 5G + AI "piaosi"/"piaozha" detection, and 5G wireless data information collection. Empowered by 5G technology, Xinfengming Group has been able to enhance its production management capabilities, production efficiency, and product quality.

CHALLENGES

The global synthetic fibre industry has entered a critical phase of digital transformation, and their challenges related to connectivity include:



Traditional networks are not able to meet low end-to-end latency, high stability and reliability requirements from factory equipment.



Complicated networking structure; high costs of wiring, operations and maintenance; and a lack of safety management capabilities.



Traditional network approaches could not keep up with a number of operations in the factory, in particular certain video services (such as HD video surveillance and machine vision operations) that require high bandwidth.

The digital transformation of smart factories therefore needs a simple and easy-to-deploy network that satisfies industry's needs for high bandwidth, low latency, and high reliability to connect factory equipment and enable intelligent production and operation.

SOLUTION

The use of 5G for equipment communications in polyester factories not only brought significant improvements in terms of bandwidth, latency, and security of the factory network, but also promotes further integration of factory equipment with 5G terminals and networks, thus driving a transformative impact to the ecosystem of factory applications. Factory equipment vendors will also help drive the development of 5G ecosystem by upgrading applications with 5G features and shift to produce 5G-ready products.

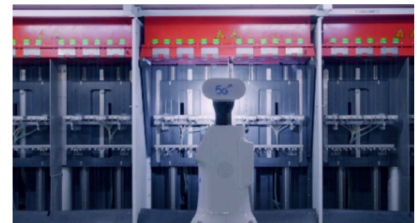
01 5G-enabled mobile HD video surveillance

Safe production on the factory floor is facilitated by a variety of camera equipment. Mobile IGVs fitted with cameras can provide real-time monitoring to ensure safe production. Video data from the cameras is then uploaded to Xinfengming's video processing centre through the local 5G MEC network, which ensures the security of enterprise data and avoids data leak at external data centres. Applications that need video data can access it from the video processing centre, which removes the need for the previous private 4G network and improves efficiency. 5G-enabled mobile HD video surveillance can be deployed at a low cost on demand and provide surveillance service on the move. The use of MEC has helped to achieve local data distribution to ensure security of enterprise data while improving production safety in the factory.



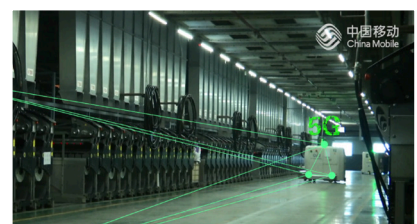
02 Detection of “piaosi” and “piaoza” in real time

The longstanding challenges of “piaosi” and “piaoza” have caused significant losses to the chemical fibre industry every year. Xin Fengming's core product is filament, which is made of hundreds of micron-level fibres spun up at a speed of 4,000 meters per minute. “Piaosi” are fibres that have drifted away from the track when they are being fed to the machines. “Piaoza” are those fibres that have drifted to a nearby track. The main challenges here are the speed and width of those fibres which are fed into the machines at a speed of kilometres per minute. We mitigated these challenges by the uses of inspection robots and 8k high-definition cameras that return data for AI processing through the 5G network. This project has filled the gap in this field, and helped to accelerate the application of 5G + MEC technology in the chemical fibre industry. The 5G network provides an uplink bandwidth of over 100Mbps (allowing for the use of 8K HD images) and ultra-low latency that enables the “piaosi”/“piaoza” detection process, improves product quality, and helps to resolve those challenges faced by the industry.



03 Unmanned IGVs

IGVs move a large volume of fibre cakes on the factory floor. The deployment of the 5G network has made it possible for unmanned IGV operations with smart dispatch control. Under the 5G network, unmanned IGV operates with greater stability, improved transport efficiency, and facilitates safer production. Compared to traditional WiFi solutions, the use of 5G greatly reduced disconnection rates from IGVs and reduced control latency to less than 10ms.



04 5G wireless data information collection

There is a large amount of sensor data from factory operations that needs to be transmitted back to the data centre where the data is used to determine if the status of the production process. The 5G network with its high bandwidth and low latency capabilities replaced the traditional fixed network, and enabled real-time transmission of sensor data to the data centre. This has helped to reduce costs of wiring and maintenance, shorten the engineering turnaround, and improve the efficiency of data collection.

Following the deployment of the 5G network, there has been a great improvement to network performance, such as higher uplink bandwidth of 100Mbps, latency of less than 20ms, and increased number of connections. It has facilitated further improvements to the software architecture, use of AI, and big data, the establishment of the MEC platform, and upgrades to modules and terminals in IoT equipment. It also helps operators explore new business models through the end-to-end network slicing solutions deployed at the factory.

REFLECTION

Over the course of project implementation, legacy 4G, WiFi and fixed networks were replaced with a 5G network, and services migrated to this new network. At present, we are still in the initial stages of 5G application with deployment and trials at one workshop. The current focus is on the ongoing deployment of 5G network coverage and pilot 5G applications, and further considerations are required:

It will be a gradual process for industry stakeholders to recognise the benefits of 5G, and this could be supported by practical use cases and applications

Industry stakeholders require not only technical solutions such as MEC and network slicing, but also low-cost, cost-effective commercial 5G business models.



The development of 5G requires cooperation across the supply chain. At present, 5G modules have not yet been commercialised in a large scale, which limits the adoption of new 5G services.

In the future, the project will gradually replace legacy networks with 5G across the factory to enable more efficient communication between equipment, multi-channel video feeds, highly automated and intelligent operations that will pave the way to a “Dark Factory”. The integration of 5G into production processes will empower new solutions for the chemical fibre industry and new possibilities for fully intelligent factories.

SANY Heavy Industry 5G and Smart Manufacturing



SANY Heavy Industry 5G and Smart Manufacturing

SANY Group Co. Ltd has collaborated with its partners during the inaugural year of 5G to jointly develop 5G smart manufacturing applications that showcased the revolutionary impacts of 5G to industrial production. In the future, we look forward to in-depth integration with 5G technology, and using digital-centric thinking to create new business models and ecosystem, driving high-quality development of the entire industry, and promoting the digital transformation and upgrading of China's manufacturing industry.

Dai Qinghua

Director of SANY Group, Senior Vice President of SANY Heavy

SOLUTION PARTNERS



OVERVIEW

Founded in 1994 by SANY Group, SANY Heavy Industry is China's largest and the world's fifth largest construction machinery manufacturer. It is also the largest concrete machinery manufacturer in the world.

ZTE has partnered with mobile operators since May 2019 to build commercial 5G networks and MEC edge cloud systems for SANY Group in Beijing, Changsha, Changshu and Kunshan cities. It provides the most advanced 5G environment for the intelligent upgrades of the SANY Group to demonstrate use cases in video surveillance, remote mining among other applications. The "SANY Heavy Industry 5G + Smart Manufacturing" demonstration pilot takes full advantage of 5G's high bandwidth and low latency. It also showcased how 5G could be used in manufacturing applications to substantially increase production efficiency. Going forward, new business models for 5G + intelligent manufacturing will be further explored to promote the transformation and upgrading of the manufacturing industry.

CHALLENGES

Manufacturing automation is becoming more intelligent, but this transition is facing challenges with connectivity in a few key areas:

- 01 For mobile data collection applications, it is difficult and expensive to deploy wired connections, especially in traditional factories and for hand-held, mobile, or rotating equipment
- 02 Industrial wearable devices require a high degree of mobility and bandwidth. AR/VR applications are limited by connectivity and performance
- 03 For industrial control (in situ/remote) applications, it takes a long time to deploy and modify production lines. Outdoor excavators, indoor AGVs, and other mobile

equipment can't be controlled with wired connections.

As one of the world's leading equipment manufacturers, SANY Heavy Industry has to deal with complex challenges in network security, service centralisation, and physical environment, and therefore, it is difficult for existing wired and wireless private networks to meet the communication requirements. There is an urgent need for high-bandwidth, low-latency, high-reliability, and easy-to-deploy networks to provide connected and smart operational support for smart manufacturing.

SOLUTION

ZTE started to work with mobile operators from May 2019 to deploy 5G networks to empower SANY's high-definition surveillance, panoramic VR live broadcasts, industrial data acquisition, machine vision cloud AGV, remote excavator control, smart mining, and other applications. In addition, innovative pilots such as 5G AR, real-time industrial control, cloud AGV, remote control, and autonomous driving all contribute to the development and commercialisation of 5G-enabled smart manufacturing applications.



Testing of SANY 5G network

01 5G high-definition security surveillance May 2019

At the No. 18 factory of SANY Group Headquarter, by replacing the legacy fixed connection with 5G, two video streams of HD surveillance data is transmitted and distributed to campus monitoring centre using MEC through the 5G network.



Value of 5G application

the 5G network provides a uplink bandwidth of 60 Mbps (capable of 4K high-definition video) which fully meets the requirement for HD video surveillance at SANY's campus.

02 5G panoramic VR live broadcast on the industrial campus 2019 May

VR panoramic cameras set up on the rooftop of the office building at SANY's Changsha Headquarter campus can stream back VR video feeds in real-time to the SANY video management platform through the 5G network and MEC. The live video feeds can be shown on a panoramic screen and on VR headsets in SANY Beijing.



Value of 5G application

By utilising 5G's high bandwidth, it has enabled a 360-degree panoramic monitoring of the campus across ultra-long distances and a better user experience through VR.

03 5G industrial data acquisition May 2019

Using a 5G network to replace traditional fixed network, SANY is able to collect data acquisitions of the CNC machines at the No. 18 factory in its Changsha campus in real time, and display them on the digital meters at the control centre without any modification to the meters nor the control network. At the same time, the data is converted to the IP protocol at the industrial gateway.



Value of 5G application

5G network supports highly simultaneous and data intensive communications, and provides high density connections for data collection, operational monitoring and centralised management of instruments and equipment.

04 5G visual navigation + cloud AGV scheduling November 2019

On SANY's Changshu industrial campus, a 5G-based visual navigation + cloud AGV scheduling system has been deployed to utilise 5G's high bandwidth capabilities for real-time data transmission and 5G MEC's visual processing and scheduling capabilities to provide a low-cost and easy-to-deploy solution for smart transportation within the campus.



Value of 5G application

Compared to magnetic stripes, magnetic tapes, or other traditional navigation methods as well as WiFi, 5G-based navigation provides higher flexibility and better network stability that can support more extensive AGVs networking and scheduling. In addition, the centralised visual processing based on MEC cloud can achieve a 10% cost saving per AGV compared to laser navigation.

05 5G smart mining trucks
December 2019

The combination of 5G and smart mining truck technologies significantly improved environment-sensing capabilities of SANY's autonomous mining trucks. By continuously enhancing the 5G edge and cloud computing capabilities, a more powerful "brain" for autonomous driving's tiered decision-making could be achieved to meet the need of high-performance computing for autonomous driving.



Value of 5G application

The implementation of autonomous driving in 5G-covered mining area can greatly improve the safety of production, challenges to recruit mining drivers, management of mines, as well as overall operational efficiency through the use of big data.

06 5G remote excavator
December 2019

Successfully completed the 5G-enabled remote excavator pilot at the Kunshan campus of SANY Heavy Industry that controlled unmanned excavator in real time from the remote control console with real-time feedback of operational environment and panoramic video feeds. This proved that 5G technology could facilitate safer excavator operations in harsh environment.



Value of 5G application

It provides end-to-end low latency communication to ensure the safety and reliability of remote mining operations.



▲ 5G remote excavator demonstration site

In summary, through the efforts of multiple 5G MEC pilots, it has been proven that 5G can play a tremendous role in smart manufacturing. Going forward, more efforts will be placed in the development and innovation of 5G + Industrial Internet services. 5G can be the foundation of Industrial Internet and smart manufacturing.

REFLECTION

The 5G innovative pilots conducted jointly with SANY Heavy Industry has strengthened the understanding of telecommunication operators on the core requirements from smart manufacturing industry:

- Support the migration of the connected industry ecosystem towards better networking, intelligence and connectivity
- A 5G industrial private network, a variety of 5G use cases, and a series of industry specifications
- A 5G + AI industrial cloud platform that is designed

through international cooperation and tailored to different requirements.

5G-empowered applications that are planned for 2020 deployments include: AR remote industrial inspection, product quality inspection, inventory management, autonomous driving, robotic control and etc. The integration of 5G technology will facilitate innovative connectivity solutions for the manufacturing industry and act as a new benchmark for the digital transformation of other industries worldwide.

SANY Heavy Industry 5G + MEC Cloud AGV Project

AGV is an important element for flexible logistics in productions, and a critical breakthrough area for the digital and intelligent transformation of factories. SANY's 5G smart-connected AGV is highly standardised and low cost. It doesn't require modification to existing operating environment, and can be flexibly produced and deployed to help factories expedite their digital transformation.

Dai Qinghua
Director and Senior Vice President of SANY Group

SOLUTION PARTNERS



OVERVIEW

In 2019, SANY Heavy Industry, China Telecom, and Huawei jointly launched a 5G-based smart connected cloud-based AGV project. It utilised 5G, MEC and AI technologies to migrate the laser-based navigation to machine vision taking advantage of 5G's large uplink bandwidth, and move its deep learning algorithms to the 5G edge computing MEC platform to greatly reduce the complexity and cost of AGVs, and to make them more intelligent and standardised. The project provided SANY cost reductions for labour, improved efficiency, and supported its digital and intelligent transformations

The cloud-based AGVs have completed their testing and verification, and been deployed into service. The next generation of commercial-grade AGV products are being developed for the industry.

CHALLENGES

All SANY industrial facilities occupy large-scale industrial campuses. The area of a single factory is around 45,000 square meters producing heavy equipment. To become a leader in global smart manufacturing, the company is facing two major challenges in terms of network transformation and cost reduction in the digitalisation process.

1. Complex Network Requirements

- High costs for maintenance and upgrades. Modifications to wirings are complex;
- Each department deploys its own WiFi that is prone to interference, difficult to locate faults, and doesn't support roaming between WiFi networks;
- Current network's uplink bandwidth capacity is limited and doesn't support the large number of IoT equipment or the demand to upload many different types of data;
- Stringent data security requirements such as isolation and localisation of data.

2. Tremendous need for cost reduction and efficiency boost

The transportation of materials is a key process during production, and is done mostly by manually-controlled

forklifts and presents the following disadvantages:

- High labour costs, low production efficiency, and potential safety hazards; unable to easily track and trace the source of materials during production;
- Traditional AGV vehicles are mostly guided by magnetic strips, guiding rails, and laser reflectors along fixed paths, which are unable to support the flexible production and scheduling requirements;
- Traditional AGVs are evolving into new smart industrial robots that feature real-time sensing, safety identification, multiple obstacle avoidance, smart decision-making, and auto-execution. AGVs built with traditional localised computing and sensors are costly and complicated to schedule;
- Common practices in the industry to upgrade AGVs with intelligent capabilities are to retrofit with new functions, such as laser/visual SLAM navigation and sensing equipment. However, there is only a limited amount of space and battery capacity on the AGVs and the introduction of SLAM requires additional costs of 100,000 to 300,000 RMB per vehicle while GPU with integrated visual SLAM is also expensive and unstable.

SOLUTION

In order to solve these challenges, Huawei partnered with China Telecom and SANY Heavy Industry to launch research and technology verification projects for the application of 5G, MEC, and AI with AGV. In May 2019, four 5G macro base stations and over thirty 5G digital indoor systems were deployed in SANY's Nankou production facility in Beijing, and by September 2019, a smart-connected cloud-based AGV system was implemented in the Nankou facility. At the same time, a dedicated 5G

connection was established between the Nankou factory and the Huilongguan factory to support real-time monitoring of AGV operation in Nankou from Huilongguan.

The project deployed full 5G coverage at two campuses of SANY Heavy Industry, an edge computing platform, and brought online a key scenario algorithm. It provides stable uplink bandwidth of 131 Mbps (40Mbps required) and latency of around 19ms (40-50ms required) (measured as 19ms approx.) which satisfies the requirement of a precision within 12cm in obstacle avoidance at 1m/s speed.

It was implemented in 2 phases: 1) Replace LIDARs on the side of AGV with a range of sensors such as high-definition cameras and single-line radars; 2) Remove the radars and adopt only the visual SLAM navigation system.

Dual-lens cameras were implemented which enable visual SLAM navigation at 80% of the time; in 2020, six-lens cameras will be implemented to enable 100% visual SLAM navigation.

The data collected by the cameras was transmitted via 5G to the MEC edge servers deployed in the core network at the industrial campus, while SANY's in-house visual sensing, deep learning, and other algorithms were deployed in the

MEC to allow for real-time intelligent big data analysis of the operating environment, which achieved full automation of factory logistics and reduced labour costs.

Value of 5G application

- **Uninterrupted mobility:** 5G resolved many issues with the fixed networks such as complicated wiring and high maintenance costs, and provides full wireless coverage for the entire industrial campus and satisfies the requirements of uninterrupted mobility.
- **High uplink bandwidth:** The AGVs have many high-definition cameras that require an uplink bandwidth of 20-50 Mbps. 5G provides ultra-reliable communication, ultra-high uplink bandwidth, and guarantees the SLAs for a range of uplink bandwidth requirements. It also supports highly simultaneous communication that can accommodate a large number of 5G terminals.
- **Low latency:** 5G can guarantee end-to-end low latency communications with measured latency of around 19ms through its MEC platform, which far exceeds the 60ms latency required by AGV's real-time image processing.
- **Data security:** Enterprise data can stay on campus with a virtual private 5G network and MEC, which meet enterprise data security requirements.
- **Edge computing:** The MEC platform is integrated with GPUs to reduce local computing requirements at AGVs and consequently reduce their complexity and costs. AGV visual sensing algorithm integrated in the MEC platform can continuously iterate through deep learning to support coordinated scheduling of 200+ AGVs in the factory area, without the need to modify the existing environment at the factory to achieve flexible production.
- **Cost reduction and efficiency boost:** The cost of a 5G-based vision SLAM AGV is estimated to be only 1/9 of the that for laser SLAM, which is a significant cost reduction and can be deployed widely.

**Sany innovation:
lidar + vision navigation, cost-effective and reliable**

	Lidar	Vision navigation
Equipment cost	High, tens of thousands to hundreds of thousands	Low technical threshold, millimeter
Safe and stable	Medium	High
Computation requirements	Low	High
Perception analysis	2D	3D
Positioning accuracy	Low technical threshold, millimeter	High technical threshold, millimeter

Mainly lidar, supplemented by vision navigation

Mainly vision navigation, supplemented by lidar

Mainly vision navigation, V2X + lidar, etc.

REFLECTION

Cloud AGV products are being fitted with Huawei's 5G modules and will be commercially available during Q1 2020. It is the first project in China to apply MEC in an industrial environment with MEP added to UPF to implement an edge computing platform and a set of visual navigation core algorithms.

This project further clarified the pain points and requirements from industrial scenarios, as well as 5G functional use cases, including:

- High uplink bandwidth is required in industrial scenarios and can be further improved with industrial collaboration;
- Guaranteed low latency is required and can be facilitated by MEC and network slicing.

In 2020, SANY Heavy Industry, China Telecom, and Huawei will continue to work together on 5G innovations such as AIoT platforms, smart video surveillance, low speed

autonomous driving platform to explore:

- 100% machine vision navigation based on six-lens cameras and a stable uplink bandwidth of 40 Mbps over the 5G networks;
- Promote the use of AGV's machine vision navigation in trolleys and forklifts; implement low-speed autonomous driving service platform and integrate with V2X to manage autonomous mobile robotic equipment;
- 5G-based video surveillance and intelligent analysis for machine vision quality inspection, material identification, factory 6S management to establish visualised factories;
- 5G-connected AGVs and implementation of 5G smart video surveillance in the Sany lighthouse factory;
- New business models that will commercialise 5G for smart manufacturing and be replicated in scale globally.

Xiangtan Iron & Steel's 5G Smart Plant



Embracing the 5G era and building the Smart Xiangtan Iron & Steel plant to have the equipment “talk”, machines to run autonomously and our employees work with safety and dignity. There are many places inside a steel plant that have high temperatures, high pressure, or toxic gas where workers are not able, even with equipment, to access. But now, we are able to successfully connect all systems and applications. In the future for our plant, 5G with massive connections will connect everything from giving and receiving orders, production, and production to shipping.

Yu Weigang
Executive Vice-President, Xiangtan Iron & Steel Co., Ltd.

SOLUTION PARTNERS



OVERVIEW

Valin Xiangtan Iron & Steel is the largest and the most prominent state-owned enterprise in Hunan Province, and is the “pioneer” of Hunan’s iron and steel industry.

In July 2019, Xiangtan Iron & Steel, jointly with China Mobile Hunan Branch and Huawei, kicked off the Hunan Xiangtan Smart 5G Steel Plant project. The project pilot was conducted at the five-meters-width thick plate plant, one of the subsidiary plants, where four typical application scenarios were trialled including remote centralised control of cranes, unmanned cranes, remote control of robotic arms, and high-definition video surveillance for high-risk areas. In 2020, the project will gradually expand to different areas, such as metals bars production facilities, wharf, the thick and wide metal plate facilities, and wirings. Ultimately, all plant equipment will be fully interconnected, and be managed and controlled through the new converged terminal-connectivity-cloud network architecture, to achieve the goal of a fully autonomous plant through the remote control and semi-automated stage. A fully autonomous plant will enable employees to work in a green and smart environment away from occupational and health hazards.

CHALLENGES

The key demands from an enterprise’s smart transformation are production increase and cost reduction for which labour is a major cost factor. Highly hazardous operations, round the clock working shifts, dusty, high temperature and noisy environments all contribute to challenging working environment and increased working hours which result in low staff morale and efficiency. It is therefore imperative that automated, unmanned operations be implemented as soon as possible. However, traditional fibre network is difficult and expensive to be deployed while WiFi is prone to interference and lacks both stability and capacity.

SOLUTION

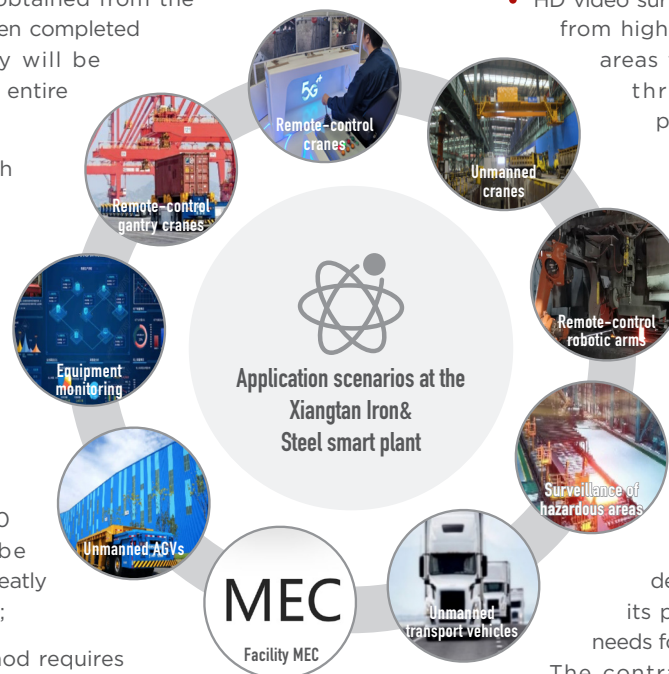
In 2019, the project first completed full 5G coverage for the open areas outside the five-meters-width thick plate production facility, the converter control building, the steel scrap bay, and the slag bay. Four usage scenarios were piloted taking advantage of improved HD video transmission and control signal data transmission between PLCs.

- Centralised remote control of four overhead steel scrap cranes: Accurate real-time remote control with eight-channel HD video streaming.
- One unmanned crane in the slag bay: Equipped with eleven cameras, two scanners, one rangefinder, and one encoder.
- One remotely controlled robotic arm in the steelmaking zone

- HD video surveillance in hazardous areas

The plant has a total of 400 cranes and 1,500 operators. 120 cranes out of the total are stationed 24/7 with 480 operators. Based on data obtained from the pilot scenarios that have been completed to date, overall efficiency will be increased by 20% after the entire plant has been upgraded.

- Operators can be freed with the shift from manual control to autonomous operations. 20 cranes are modified for unmanned operations to work round the clock which lead to a 25% increase in production efficiency;
- One operator can operate three cranes at a time with semi-automatic control. 100 cranes are modified to be remotely controlled which greatly improved working conditions;
- Traditional working method requires two operators to work in a high-temperature and hazardous area. After 12 robotic arms are modified to be remotely controlled, there expects to be a 5% saving in slag. At the same time, slag will be added and mixed more



evenly which effectively improves product quality when operators can avoid working in high temperature and high dust areas.

- HD video surveillance keeps operators away from high temperature and hazardous areas to minimise safety incidents through early warnings and proactive interventions;
- The shift from fixed connection to wireless access can improve efficiency by more than 50%.

The project explored new business models: China Mobile signed a commercial contract with the Xiangtan Iron & Steel plant that included a private network deployment and an annual subscription package. It satisfies the plant's demands to be able to customise its private network, and coverage needs for its unique all-steel structures.

The contract also included planning and deployment of a converged terminal-connectivity-cloud network structure and the commercial operations of public/private cloud services.

REFLECTION

The intelligent transformation of Valin Xiang Steel has been supported by thorough planning and the endorsements of senior leaders. Key usage scenarios were identified by close collaborations:

- The transformation from remote control to semi-automatic and fully autonomous operations;
- Autonomous sorting by robotic arms;
- Automatic volume and weight identification of stockpiles using 5G and AI technologies (accuracy to tens of tons per 10,000 tons, three times a day);
- From high-definition monitoring to the use of smart monitoring glasses for facial recognition, trajectory tracking, and electronic fences for certain areas;
- Plant transformation and unmanned wharfs;
- Mobilised plant management;
- Real-time monitoring of all gas pipelines in the plant;
- Full 5G network coverage and private cloud deployment at the plant to allow better information exchange within the plant, equipment control, provision of early warnings, positioning capabilities, and early interventions to improve safety and production efficiency.

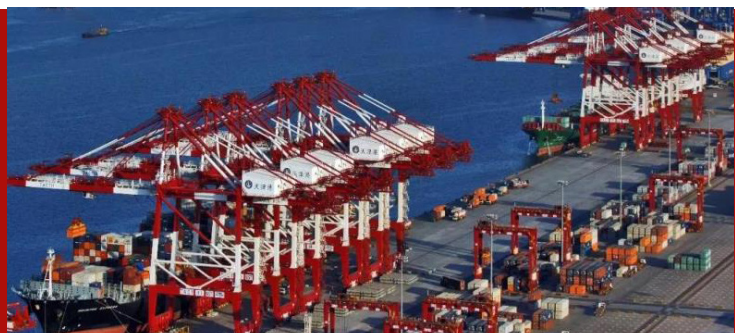
For network deployment, macro base stations and small cell lamp stations were deployed to achieve bespoke full network coverage across the plant; and the implementation of MEC technology helped to reduce latency, increase computing power, and ensured localised enterprise data on campus. Overall it achieved a highly stable, highly reliable and highly secure private 5G network.

The deployment of a private cloud enabled the migration of applications to the cloud over time to create an intelligent factory "brain" that centralised control, operations and maintenance, allowing the plant to shift from "always online" to "always onsite" whereby production is no longer limited by time and space.

However, Industrial Internet demands stringent requirements from plant environment, end-to-end electronic equipment, network capabilities, key performance indicators, and end-to-end fault detection. These would require concerted efforts from the industry and wider ecosystem to establish and refine common specifications and management processes.

Xiangtan Iron & Steel will expand the scale of deployment to cover the bar plant area and the wharf, and complete the construction of the MEC facility by the first half of 2020. Full 5G coverage over the entire Xiangtan Iron & Steel plant and its roads is expected to be completed by the end of 2020.

The Tianjin 5G Smart Port



In the first year of commercial 5G, China Unicom cooperated with other ecosystem partners to build a high quality 5G network and put industry application into practice. We have achieved milestone results at Tianjin Port and showcased the important role 5G can play as ports and manufacturing sector seek to transform their operations using smart and automation techniques. In the future, we will work with our partners to promote the integration of 5G technology with other emerging technologies and into different social and industrial aspects to jointly shape a brighter future for a smart information society.

Fu Qiang
CTO, China Unicom

SOLUTION PARTNERS



OVERVIEW

Tianjin Port is one of China's most historical ports. It was the first in northern China to reach the 100 million-tonnes mark in 2001, and ranked the ninth in port cargo throughput globally in 2018. From August 2018, together with China Unicom Tianjin and Trunk Technology, ZTE commenced the deployment of a commercial 5G network and a MEC edge cloud system at Tianjin Port's container terminal. Nine 5G macro base stations (3.5 GHz) and a MEC edge computing service platform were deployed to provide a quasi-private 5G network environment that would meet the port's smart computing needs. By November 2019, the project had completed 5G use case pilots in autonomous driving, quay crane control, customs traffic management, and mobile supervision, etc. The port's traditional private network services will also be gradually switched over to the 5G network to validate and optimise their stability, reliability and security as well as new business models under 5G.



▲ 5G Base Station Installation



▲ 5G Network Deployment

CHALLENGES

The global port business has entered a critical phase of digital transformation. Connectivity has become an important enabler for smart ports, and is facing the following challenges:

- Traditional network can't handle the millisecond-level end-to-end latency, high stability and reliability that port equipment requires
- Complex equipment structures; high costs of manufacturing, operation and maintenance; insufficient security management capabilities
- A multitude of port services that demand a wide range of connectivity requirements and currently host a variety of solutions such as WiFi, NB-IoT/LoRa, LTE private network, and 2/3/4G public networks. High operational costs.

Smart ports urgently need networks that provide high bandwidth, low latency, high reliability, and are simple to deploy to enable connected port equipment and smart operational support. The low latency, high reliability, high bandwidth, and large throughput capabilities from 5G are well suited to empower innovative connectivity solutions for equipment automation at ports.

SOLUTION

The successful deployment of the 5G network at Tianjin Port has brought dramatic improvements in network bandwidth, latency and security, and promoted deeper integration of smart port equipment with 5G technology, that created a transformative impact on port systems. The port's IT vendors will upgrade the respective port applications based on 5G features and shift towards the production of 5G embedded products that will drive the development of the 5G industry chain from the source. At the same time, with 5G products being integrated into the port production system, the mobile operator is able to shift from a singular service model to an on-demand tiered service model to accommodate different requirements from different port businesses and significantly improve the quality of its service offerings.

01 Smart 5G quay crane control July 2019

The port 5G network (100Mbps uplink and 20ms latency) replaced the fibre connections (latency around 60ms) to enable remote control of the quay cranes.



▲ 5G quay crane control

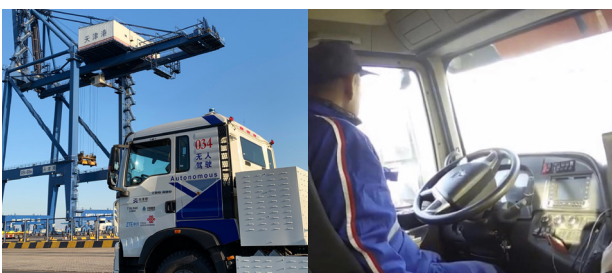
Value of 5G application



It showed that heavy equipment such as quay cranes can be remotely controlled using 5G, which significantly improved crane operator's experience, and promoted the application of 5G and MEC for ports.

02 5G remote monitoring and control of unmanned container trucks December 2018

By replacing the legacy 4G network with the port 5G network, high-definition video feeds from container trucks can be sent back and distributed to the local control centre via the 5G network and MEC for remote monitoring. At the same time, when a smart container truck is malfunctioning, the administrator can take over control of the vehicle remotely as a result the 5G network's low latency.



▲ 5G Smart Container Truck Application

Value of 5G application

With the adoption of 5G, unmanned container trucks have travelled more than 20,000 kilometres, completed 3,000 operation cycles, and transported 4,500 containers, making it the first case in the world of an integrated port transportation system that has been put into commercial operation.



20,000

Total travelled (kilometres)



3000

operation cycles



4500

Total transported

03 Customs enforcement on-the-go and information distribution with 5G November 2018

Customs inspection and quarantine services at the port require the use of wireless networks, and their tablets can distribute customs data, such as video surveillance and inspection records, to the Customs network through 5G MEC.

Value of 5G application

Improved data security and reduced latency compared to the public 4G network.

04 High-definition 5G video surveillance April 2019

Surveillance and monitoring at the port rely on a variety of equipment and systems installed at entrances and exits, freight yards, container bay, and the transaction centre. Video streams can be uploaded via the 5G network, that replaced the legacy 4G private network, at a speed of more than 80Mbps and then distributed through the MEC to the port's video cloud.

Value of 5G application

5G improved the video quality of the mobile surveillance systems from standard definition to high definition, and lowered the costs of their deployment. It also empowered the MEC platform to perform real-time video analysis that elevated the safety level of port operations.

The 5G network deployed at Tianjin Port offers excellent performance in bandwidth that is ten times the peak bandwidth of 4G, latency at the millisecond level, and a capacity of 100 billion connections. It can be integrated into IoT modules and terminals commonly used in port

operations, support the development of MEC platform, software architecture, AI and big data analysis that are tailored to edge computing, and help the mobile operator explore new business models with end-to-end network slicing.



▲ High-definition 5G video surveillance

REFLECTION

Replacing the port's 4G private network with the new 5G network and then migrating existing services to the 5G network were the key components of this project. During their implementations, due to the lack of commercial 5G devices and terminals and an evolving 5G standard, the team faced challenges such as the constraint to share a single 5G CPE with multiple service terminals and the difficulty to translate fixed IP addresses of terminals from the 4G private network to the 5G public network. These issues have since been successfully tackled through experimentation and collaboration that greatly enhanced confidence in 5G from the industry and provided valuable experiences for future applications:

- What industry customers need is not just 99.999% of network reliability in a 5G network but also solutions for the 0.001% of the time when problems occur.
- Not only do industry customers require 5G features such as low latency and high bandwidth, they also need solutions that allow for the smooth migration of existing services in the legacy private network.

- Industry customers demand not only technical solutions such as MEC and network slicing, but also low cost and cost effective 5G business models.

Going forward, this project will gradually replace existing connectivity solutions with 5G to accommodate the port's needs for synchronous and reliable transmission of control data and simultaneous video feeds from equipment at automated docks, cooperative vehicle infrastructure system, security inspections using unmanned drones and vessels, and smart quay crane operations. The next phase of the project aims to accelerate the complete integration of the port's information systems with its business operations and incentivise the convergence of information from logistics, transactions, cargo and commute to expedite the transformation to a fully automated and intelligent port. The successful implementation of the 5G & MEC Smart Port project at Tianjin Port has helped to advance the port's efforts to digitalise its systems and operations, and opened new thinking for the future of ports and showed a practical path for comprehensive use of 5G in port operations.

5G Intelligent Connected Vehicle Pilot in Wuhan



The 5G Intelligent Connected Vehicle Demonstration Zone in Wuhan is one of the first in China for testing and operation of connected vehicles in open roads. Wuhan issued the world's first commercial license for autonomous vehicle, making a significant step towards the commercialisation of autonomous driving in China.

Fan Bingheng
CEO, China Mobile Hubei Branch

SOLUTION PARTNERS



OVERVIEW

The 5G Intelligent Connected Vehicle Demonstration Zone in Wuhan, Hubei Province, is to date the largest of its kind in China, with a total area of 90 square kilometres. 170 kilometres of roads and 200 5G base stations that have been planned. So far, it has completed work on 28 kilometres of roads and 70 base stations, and an investment of RMB 217 million for 5G deployment and roadside equipment.

It is China's first 5G open-road testing and operations zone for intelligent connected vehicles, and is fitted with intelligent infrastructure and smart operation platforms. The intelligent infrastructure includes the smart sensing system, BeiDou differential positioning system, edge computing platform, electronic/digital traffic signals, and connected signal control system. The smart operations platforms include the V2X cooperative vehicle infrastructure system, dispatch and monitoring platform, equipment management platform, data analysis and SDK platform.

China Mobile Hubei provided continuous 5G coverage along the road with its network (macro base stations supplemented by small cells) using 160 MHz of its 2.6 GHz spectrum. It planned for a comprehensive framework that serves vehicles, roads, cloud and connectivity to tackle challenges in single vehicle autonomous driving and to explore interoperability between smart vehicle systems and transport infrastructure, that in turn would drive the development of an ecosystem for connected vehicles.

The demonstration zone covers a number of road conditions, such as highways, urban roads, mountain roads,

bridges, tree-lined roads, country roads, and maintenance roads. At the same time, a wide variety of vehicles are being tested, such as unmanned road sweepers, unmanned buses, unmanned buggys, unmanned ride-hail vehicles, smart parking, unmanned logistics vehicles, unmanned vending vehicles, and mobile newspaper kiosks.



SOLUTION

A converged solution framework that connects 5G connected vehicle cloud, connectivity, edge, and terminal devices is established for the demonstration zone to accelerate collaborations among related sectors. The pilot project brought together telecommunication companies, automakers, smart vehicle companies, auto parts makers, and players in the adjacent sectors to conduct trials in the following areas, especially testing and operations, vehicle dispatch, and demonstration applications:

Category	Sub-category	Category page	Indicator name
Test operations	Test operations	Test operations	Battery life alert
			Top 10 vehicles by malfunctions
			Top 10 vehicles by infringements
			Real-time incidents
			Smart travel
			Smart logistics
			Smart sanitation services
			New smart retail
			Real-time alert info
			Operation locations
		Vehicle monitoring and management	Locations where vehicle rule infringements are common
			Locations where malfunctions are common
			Layer control
			Basic vehicle info
			Safety personnel info
			Vehicle operations info
			Statistics on past malfunction alerts
			Route planning
			Vehicle exterior monitoring
			Vehicle interior monitoring

Category	Sub-category	Category page	Indicator name
Vehicle dispatch	Vehicle dispatch	Vehicle dispatch	Smart passenger vehicles
			Smart buses
			Smart taxis
			Smart shuttle buses
			Smart logistics vehicles
			Smart sanitation vehicles
			Smart police vehicles

Category	Sub-category	Category page	Indicator name	
Demonstration and application	Smart travel	Smart travel	Service capacity	
			Top 5 stations in terms of service frequency for the day	
		Smart travel (micro level)	Basic vehicle info	
			Safety personnel info	
			Vehicle operations info	
			Statistics on past malfunction alerts	
			Route planning	
			Vehicle exterior monitoring	
			Vehicle interior monitoring	
			Smart logistics	Smart logistics
	Unmanned containers			
	Smart logistics (micro level)	Trunk line logistics fatigue status		
		Basic vehicle info		
		Safety personnel info		
		Vehicle operations info		
		Statistics on past malfunction alerts		
		Route planning		
		Vehicle exterior monitoring		
		Vehicle interior monitoring		
	Smart sanitation services	Smart sanitation services	Cleaning capacity	
			360-degree monitoring of vehicle exterior	
		Smart sanitation services (micro level)	Basic vehicle info	
			Safety personnel info	
			Vehicle operations info	
			Statistics on past malfunction alerts	
			Vehicle exterior monitoring	
			Vehicle interior monitoring	
			Smart security	Smart security
Total number of security shots taken for the day				
Vehicle identification video				
Video source group				

Accelerate availability of commercial 5G equipment

The coordinated deployment of 5G macro stations and 5G lamp post stations in the same network helped to mitigate the lack of sites and slow roadside deployment. It improved the functionality of lamp post sites and drove the development and availability of corresponding commercial equipment.

Overcome key network performance bottlenecks for connected vehicles

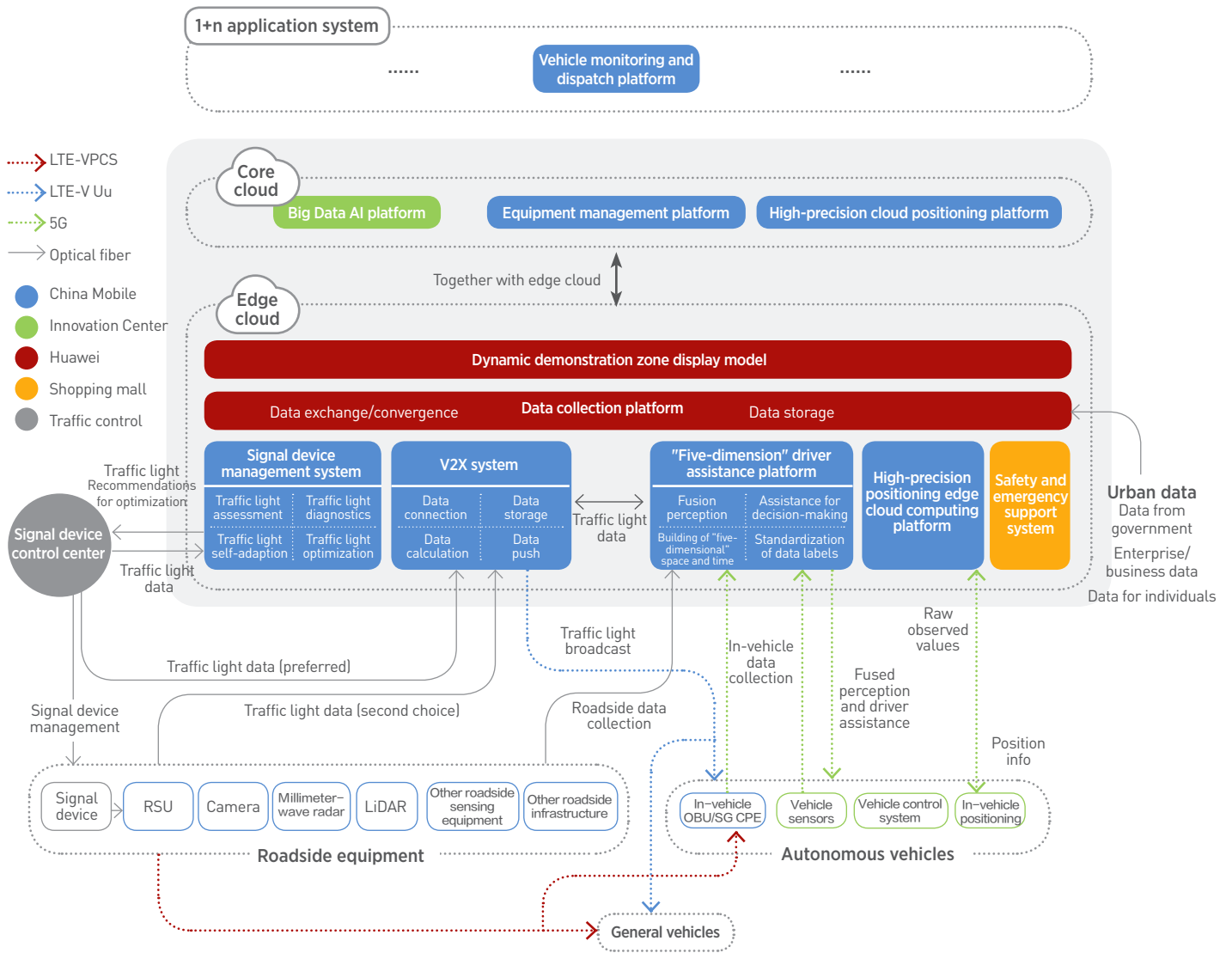
A contiguous 5G coverage of an uplink speed of 72 Mbps and an end-to-end latency of 14ms was achieved along a 28 kilometres section of roads, which satisfied the high bandwidth and low latency requirements from existing connected driving pilots.

Mitigate satellite navigation reception blackspots

GPS and Beidou navigation signal reception is usually bad or not possible in sheltered areas such as tunnels and beneath large buildings. The 5G network was used to transmit positioning information to improve the performance of BeiDou terminals, shorten its time needed for establishing position, improve positioning accuracy, that lift the overall performance of retail and industrial Beidou devices.

The implementation of C-V2X use cases

- Hazard alerts (water pooling, high temperatures, icing)
- Congestion alerts
- Traffic-light signal push
- Lane change assistance



REFLECTION

- Complete 5G coverage for the remaining 170 kilometres of roads in 2020. Establish a common 5G intelligent connected vehicle testing and demonstration platform to allow standardised access of enterprises, protocols, data.
- Establish 5G network specifications for deployment, testing, acceptance, and operation for intelligent connected vehicles.
- Migrate services that are currently on the LTE-V network to the 5G network.
- Build test environment for complex scenarios, such as night environment and different weather conditions (fog, rain, snow, thunder, and lightning)
- Implement commercial services, especially for city sanitation, logistics, vending machines.



5G BRT Connected Vehicle-Infrastructure Cooperative System



5G has arrived in the beautiful city of Xiamen. As China's first 5G/C-V2X commercial implementation and the world's first commercial application of 5G for intelligent connected buses, Xiamen's 5G BRT Connected Vehicle-Infrastructure Cooperative System project successfully implemented intelligent vehicle speed strategies, real-time cooperative vehicle infrastructure system, and other typical applications that take full advantage of 5G's large bandwidth and low latency. In the future, The technology and commercial model can be replicated for deployment in other regions, and provide rich services for commercial vehicles, special vehicles, and even private vehicles.

Chen Shanzhi

Vice President of China Information and Communication Technology Group

SOLUTION PARTNERS



OVERVIEW

In 2018, Datang Mobile and Xiamen Transportation Bureau reached a strategic cooperation agreement to jointly promote the development of intelligent transportation applications based on 5G in Xiamen. In September of the same year, in collaboration with Xiamen Public Transport Group and China Unicom Group, China's first city-level 5G intelligent connected application - the Xiamen 5G BRT Connected Vehicle-Infrastructure Cooperative System was launched.

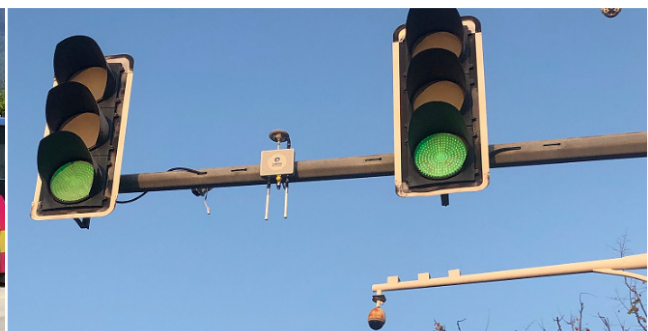
The Xiamen Bus Rapid Transit (BRT) system operates on dedicated bus lanes which are isolated from other traffic except for a few intersections, making it perfectly suited for the deployment of Internet of Vehicles (IoV) applications. In the initial stage of the project, two BRT buses were upgraded with 5G equipment to achieve Vehicle-to-Vehicle,

Vehicle-to-Infrastructure, Vehicle-to-Cloud communications, and at the same time, five intersections were upgraded with laser radar, high-definition cameras, RSU, and 5G Multi-access edge computing (MEC) servers. Empowered by 5G's low latency and high bandwidth capabilities, the project then launched four commercial services: non-LOS anti-collision, real-time cooperative vehicle infrastructure system, intelligent speed strategies, and safe and precise parking.

By November 2019, the two BRT buses had tested over 6,000 km and successfully passed customers' evaluation for efficiency and energy saving, and are recognised by the Xiamen Public Transport Group. As a result, a total of 50 buses were ordered and delivered at the end, making it the first successful commercial implementation in China of its kind.



▲ BRT Intelligent Connected Buses



▲ Intelligent Intersection Equipment

CHALLENGES

As China’s urbanisation process accelerates, issues such as traffic congestion, accidents, vehicle emissions, and other related problems are worsening, and public buses, as integral components of the city transport network, contribute to those issues as well. Xiamen Public Transportation Group’s statistics show that, on one hand, complaints on public transportation efficiency account for over 50% of all complaints, and on the other, fuel consumption represents over 15% of the total operating costs and is a major factor to air pollution. Also, passengers could easily fall into the platform gaps because the platforms are quite high off the ground and some distance away from the buses.

To address the aforementioned problems, Xiamen’s 5G BRT connected vehicle- infrastructure cooperative system uses 5G and V2X technologies to enable Vehicle-to-Vehicle, Vehicle-to-Infrastructure, Vehicle-to-Cloudcommunications, which not only facilitates active safety measures to reduce the frequency of accidents involving BRT buses in public intersections and improves operational efficiency, but also increases energy efficiency and parking accuracy at stations through the adoption of big data, energy-saving optimisation algorithms, high precise maps, intelligent route planning on the 5G MEC platform.

SOLUTION

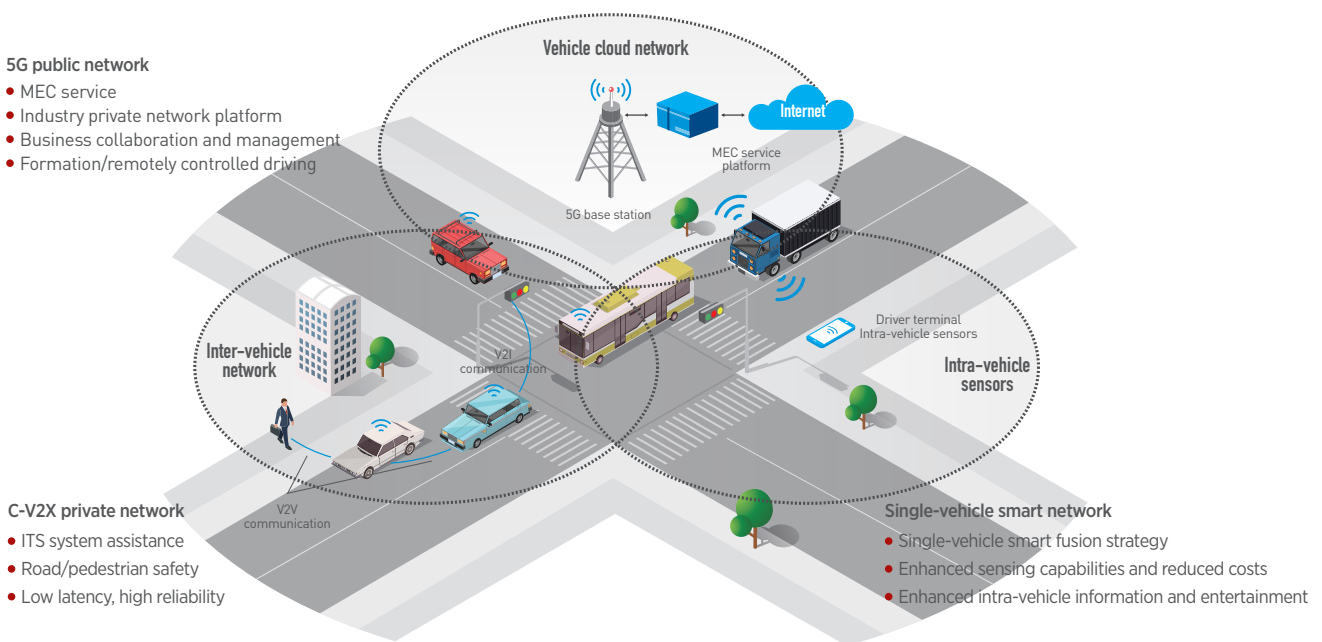
Datang Mobile integrated C-V2X, 5G, MEC and other advanced communication technologies with on-board vehicle intelligent driving technology to create an intelligent connected solution and an IoV system architecture that consolidates information from intra-vehicle, inter-vehicle, and vehicle cloud networks.

- Intra-vehicle network: Integration of onboard smart terminals and vehicle sensors, implemented with converged sensing algorithms, that provide more comprehensive reference data to on-board decision unit to satisfy stringent low latency requirements related to vehicle safety.
- Inter-vehicle network: Allows vehicles to interact with

other vehicles and roadside infrastructure (such as traffic lights) using V2V and V2I technologies.

- Vehicle cloud network: Provide route planning, energy-saving strategies, high-precision regional maps and other applications to buses using the public 5G network and roadside MEC platforms.

A converged intra-vehicle, inter-vehicle, and vehicle cloud network empowers many types of applications across different layers for connected vehicles. It effectively improves vehicle safety and transportation efficiency, and consequently advances the intelligent transformation of the city’s transportation network. To implement the converged network, the project needed to upgrade



▲ Converged Network for 5G Intelligent Connected System Architecture

equipment and facilities on board BRT buses and at public intersections. For public intersections in particular, it was difficult to deploy fixed connections due to challenges of rights of way and construction processes. Therefore, 5G was used to provide connectivity between the sensors at the intersections and the MEC platform that meets both their bandwidth and latency requirements.

For the bandwidth requirements, a typical simultaneous video surveillance (e.g. 4-channel 1080p feeds at 30fps) at intersection will require an uplink bandwidth of at least 32 Mbps; and for latency, 3GPP, ETSI, and other standardisation organizations require no greater than 100ms of end-to-end latency for active security applications. However, the inherent latency from video collection and encoding is already around 60ms, forcing transmission delay to be at the most 30ms. As a result,

	Uplink Speed	Downlink Speed	End-to-End Latency
4G Network (average values)	10Mbps	90Mbps	58ms
5G Network (average values)	500Mbps	1.6Gbps	16ms

only QoS of 5G network is capable of meeting these bandwidth and latency requirements. The table below shows the results of a field test on 4G and 5G networks in Xiamen.

Leveraging the advantages of 5G and C-V2X technology, the project implements four main commercial applications: real-time cooperative vehicle infrastructure system, Intelligent Speed Strategy, safe and precise parking, and non-LOS anti-collision.

01 Real-time Vehicle-Infrastructure Coordination

A cooperative vehicle infrastructure system can realize 360° blind spot detection at intersections. It uses MEC to consolidate information from multiple sensors, such as of detailed information regarding pedestrians, moving vehicles, stationary vehicles, and other obstacles at an intersection, to predict behaviours, and then transmits processed data from MEC to nearby vehicles over the 5G network. With 5G's low latency and high bandwidth, the system can transmit safety information in real time and richer multi-dimensional data about the intersection to the connected vehicles which can then use this information to make better safety decisions to avoid collisions, that effectively reduce the number of accidents at intersections.

The system can also facilitate smoother green light traffic flow. A vehicles can derive the optimal speed to smoothly pass the intersection based on current speed and location and the upcoming traffic signal information obtained from roadside communication. At the same time, the system could



▲ Real-time Vehicle-Road Collaboration Application

adjust traffic light signals ahead to give BRT buses priority passage to increase the efficiency of public transport. According to analysis, these techniques could reduce the average bus travel time by more than 15%.

02 Intelligent Speed Strategy

Vehicles can take advantage of 5G's low latency to report vehicle operational data, status information, road conditions, and regional information in real time to the system, while the 5G MEC derives optimal driving speeds based on real-time road conditions and send them to vehicles over the 5G network. This allows vehicles to adjust their speeds more smoothly and avoid sudden acceleration/deceleration or stops. Intelligent Speed Strategy would also cut down on emissions and reduce fuel consumption by about 10% of every 100 km which translates to nearly 20,000 RMB of fuel savings per vehicle, per year.



▲ Intelligent Speed Strategy

03 Safe and Precise Parking

With high precision maps, converged sensing algorithms, route planning, and other strategies deployed on 5G MEC, the MEC platform can send a large amount of data to vehicles in real time benefiting from 5G's high throughput. Vehicles will then be able to better adjust their entry path when approaching stations to ensure that the gap between the bus and platform is less than 10 cm. This would improve the safety of passengers when getting on and off the bus, and further improve Xiamen BRT's reputation for quality, efficiency, and safety.



▲ Safe and Precise Parking

04 Non-LOS anti-collision Non-LOS Anti-collision

Vehicles can use V2V technology to exchange their mutual distances, speeds, and locations information in real-time to help them derive their Time to Collision (TTC). Autonomous vehicles could then adopt gradual deceleration or braking strategies to avoid collisions during driving or crossing, even when the other vehicle is not within sight. It is not impeded by poor visibility or weather conditions, and can increase the vehicle's range of perception up to over 450 metres. Provided the application is cost-effective enough to be widely adopted, it will help reduce the number of traffic accidents and therefore improve transport safety.



▲ Non-LOS anti-collision Non-LOS Anti-collision

REFLECTION

The implementation of 5G BRT Connected Vehicle-Infrastructure Cooperative System brings improved safety, operational efficiency, and better fuel efficiency to the transport industry. Intelligent Speed Strategy Intelligent speed strategy help reduce fuel consumption by 10%, directly lowering vehicle operating costs; safe and precise parking ensures a gap no greater than 10 cm between bus and platform, improving the safety of passengers and reducing the number of complaints; and 360° blind spot detection will significantly improve the safety of BRT buses when crossing intersections, reduce chances of collisions, and facilitate a more efficient flow of traffic. Going forward, more applications and services can be developed leveraging 5G's capabilities to meet the needs of the transport industry.

The system can be implemented and deployed in phases, and support backward compatibility and future evolution,

and is already stable for wider commercial deployment. It has been demonstrated in various cities throughout China and in commercial operations in Xiamen, Zhengzhou, and Tianjin. It can be quickly replicated in more places and expanded into other public transport systems, such as taxis, ride-hailing platforms, freight transport, and eventually private vehicles, making it a vital support system for intelligent transport.

The successful delivery of this project greatly enhanced the development and technical capabilities for Xiamen's 5G connected industry ecosystem, and created more jobs, promoted greener travel, increased transport efficiency, and improved passenger experience. At the same time, it provided valuable experiences for local 5G intelligent transport specifications and standards, and regulatory frameworks for the deployment, testing, operation, and management of intelligent transport systems.

5G for Smart Grid



After close collaboration in the past two years, China Southern Power Grid (CSG), China Mobile and Huawei's joint efforts for "5G + Smart Grid" are entering a critical stage. The power grid employs a extensive range of applications from power generation, transmission, conversion, distribution, and use, and can benefit from all three 5G usage scenarios. 5G network slicing could function as a wireless virtual private network that provide comprehensive security isolation and customised services. Compared with previous mobile communication technologies, 5G is expected to solve the communication "bottlenecks" from access to power grid by a massive amount of terminals, such that it can better satisfy the requirements for security, reliability, and flexibility in power grid. We look forward to the release of bespoke 5G terminals and modules for power grid in 2020, and will continue working together with our partners and launch scaled pilot projects in five provinces in southern China.

Yang Junquan

Deputy Director of Power Dispatching and Control Center, China Southern Power Grid

SOLUTION PARTNERS



OVERVIEW

CSG, China Mobile and Huawei started strategic cooperations on the "5G+ smart grid" project in 2018, and achieved major breakthroughs in technologies and services. 5G has empowered a highly reliable virtual private network with security isolation for smart grid. The project achieved six world's firsts in top level design, international standardisation, key technologies, field pilots, terminals & modules, and service operations:

- Publication of the "5G+ Smart Grid Whitepaper" during MWC Shanghai 2018
- Top contributor globally of proposals related to "5G+

power grid" to the 3GPP

- "5G+ Differential Protection" for existing networks piloted in Shenzhen
- "5G+ PMU" for existing networks piloted in Shenzhen
- End-to-end network slicing for existing networks piloted in Shenzhen, which included the first CPE designed for power grid
- Continued incubation of products and business models for commercial use which are expected to be commercially available from 2020-2021 in five provinces in southern China.



CHALLENGES

A smart grid is expected to satisfy the needs of massive connections, security and efficiency, and peripheral expansion, but faces the following challenges:

An urgent need to improve stability of supply to the power distribution networks, and the precise detection and identification of failures: Traditional power distribution networks use overcurrent protection which would affect a wide area of services during power outages and make fault detection difficult.

Difficulties in deploying fibre in the distribution networks: The main distribution network has been fully covered with fibre, but peripheral networks are still unconnected due to their large coverage, high costs, long lead time and maintenance difficulties (RMB 150,000/km).

Very high requirements for the adoption of 5G in smart differential protection for distribution networks and synchronised phasor measurement units PMU: Average latency must be within 15ms, time service in less than 1Qs, and reliability at 99.99%.

SOLUTION

5G can provide the power grid with a flexible virtual private network, isolated network slices for increased safety, high-precision time service, and low latency. It also enables new wireless access solutions for the electric power industry, and opens new business opportunities for mobile operators.

Starting with the top level design, the project published the world's first "5G + Smart Grid" whitepaper in Shanghai in 2018, and had 15 proposals related to 5G + power grid accepted by the 3GPP. The top level design covered end-to-end network slicing, time service, and latency solutions tailored to the electric power industry's needs and requirements.

On technical innovations, the project achieved the first integrated end-to-end network slicing solution with grid operational management in China, developed proposals for industry time service standards, and conducted corresponding field pilots in Shenzhen:

01 Innovative end-to-end network slicing

physical and logical isolation of end-to-end network slices from the core network (UPF isolation, virtual machine isolation), to transmission (Flex hardware slicing, VPN), and to RAN (QCI and ARP). Established platforms of Communication Service Management Function (CSMF), Network Slice Management Function (NSMF), and Grid Slice Management, and completed testing of their operations on live grid:

Grid slice management platform

a network slice management portal at grid company that manages the purchases of network slices and the monitoring of the respective slices during operations.

Communication Service Management Function (CSMF)

a network slice operations portal that is designed for a mobile operator's departments of government, enterprises, and marketing to configure slicing templates, customise slices for key clients, and manage slice inventory.

Network Slice Management Function (NSMF)

a network slice management portal that is designed for a mobile operator's network and planning departments to design slices, distribute cross-domain configuration settings, monitor status, and plan SLAs.

Independently developed transmission and forwarding chip that provides dedicated forwarding mechanism for grid services with determined forwarding delay.

02 Innovative time service

Power grid requires a comparison between waveforms and phases of adjacent nodes at the same time point in a current cycle (within 20 ms), which demands an end-to-end communication latency of less than 15ms and a time service accuracy at air interface of 10Qs. The project carried out targeted developments on networking, equipment, and terminals and achieved a field tested average latency of 10ms, and was conducted. After field tests, the average latency reached ten milliseconds. Based on the 3GPP R16 standards, from the clock source at the base station to the terminal, the air interface time service accuracy could be reduced down to 300ns.

03 Latency solution

Huawei's independently developed NP chip was used for transmission, whose forwarding delay is lower than the industry specification. The core network used MEC to reduce latency, and optimised its processing capabilities for a determined latency while improving reliability of the RAN.

04 Industry CPE terminal

A CPE with time service function designed to the industry's requirements.

05 Network pilot testing

A small-scale pilot 5G network was deployed in Shenzhen, targeting for commercial use.

Completed field tests for differential protection and PMU in Shenzhen in May 2019.

The standalone (SA) end-to-end network slicing was trialled during MWC Shanghai in June 2019; the grid slice retained a consistent performance even when the public slice experienced a significant amount of errors and package loss, which sufficiently verified that commercial 5G networks are capable of meeting the requirements from the smart grid.

Commenced commercial operation of the world's first 5G SA end-to-end network slicing implementation in September 2019. Established a virtual private network that enabled the application of network slicing in commercial service and implemented slices that were managed, controllable, and operational.

REFLECTION

The electric power industry demands the top level of safety and security which need endorsement from national safety standards and downstream terminal manufacturers to comply with the latest deployment standards. To this end, CSG has already planned to carry out pilot programmes on a large scale, which will soon be executed across various provinces to help establish industry specifications for networks, terminals, and applications.

The project has so far has evaluated 52 grid application scenarios which covered an extensive range of processes from power generation, transmission, conversion, distribution, and use, and started pilot services for automated power distribution, video inspection of power transmission and conversion networks, and electronic metering in Shenzhen with a plan to expand into live grid trials in 2020 in five provinces across southern China (Guangdong, Guangxi, Hainan, Yunnan, and Guizhou), and in particular a Nansha Demonstration Zone in Guangzhou.

The smart grid project is estimated to serve more than 10 million customers in the future, and generate a socio-economic impact of more than RMB 5 billion.



Migu's "Quick Gaming" Platform



In the 5G era, content consumption is increasingly delivered through the cloud. Cloud gaming, which is widely recognised as a "killer application" in the 5G era, expands available contents, time and space for users and provides a fully immersive gaming experience. As the largest cloud gaming operator in China, Migu Interactive Entertainment will work hand-in-hand with our industry partners to jointly promote the healthy and sustainable development of the cloud gaming industry.

Feng Lin
CEO, Migu Interactive Entertainment Co., Ltd.

SOLUTION PARTNERS



OVERVIEW

In 2019, in line with China Mobile's strategic 5G deployment plans, China Mobile Migu (Migu) created a new cloud gaming service platform -MiguPlay. It is based on the X86/ARM architecture, and fully harnesses 5G's ultra-low latency and high bandwidth features. The platform renders all games on the cloud and sends the game display to the user's device through the 5G network.

Based on the "5G Quick Gaming" platform, a game is no longer dependent on the physical hardware of an user's device such as processors and graphics cards. It would even empower thin clients that have limited graphics processing and computing capabilities to run high-quality games.

The "5G Quick Gaming" platform will also change the way users access their games. Instead of traditional methods of download and in-app purchase model, it will enable a subscription-based click-to-play model. This new approach

will drive new business models of 5G in the online gaming industry, and revolutionise game development, distribution, and user habits.



CHALLENGES

The concept of cloud gaming has been in development over seven years during which time many major international players have launched their respective cloud gaming platforms. However, due to limitations of latency and bandwidth those cloud games could only be deployed in controlled environments, and haven't been commercialised successfully or received recognition from customers.

At the same time, the gaming industry is also facing the following challenges:

- 01 A major conflict between high performance and weight reduction of devices;
- 01 Copyright protection with games downloaded to local devices;
- 01 The popular free-to-play model has led the gaming industry to focus on pay conversion but user experience, which signified the problem where good games are often commercially unsuccessful.

SOLUTION

"5G Quick Gaming" is Migu's new-generation of cloud gaming platform based on cloud computing technology. It allows the games to run from the cloud, and requires no local download. Users simply click-to-play and enjoy an ultra-high-definition and fully immersive experience.

- **Cloud computing:** it utilises cloud capabilities to enable games that were only possible on consoles such as PlayStation and Xbox to be played on normal smartphone, PC or set-top box, which disrupts the gaming landscape.
- **Billing model:** innovative billing based on play time for the gaming industry which moves away from the usual in-app purchase model, and when combined with a subscription service it makes "Game as a Service" a commercial reality.
- **Network performance:** for gamers, network latency and jitter are key performance indicators for gaming experience. The platform can effectively accommodate cloud gaming's requirements on computing power, picture quality and network latency using 5G's edge computing and network slicing capabilities. It can support 4K HDR rendering at 60fps with a latency of less than 50ms and download speed of 50-150Mbps.

Key features

01 New technologies: centralised content management and control

All game contents on the "5G Quick Gaming" platform are stored on a central cloud service which distributes gaming display via video streaming to user devices. Through the cloud platform, an operator can exercise real-time content classification, game adjustment, and removal of game listing.

01 New business model: a green and healthy subscription model

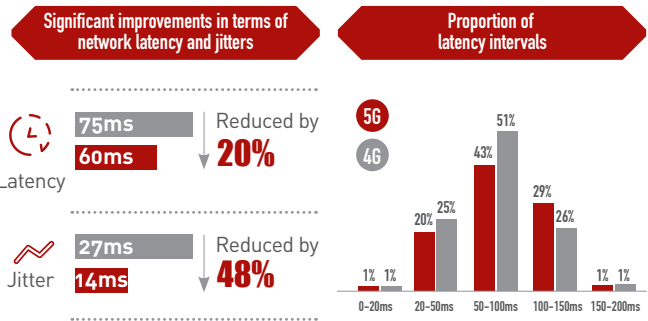
Migu's "5G Quick Gaming" is based on a subscription model to provide rights service on a monthly basis and require no in-app purchases, which helps to ensure ads-free and all-inclusive gaming contents. Cloud-based games attract customers with positive and high-quality contents rather than incentivising impulse purchases.

REFLECTION

"5G Quick Gaming" has become China's largest cloud gaming platform. It carries more than 3,000 game titles, and hosts the largest reserve of contents among cloud gaming platforms in China.

Currently, the platform supports contents from consoles, PCs, and mobiles. Going forward, supported by improved 5G coverage, it will continue to enhance key capabilities such as GPU virtualisation and video encoding and elevate picture quality to 4K at 60fps, and at the same time improve network capacities for "cloud VR" which requires network latency of less than 20ms and higher network bandwidth compared to normal cloud games.

In terms of the development of the industry ecosystem, in



01 New responsibility: mitigate gaming addictions

All games on the "Quick Gaming" platform are run on the cloud server, and are called via designated user clients (such as Migu Games). Minors can be further protected by the platform's parental control capabilities such as user authentication, play time restriction, and content control.

01 New mechanisms: protection of intellectual property rights

Copyright is further protected with contents stored and run online. "5G Quick Gaming" delivers the gaming experience via video streaming to user devices which avoids an user accessing game contents directly and therefore prevents game "cracking" and pirated copies. The platform can immediately remove any rights-infringing content from the cloud servers.

01 Blue oceans: innovative new business opportunities

User base for cloud gaming will grow significantly at an increase of 45-50% driven by user demands, scaled 5G network deployments, and a reduction of cloud computing costs

Cloud gaming can create a differentiated console + Android content ecosystem with a unified rights strategy across multiple screens (unified pricing, gaming accounts, and business models), and a dividend business model based on play time tiers. It can effectively incentivise partners to focus more on contents and user experiences.

2019, Migu and industry partners established a dedicated studio for cloud gaming contents in order to expedite the development of cloud-native games to establish a cloud gaming ecosystem based on innovative cloud gaming business model.

In October 2019, Migu Interactive Entertainment took the lead in the formation of the "5G Cloud Gaming Industry Alliance" and began preparatory work for the "World 5G Cloud Game Industry Conference" and the "Global 5G-XR Game Industry Alliance", and based on which Migu will further its efforts for the broader development of the 5G gaming ecosystem in 2020.

5G Cloud VR Demonstration Zone in Honggutan, Nanchang, Jiangxi Province



5G has not only enhanced existing VR experience, but also unleashed the unique advantages of VR and AR for mobile devices and their innovative use cases. On the other hand, VR also complements the 5G's development by bringing a wide range of new applications and use cases. The establishment of the Nanchang 5G + Cloud VR demonstration zone shows an example of harmonised development of technologies and industries.

Huang Xiaoqing
General Manager of Jiangxi Telecom

SOLUTION PARTNERS

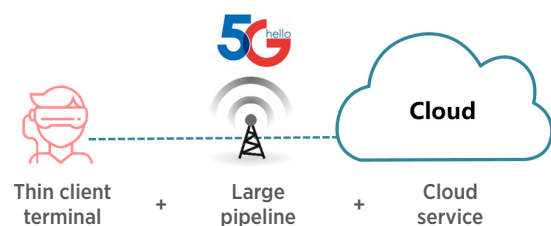


OVERVIEW

In early November 2019, China Telecom launched 5G commercial services in 50 cities, and 5G applications including its e-Cloud VR which uses its super-fast 5G network to host the VR contents and rendering in the cloud. China Telecom (Jiangxi) partnered with Huawei to establish the first 5G cloud VR demonstration zone in Honggutan District in Nanchang. The demonstration zone covers an area of 37 km² and is a modern city centre that accommodates a variety of city functions such as commerce, finance, government administration, information, culture, and residential. 101 NR macro base stations are planned to match the scale of the existing LTE network. There are 289 planned cells of which 219 are currently online. 6 NR base stations covering the main 5G areas are already online, of which four are ground stations and two are rooftop stations, with a total of 18 AAUs installed.

Key objectives for the demonstration zone include:

- 01 Verify the experience model for 5G cloud VR service based on China Telecom's e-Cloud;
- 02 Formulate network deployment strategies for 5G cloud VR under different usage scenarios, and publish a whitepaper on 5G network deployment specification ;
- 03 Establish a quality assurance framework for 5G cloud VR.



▲ China Telecom 5G cloud VR development strategy

CHALLENGES

With 4G, ultra-high-definition videos and panoramic VR contents were mainly stored and accessed locally, which significantly limited their wider applications. In the 5G era, demands for VR are moving from immersive audio-visual towards more interactive and live experiences. Key challenges in this transition include:

Lack of a clear and unified experience model

The lack of a common set of quantifiable indicators for user experience makes it very difficult to guide the development of VR towards experience-driven designs.

Lack of network planning and deployment specifications

Cloud VR services' high reliance on the performance of bandwidth, latency and packet loss determined that network deployment has to cater for specific requirements of different use cases. However, network deployment and planning specifications for VR services are still lacking, and therefore it was difficult to provide a requirement matrix for the deployment of 5G.

Unable to quickly respond and troubleshoot problems

There isn't any well-defined quality assurance framework for 5G cloud VR services, which prevents quick identification and location of problems in the respective device, connectivity and cloud domains that ultimately affects the user experience.

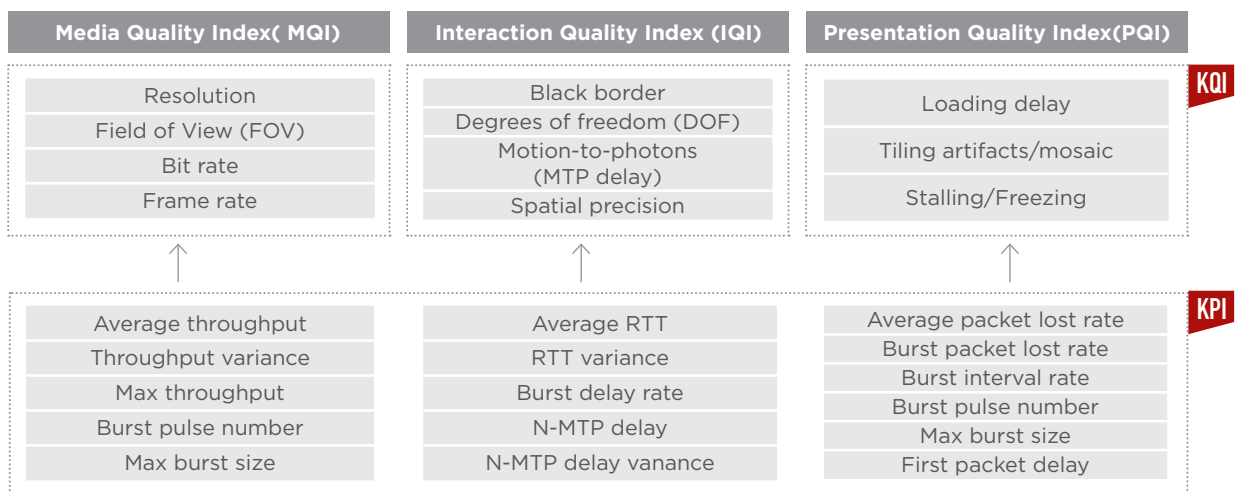
SOLUTION

01 Experience model for 5G cloud VR services

The experience model for cloud VR services include three indicators - Media Quality Index (MQI), Interaction Quality Index (IQI), and Presentation Quality Index (PQI) which are rated and scored to evaluate user experience of different VR services. This model can be applied to a wide range of scenarios such as VR games, VR 360° videos, VR live broadcasts, IMAX screen cinemas, and VR education.

Cloud VR Immersion



See things and interact with each other like in the real world



Mapping of the user experience model to the network capability benchmark

02 Network specifications and deployment strategies for 5G cloud VR services

The experience model for cloud VR services include three indicators - Media Quality Index (MQI), Interaction Quality Index (IQI), and Presentation Quality Index (PQI) which are rated and scored to evaluate user experience of different VR services. This model can be applied to a wide range of scenarios such as VR games, VR 360° videos, VR live broadcasts, IMAX screen cinemas, and VR education.

ServiceType	Service Scenario				Network Requirement					
	Sub-Scenario	Resolution ratio	Bit rate (Mbps)	Frame rate(fps)	Bandwidth (TCP DL)	Bandwidth (TCP UL)	Network RTT Delay	Minimum RSRP(dBm)	Minimum SINR(dB)	
 Video	VR Panoramic	180° 3D	4K	100	30	150Mbps	1Mbps	≤ 35ms	-105 dBm	3dB
		360° 2D	4K	40	30	60Mbps	1Mbps	≤ 35ms	-108 dBm	3dB
		360° 3D	4K	40	30	60Mbps	1Mbps	≤ 35ms	-108 dBm	3dB
		8K 2D(FOV)	8K	60	30	90Mbps	1Mbps	≤ 35ms	-110 dBm	2dB
	3D cinema	4K	30	30	45Mbps	1Mbps	≤ 35ms	-110 dBm	2dB	
Giant screen cinema	4K	30	30	45Mbps	1Mbps	≤ 35ms	-110 dBm	2dB		
 Game	VR game (high latency sensitivity)	3K	40	60	80Mbps	4Mbps	≤ 20ms	-108 dBm	3dB	
	VR game (Medium latency sensitivity)	3K	40	60	80Mbps	4Mbps	≤ 40ms	-110 dBm	2dB	
	VR game (Low latency sensitivity)	3K	40	60	80Mbps	4Mbps	≤ 60ms	-110 dBm	2dB	

Telecom VR service 5G network construction standards

After simulation analysis and scenario-based service verification for the 5G network in Honggutan District, Nanchang, Jiangxi, the following 5G VR network deployment strategies were recommended:



High-rise buildings
including residential
buildings/office
buildings/hotels

Scenario features:

tall & ultra-tall buildings, height > 100 m, high building density, blocked views, nomadic user locations, attenuation of at least one wall (26 dB) between indoor and outdoor areas.

Network deployment strategy:

For ultra-tall buildings, it is recommended to use 5G + WiFi 6 complementary solutions as regular macro base stations wouldn't be able to achieve full coverage. 5G can be used to cover outdoor areas and lower floors, while a XGPON + WiFi 6 solution can be used to complement 5G indoor coverage for a seamless experience.



Medium-rise buildings
including airports/
stations/large
commercial streets/
shopping centres

Scenario features:

large construction areas (tens of thousands of square meters), relatively low height (less than 20m), large indoor space; concentrated business distribution, high foot traffic, relatively high cell loading; large glass wall exterior or a semi-open external structure, that introduces relatively low attenuation (less than 10 dB).

Network deployment strategy:

For places such as airports, stations, large commercial complex that require higher capacity, it is recommended to deployment 5G with active indoor distribution systems to allow for flexible network capacity expansion to guarantee user experience even under heavy usage.



Low-rise buildings
including urban villages/
low-rise residential
buildings, etc.

Scenario features:

high building density, relatively low-rise buildings; most services are indoor, in-depth indoor coverage as the main objective; difficult to coordinate, difficult to select installation site.

Network deployment strategy:

For urban villages and low-rise residential buildings, it is recommended to use a combination of macro and micro stations, and to fully utilise pole-mounted base stations, wall stations together with macro stations on rooftops. A wide coverage can be achieved via rooftop macro stations while the smaller stations fill in for coverage gaps to achieve full network coverage.



Open outdoor areas
including green spaces/
parks/plazas/streets, etc.

Scenario features:

wide open areas, large areas, irregular distribution of people and businesses; no obstruction to base stations; basically, only foliage attenuation needs to be considered.

Network deployment strategy:

Outdoor macro base stations can already achieve good coverage. Tests have shown that at a medium inter-site distance (around 500 m) and using regular tower- or rooftop-mounted stations, an average RSRP of over -95 dBm can be achieved with 95% of the area having an edge value of over -110 dBm. Furthermore, additional capacity from surrounding pole-mounted stations fitted with Easy Macro can be used for targeted coverage to increase network capacity and improve user experience at cell edge.

03 Quality assurance framework for 5G cloud VR services

By the end of 2019, there were 500,000 VR users at China Telecom and those were expected to reach five million by 2020. However, user complaints are mostly dealt with manually because there isn't yet any management solution for VR video and gaming that can visualise maintenance and identify problem domains to quickly locate and resolve issues. Therefore, there is an urgent need to deploy a tool to quickly locate and identify problems to improve service quality.

Cloud VR service quality assurance and management framework delivers three main functions - visualised service quality, service problem identification, and VR user support":

- 01 Visualised service quality through accurate measurement of cloud VR experience indicators from device data;
- 02 Quick identification and location of service problems using analysis of data from cloud, connections and devices;
- 03 Support timely problem resolution and feedback for users through customers management platforms.

From data obtained in network trials, VR indicator accuracy exceeded 95% and user complaints are reduced by 70%, while the mean time to repair (MTTR) efficiency is improved by 75%:

VR service quality visualization

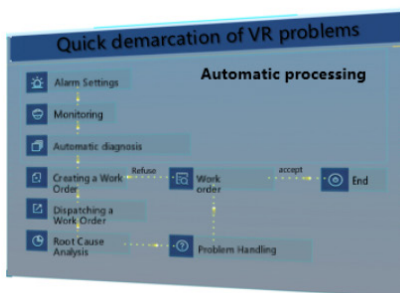
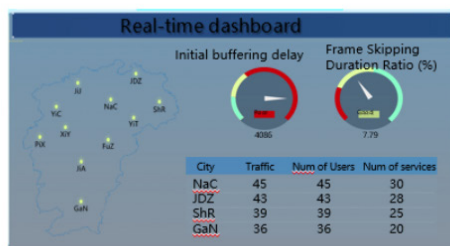
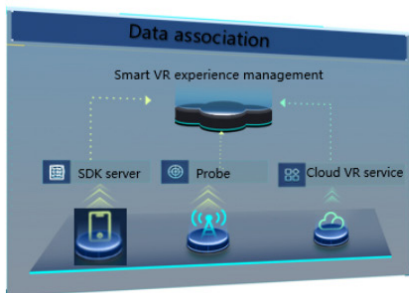
- VR experience indicator system monitoring
- Area statistics display at each layer

Service quality demarcation

- Quick perception of massive faults
- Quickly demarcate the device where the alarm is generated

VR user complaint support

- User access path
- Demarcation conclusion and handling establishment
- Abnormal event analysis



REFLECTION

The 5G VR demonstration zone in Honggutan District, Nanchang, Jiangxi conducted insightful trials and pilots for service experience modelling, network deployment strategies and specifications. The project trialled and verified the network deployment strategies and specifications, and produced the 5G deployment specification whitepaper. The project established a comprehensive set of processes and specifications that would benefit future cloud VR pilot zones in China and globally.

At the same time, based on the quality assurance framework, China Telecom is able to visualise maintenance and identify problems for VR video and gaming, and significantly improve service efficiency to ultimately provide differentiated services and deliver greater customer satisfaction.

5G Cloud VR Education Application Based on AI QoE

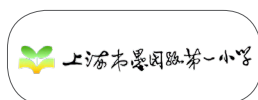


We have been monitoring the outstanding achievements of VR technology in education and teaching. Today, 5G technology provides an important foundation for the deployment and implementation of VR-based smart education. The 5G Cloud VR Education Solution received high praise from both teachers and students which gave us full confidence in our strategic partners.

Hu Rong

Principal at Shanghai Changning Yuyuan Road No. 1 Elementary School

SOLUTION PARTNERS



OVERVIEW

Virtual Reality (VR) is an important element in the exploration of new educational methods for the future. This solution brings together China Telecom's network resources, Nokia's 5G network equipments, technologies, and commercial cloud platform, as well as Baidu's extensive VR educational contents to create a comprehensive 5G+cloud VR education solution with a sustainable business model. The project delivered a VR education classroom solution at Shanghai Changning Yuyuan Road No. 1 Elementary School which can hosts VR natural science courses for over 40 classes at the school.

CHALLENGES

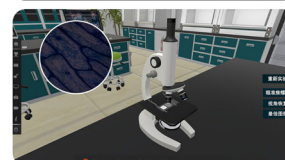
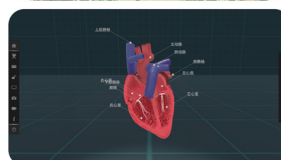
VR technology can provide students immersive learning experiences in traditional primary and secondary schools, and a virtualised learning environment can help enhance students' understanding of knowledge and facilitate more affordable virtual laboratories.

There were many challenges from previous VR methods before 5G was introduced:

- **PC VR:** When using a PC to support a single VR device, it must be connected by a cable which resulted in poor student experience. For schools, procurement, wiring, deployment, and maintenance of PC hardware require significant resources, and can't be shared between schools.
- **All-in-one VR headset** In this approach, VR educational contents are run directly on all-in-one VR headset. Although this solves the problems of wiring and mobility, all-in-one VR headset have limited computing power that leads to poor image quality and stability.
- **Cloud VR + Broadband:** Contents are managed in a VR cloud platform and delivered to the classroom via FTTX broadband connections, which can facilitate wireless and lightweight VR deployment in classrooms. However, normal fixed broadband connections suffer from poor stability, high

latency, and network jitter, and is therefore unable to meet requirements for stable commercial operations.

- **Cloud VR + lease line:** Contents are managed in a VR cloud platform and delivered to the classroom via a lease line, which can facilitate wireless and lightweight VR deployment in classrooms. A lease line provides sufficient bandwidth and latency performance, but takes a long time to be installed and is very expensive for the bandwidth required (a downlink bandwidth of at least 600 Mbps for each classroom).



SOLUTION

This project utilized China Telecom’s cloud computing resources and 5G network coverage to create a VR classroom solution at the Shanghai Changning Yuyuan Road No. 1 Elementary School, which can host VR natural science courses for over 40 classes at the school. The project was started in March 2019 and finished deployment in May. It is now in commercial operation after six months of pilot.

The 5G Cloud VR Education Solution takes full advantage of 5G’s large bandwidth and edge computing’s low latency features to create a lightweight, wireless, easy-to-manage, mobile, and sharable VR education service model. In addition, it is integrated with advanced AI-empowered Quality of Experience (QoE) capabilities, and uses AI techniques such as automatic content identification, bandwidth prediction, real-time VR user experience evaluation to ensure an efficient VR streaming experience for users in a 5G network.

This project deploys a VR education cloud platform at an edge cloud data centre near the school and hosts a variety of custom VR course materials on the platform. The platform renders and encodes the VR educational contents in real time and pushes them via streaming over the 5G network to all-in-one VR headset (via WiFi during pilot) in the classroom to enable VR education.

The 5G network needs to meet the simultaneous downlink streaming requirements of a VR classroom (with at least 8 devices): each VR stream requires an average downlink speed of 60 Mbps (including split stream for casting to the monitors) and a 10 ms two-way delay to avoid VR image lag and glitches. To meet those requirements, a 5G small cell is installed in the VR classroom to provide over 1 Gbps in downlink bandwidth to satisfy the downlink requirements, while the VR education cloud platform deployed at an edge cloud data centre nearby allows for high volume of data

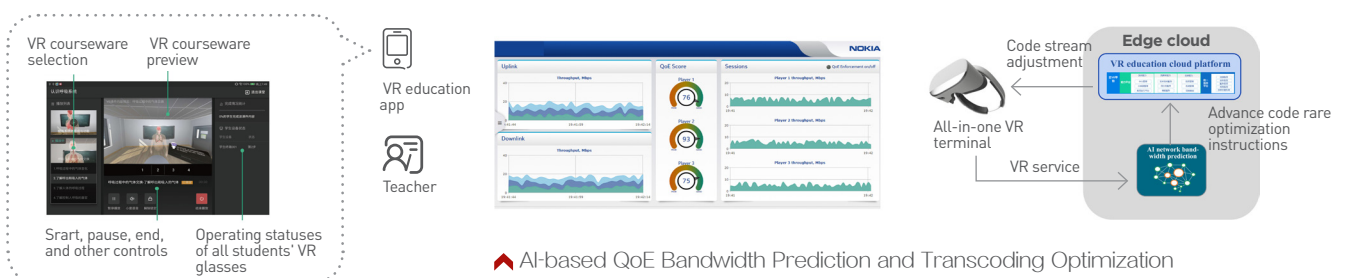


offload and low two-way delays.

The VR classroom is set up with desks according to the number of students, and places one all-in-one VR headset with interactive controllers and a monitor to synchronously display the VR contents on each desk. Each desk seats about four to five students who would take turns to use the VR device during class for around four to five different contents at about one minute each.

A teacher can monitor the status of all VR devices in the classroom and control the course contents using a mobile app via the cloud VR education platform. The teacher firstly selects the appropriate VR course contents based on the curriculum, after which the platform would process the contents in real time and push them via streaming to the devices. This method affords a teacher with a high degree of control over the progress of the class and the students’ use of the devices.

This solution also incorporates AI-based automatic content identification, bandwidth prediction, and real-time VR user experience evaluation to predict the QoE of any specific streaming VR contents in real time. An AI algorithm can also predict the fluctuations in 5G network bandwidth and feed this information back to the VR cloud platform so that it can adjust the encoding rate to ensure a stable user experience.



CONCLUSION

From the perspective of educational value, the 5G Cloud VR Education Solution provides a truly sustainable and scalable VR education model to schools:

- **Simple hardware maintenance and high availability:** Schools only need to maintain the VR headsets and accessories with ease. The VR cloud platform is set up with

hardware redundancy to ensure high availability and to avoid disruption to classes from hardware faults.

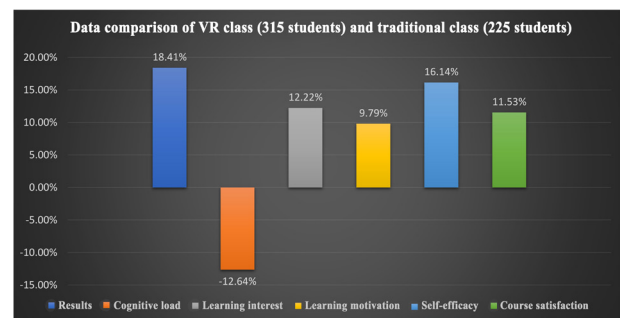
- **Wireless connection enhances the user experience:** VR headsets access and run contents from the VR cloud over the 5G network. This ensures a good experience, reduces cable clutter and improves safety in class.

- Seamless content updates and upgrades:** All course content updates and additions take place on the VR cloud platform outside of school hours, which doesn't affect teaching schedules or require the school to assign any staff to coordinate. Each classroom is then able to access the latest contents from the cloud.
 - No need to consider hardware upgrades or compatibility:** All new contents are tested and tuned to their best quality on the cloud platform before distribution to schools. Because rendering and processing are done on the cloud, schools don't need to consider hardware compatibility or performance issues. In addition, the introduction of new contents will not demand upgrades of schools' hardware.
 - Sharing of hardware and software resources:** The service model of the platform allows hardware and software resources to be shared across VR classrooms in multiple schools. This improves resource efficiency and reduces costs. The platform can flexibly allocate hardware and software resources based on the number of teaching sites and frequency of classes without impacting school curriculums.
- From the technical perspective, this solution provides a well-suited network service model using a combination of 5G, AI QoE, and edge computing technologies:
- 5G network:** VR's panoramic video streams and 3D audio require large bandwidth that can't be met by 4G networks, but can be better satisfied by 5G's high bandwidth and low latency features. Further improved by network optimization, the 5G network can provide stable and large bandwidth to meet the needs of multiple VR streaming in a class.
 - Edge computing:** The introduction of mobile edge computing (MEC) technology enables closer content

deployment to the end users and thus offers low latency and high throughput required by VR services..

- QoE optimization:** A novel approach to introduce AI for dynamic bandwidth prediction and encoding optimization. By applying AI techniques between the cloud and user device, it can automatically adjust the display quality based on the network conditions to ensure stable and high-quality operation and reduces device's dependency on the network performance.

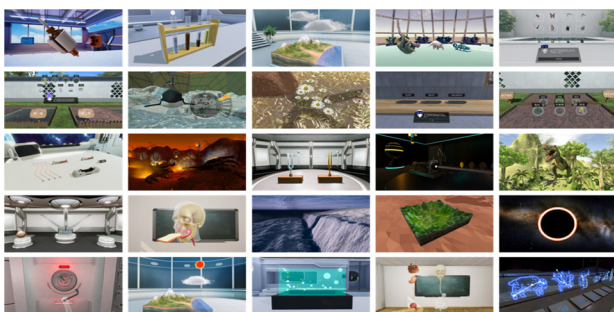
As an innovative project, many schools were eager to observe and learn about this solution during its operation phase. Teachers generally believe that VR teaching methods enhanced students' interest in the contents and improved their focus in class. In addition, because the design of VR course contents fits existing curriculum, teachers can rearrange course materials based on the VR contents without creating any additional burden to students while improving teaching quality.



▲ VR Teaching Effect Survey Results (survey of Chinese teachers, not based on this case)

REFLECTION

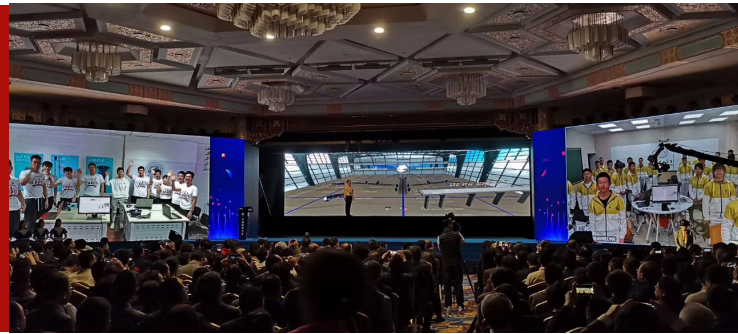
From the outcomes of this project, it is clear that the cloud VR education model raised students' interests and comprehension of course contents as originally expected. To further improve, the following considerations will be important for the integration with education services, in addition to the enablement of 5G and cloud VR technologies:



▲ Examples of Science Courses Based on Existing Teaching Materials

- Commercial VR education contents must offer a comprehensive range of topics, and be tailored to existing teaching materials and consequently fully integrated into the curriculum. It will also be easier for schools to accept if it doesn't create any additional burden to students when transforming the teaching methods. At the same time, the VR contents need to be adjusted for different curriculums in different places to expand the applicability.
 - Trainings are necessary for teachers to enable them to adjust course schedules based on the VR contents, and replace paper materials with VR materials without extending the course as a way to transform teaching methods.
- For the perspective of network and device, large scale edge cloud computing node deployment
- (including AI-based QoE assurance capabilities) that support the VR education platform to ensure coverage to schools within a short range (eg.5 km). Continue to reduce operational costs from contents sharing at the cloud platform, and advance the development of 5G-enabled all-in-one VR headset to optimise performance and costs.

China MOOC Conference: 5G + Remote Virtual Simulation Experiment



Virtual Simulation Experiment is one of the four key scenarios of China Unicom's "5G + Smart Education" initiative, and fully integrates 5G, MEC, cloud rendering, and VR technologies. The remote virtual simulation experiment conducted across three locations during the MOOC conference verified the feasibility of conducting interactive experiments over multiple locations using 5G. It also opened up a whole new area for virtual simulation experiments for higher education and has great commercial value.

Zhang Yong
Head of Network Technology Research Institute, China Unicom

SOLUTION PARTNERS



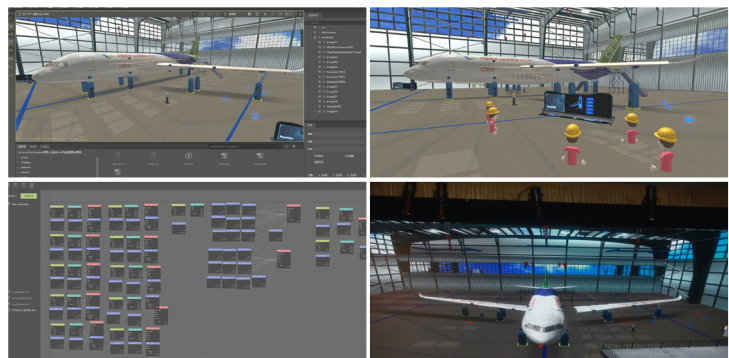
OVERVIEW

At this year's China MOOC (Massive Open Online Course) Conference hosted by the Ministry of Education, China Unicom (main technology partner), Higher Education Electronic Audio-Visual Publishing House, Digital Domain, Parallel Cloud Technology, Shanghai Graphic Design Information, HTC, and Dell partnered together to accomplish the 5G + Remote Virtual Simulation Experiment across Beijing, Guizhou, and Xi'an. It sustained a super-long-

distance communication link over a return distance of more than 4,000 km at a latency of less than 38ms using 5G, and brought together students from different schools in different cities to participate in the same virtual experiment - virtual assembly of the C919 aircraft, that showcased a revolutionary new way of remote education empowered by 5G's high bandwidth and low latency features coupled with MEC and cloud rendering technologies.



▲ Three participating locations on the map and the image of remote interaction in the host venue in Beijing



▲ C919 aircraft wing measurement and assembly experiment interface

CHALLENGES

VR applications require real-time graphical rendering of their contents, and faces the following challenges in a non-5G environment:

- VR devices are expensive and bulky;
- Contents are mostly locally stored and can't be distributed easily and efficiently;

- Difficult to access VR contents and to protect copyrights of content owners;
- Rising bandwidth demands from simultaneous use of multiple VR devices in the same class.

These challenges limited the development of VR in education, but with 5G's high bandwidth, low latency capabilities, VR contents could be stored and processed at the cloud to enable lightweight and wireless devices, real-time cloud rendering, and centralised content distribution; students can in turn enjoy immersive VR educational contents, improve study and experience; and the costs of VR solutions can also be reduced while rights of contents are better protected, which all lead to the overall development of the ecosystem for VR education.

SOLUTION

Project features

The 5G + Remote Virtual Simulation Experiment system integrates 5G, MEC, cloud, and rendering technologies to perform real-time computing and rendering in the cloud and to ensure seamless interactive experience with lightweight and wireless devices. In addition, 5G enables simultaneous and real-time demonstration and operation for a large number of students across multiple locations that satisfies the need to have coordinated participation in the virtual assembly, verification, teaching and field practice of the C919 aircraft scenarios. It greatly improves the effectiveness of teaching, learning and training, breaking the constraints of physical locations, and enables better sharing of quality teaching resources. The followings key outcomes were achieved by the project:

- 5G + 4K long-distance real-time interactive image transmission;
- Network delay of less than 38ms over a return distance of more than 4,000 km between Beijing and Guiyang;
- Real-time optimisation of video encoding/decoding and network latency that facilitated a high quality cloud VR experience;
- Lossless audio and video delivered to device at 3K resolution at 90 Hz refresh rate, with total delay of less than 15ms;
- Precise positioning at millimetre accuracy of multiple VR HMDs (Head-Mounted Displays) within very large areas;

- The virtual simulation experiment during the MOOC conference needed high bandwidth to ensure seamless experience, and a 800Mbps capacity was provided for 20 VR glasses each requiring 40Mbps during the experiment.

Commercial value

For VR related efforts, 296 projects from 184 colleges and universities have been identified as "National Virtual Simulation Experimental Education Projects", known as national Smart Course by the Ministry of Education. These projects are expected to propel scaled development of national Smart Courses and better distribute quality education contents to colleges and universities nationwide.

This project focused initially on education industry customers including not only higher education but also vocational studies and K12 institutions. Contents for higher education and vocational studies are usually specific to curriculum, while K12 tends to use common materials. In the future, the project will shift focus from business to consumer oriented, and gradually increase the amount of paid content and advertisement.

For its equipment and products, this project focussed in early stages on introducing customized lightweight terminals (with 5G modules), 5G data packages, dedicated cloud platform, connectivity solutions, and end-to-end content platform into the market. In later stages, it will bring more quality contents into the platform as its core assets, and then gradually ramp up content creation and copyright licensing efforts to diversify commercially.

REFLECTION

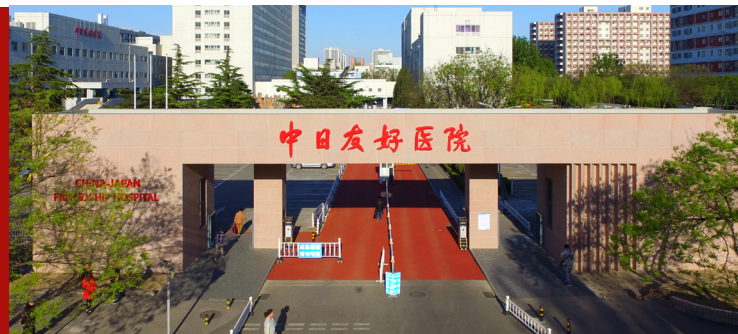
Based on the success achieved so far, the project will plan to focus on the following improvements in next steps:

- 01 Further develop the 5G + VR education cloud platform: Virtual simulation technologies can be further expanded to perform VR/AR, naked-eye 3D, and holographic displays. The 5G + VR education cloud platform provides a comprehensive solution covering 5G capabilities, platform, content, and devices: integrating 5G, MEC, cloud rendering and other key technologies at the network layer; enabling distributed deployment and multi-scenario access at the platform layer; consolidating quality resources from all curriculum in the content layer; and allowing access to VR devices, phones, and web devices at the terminal layer.
- 02 Convergence of technology and teaching: Strengthen

studies of convergence between information technology and experimental teaching methods and enhance studies for the application of VR in experimental teaching to cover as soon as possible VR educational curriculum for all 13 subject categories, 92 majors, and 630 specialities.

- 03 Expand project implementation coverage: Promote the "National Virtual Simulation Experimental Education" projects to local colleges and regional universities in western China. Strengthen teacher training to improve their capabilities to adopt VR and AI technologies in teaching. Focus on consolidation of resources during project implementation and effectively ensure benefits and rights of participating developers and stakeholders are well protected.

5G-empowered Hospital Network Architecture Standard



A good top-level design is necessary for the development of "Internet + Healthcare" for primary healthcare, together with a well-established framework to execute policies at every layer of the system. If specifications and standards are not in place and primary levels are allowed to operate as they wish, a harmonized system will then be very difficult in the future. This Standard builds on our previous experiences and consolidates knowledge of experts from both healthcare and communications to integrate 5G into hospital information systems. The Standard introduces 5G as a key infrastructure element for digital primary healthcare, helps expedite "Internet + Healthcare" deployment, improves the service capabilities of primary healthcare providers, and increases the level of convenience for accessing healthcare services.

Zhang Yong
Head of Network Technology Research Institute, China Unicom

SOLUTION PARTNERS



OVERVIEW

In May 2019, the National Telemedicine and Connected Health Centre initiated a project for the "Hospital Network Architecture Standard Based on 5G Technology" (the Standard) together with partners from both the health and communicators sectors, such as more than 30 provincial and ministry-level hospitals including the China-Japan Friendship Hospital, the China Association of Medical Equipment, the China Academy of Information and Communications Technology (CAICT), China Mobile, China Telecom, China Unicom, and Huawei. Drafting officially commenced on 4 September and was divided into three volumes on 5G wireless access network, edge computing, and 5G equipment and modules.

By October, the number of partner hospitals had grown to

95. After comprehensive validation, the first volume on 5G wireless access network was officially released on 19 October and had since been implemented by 35 hospitals in their respective networks and would be adopted by another 150 hospitals by the end of 2019.



CHALLENGES

Severe imbalance in the distribution of healthcare resources and poor clinical diagnosis and treatment capabilities at the primary healthcare level in China have gravely undermined the goal to provide fair access to health and medical services for the people. Measures such as the establishment of a tiered system of diagnosis and treatment, interconnected hospitals, promotion

of telemedicine, Internet diagnosis and treatment, Internet Hospitals are all important elements of the state's efforts to better distribute healthcare resources and to facilitate greater equality in accessing primary health services.

However, there is a significant gap in understanding between the communications and healthcare sectors. The communications sector doesn't understand specific requirements for 5G from medical applications and services, while the medical sector finds it difficult to construct details requirements due to the lack of understanding of communication technologies. There are over 13,000 hospitals at the Class II and above in China, and the sheer costs of mis-communication would be unthinkable if all of them were to deploy 5G networks.

The National Telemedicine and Connected Health Centre and the China-Japan Friendship Hospital since proposed that the priority was to establish standards for hospital 5G networks to provide a uniform reference to hospitals to upgrade their information systems, which would in turn expedite deployment of 5G networks and applications in hospitals, reduce costs of information sharing and interconnect between medical institutions, and accelerate the provisions of universal healthcare services. The healthcare sector responded swiftly to the proposal with 95 hospitals and the China Association of Medical Equipment soon starting the preparatory work together with the communications sector for the Standard.

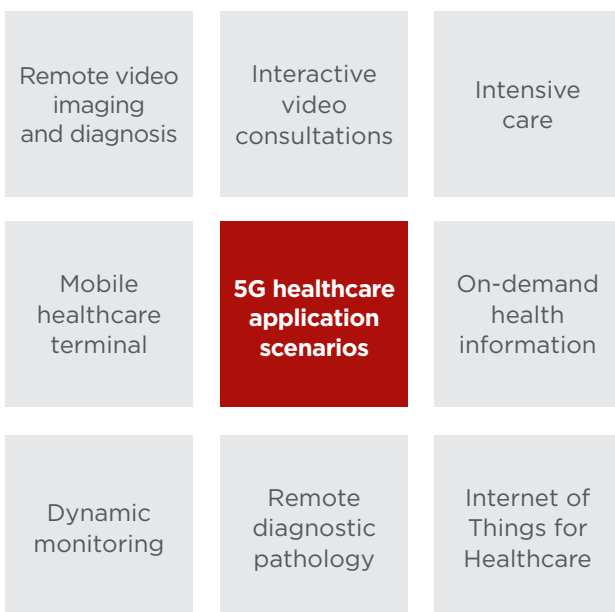
SOLUTION

The Standard covers the entire value chain and divides a hospital 5G network into three parts - the 5G radio access network, edge computing, and 5G medical modules which are then described in details across three volumes respectively. The first volume on 5G radio access network was released on 19 October, 2019 and contained requirements for 5G networks in areas such as functionality, performance, security, reliability, maintenance, environmental impact, and future evolutions that had been validated by nearly 100 hospitals, and research institutes and companies from the communications sector.

To provide flexibility to hospitals to deploy networks that meet their specific needs, the Standards specified typical 5G healthcare application scenarios with the corresponding technical specifications. There eight typical 5G healthcare application scenarios:

Remote Imaging Diagnosis Video Interactive Consultation Intensive Care Unit Mobile Care Terminal Convenience Information Services Dynamic Medical Monitoring Remote Pathological Diagnosis Internet of Medical Things 35 hospitals completed their deployment of 5G radio access network in alignment with the Standard, which in turn benefited 17% of their doctors and 23% of patients with the efficiency and convenience gains from the 5G healthcare applications.

According to plan, the volumes on edge computing and 5G healthcare modules will be issued in June and September 2020 respectively. The volume on edge computing will focus on the development of 5G healthcare applications and smart service platforms, while the volume on 5G healthcare modules will define relevant technical parameters to lay the foundation for the development of specialised medical devices. The Standard is expected to become the benchmark for the Chinese healthcare industry and be promoted nationwide after being trialled and tested through extensive pilots. It is likely that more than 990,000 medical and health institutions across the country will deploy 5G healthcare applications as and when required to achieve interconnect and collaboration, to improve efficiency of healthcare services, and to ultimately afford every patient the opportunity to conveniently access quality healthcare services.



REFLECTION

The Standard's first volume on 5G radio access network had been adopted by 35 hospitals to guide their deployment of 5G as soon as it was released, which showed that it contained appropriate and useful information for hospitals, and also that taking proactive steps to establish a uniform standard was an effective approach.

The successful introduction of the Standard can be attributed to the following three factors:

- **Unify service standards:** As people's demand for healthcare continues to rise, issues around imbalanced distribution of healthcare resources and their high costs are becoming increasingly salient. Practical demand drives the healthcare system to strengthen its information infrastructure and to create innovative services through unified 5G network and smart service platform, which helps mitigate geographical limitations and enhance capabilities of less-equipped hospitals. Patients will also be able to access high-quality medical service from other cities at a hospital near them, reducing their needs to travel and consequently their costs for healthcare. It also complements different capabilities between general hospitals and specialist hospitals to provide patients with the most comprehensive treatment without having to transfer them between hospitals, and to improve the efficiency of healthcare services.
- **Bridge understanding:** 5G's large bandwidth, low latency, and massive connections coupled with key technologies such as network slicing and edge computing provide unprecedented opportunities for innovations in healthcare services. At the beginning of 5G commercialisation process, the development of the Standard helps guide innovations for healthcare services and serves to ensure the rigor and professionalism of the healthcare sector and prevents a fragmented market. At the same time, innovative healthcare services benefited from not only collaborations between hospitals and the communications industry, but also contributions from other sectors such as medical equipment and medical software. The greatest challenges here are the lack of

a common language between sectors and the lack of understanding of each other's needs. One of the goals of the Standard is therefore to employ a common language for dialogue to break down communication barriers between sectors. Stakeholders from different sectors, upstream and downstream, supply and demand sides can all specify what they need in line with the Standard and avoid hefty opportunity costs of mis-communications.

- **Forge partnerships:** the project brought together representatives from the National Telemedicine and Connected Health Centre, the China Association of Medical Equipment, 95 hospitals, the CAICT, three mobile operators, and Huawei to form a Standards Working Committee to conduct joint research and studies. Partners in the project are all leading players in their respective sectors (the National Telemedicine and Connected Health Centre connects some 5,300 medical institutions and more than 30 provincial and ministry-level hospitals, while other partners include players among the top ten mobile operators globally). This, together with the strong endorsement by the National Health Commission, has created clear demonstrative effect and push for the implementation of the Standard. At the same time, the Standard brought many benefits to the entire industry: for medical institutions such as hospitals, the provision of universal healthcare services demonstrates their social responsibility; the use of information technologies to improve healthcare coverage and serve more patients lays the foundation for higher revenue, improved medical services and overall competence for hospitals; incentivised digital transformation of the health sector, and created new growth market opportunities for medical software development and medical equipment; the implementation of 5G in hospital networks has also provided the communications industry with new growth opportunities, and examples for working with other vertical industries.

In next steps, the project will continue to finish the remaining two volumes on edge computing and 5G healthcare modules.



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