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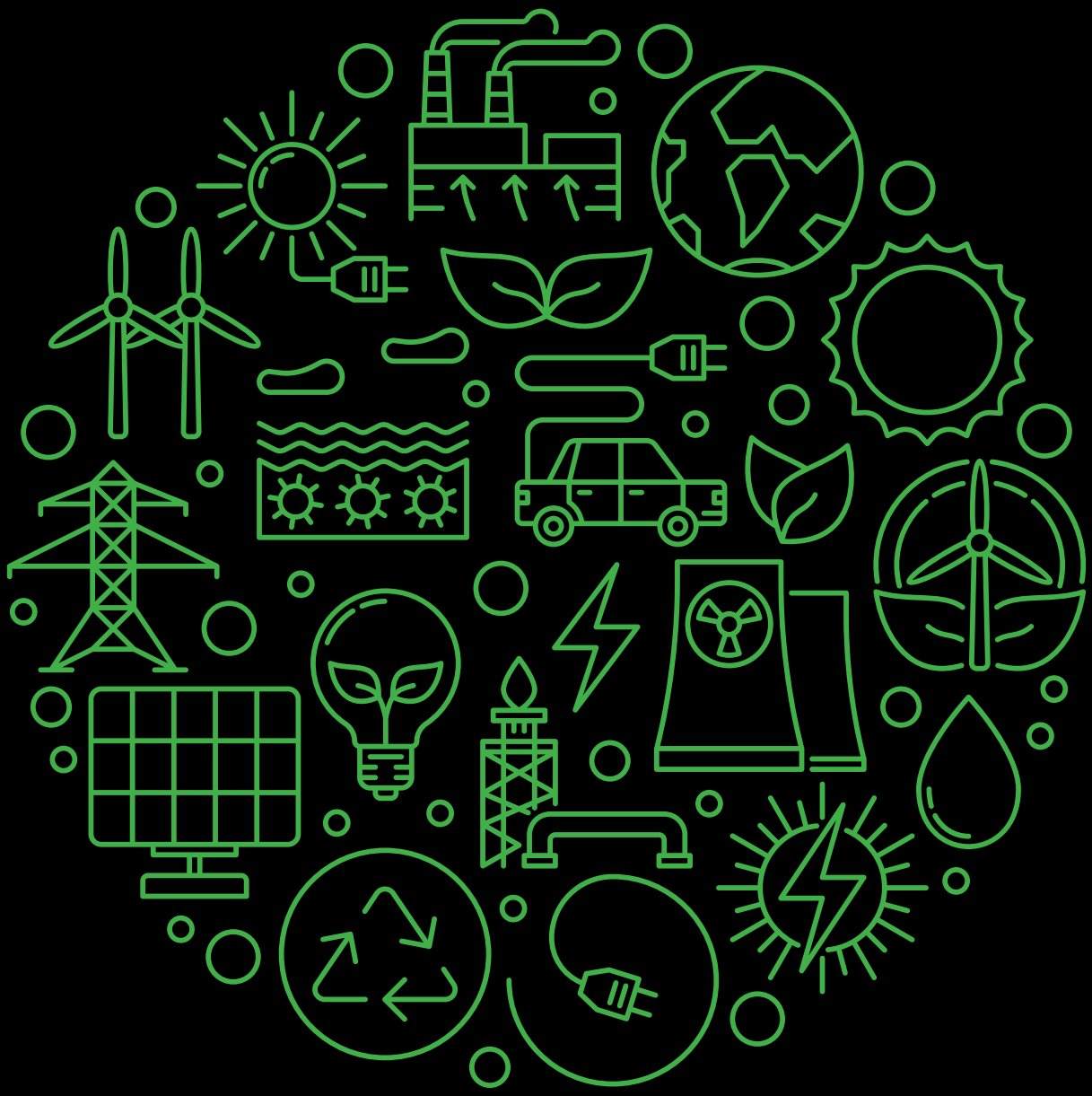


5G smart cities whitepaper

June 2020

Preface

With the rapid development and accelerated transformation of the economy and society, the limitations of traditional city management are becoming more prominent. As urbanization gains speed around the world, in order to cope with the challenges in population, resource, and the environment, many countries have resorted to smart city as a new concept in city development and a practical road ahead.

In traditional smart city practice, the sheer number of smart applications and the extensive scope of developments make it easy for one to lose focus in urban planning and development. What's more, regional disparity in industry development and resource get in the way of overall execution. The daunting scale of investment, lack of clarity in business model, inconsistent technical standards and serious fragmentation of data and information have added to the difficulty of fostering a synergy in smart city development, challenging city managers, builders and operators.

This is the context where the central government of China put forward the idea of a "New Type of Smart City", pointing city development in a new direction. The strategy calls for a full integration of next-generation IT technologies with the needs of city development, connectivity among terminals in the city and the use of digital technologies to empower refined city management.

5G network, as the latest wireless communication technology featuring ultra high speed, super low latency and massive connectivity, is bound to have a profound impact on smart cities. With 5G-based ubiquitous sensor network (USN), the Internet of Everything can become a reality in smart cities, where people, machines and things are highly integrated. When fused in depth with next-generation ITs like cloud computing, big data, AI and IoT, the 5G network can flexibly allocate network resources to different usage scenarios, so as to meet the needs for differentiated network services in a smart city. In this sense, the 5G network acts as critical blood vessels, pumping blood to the development of smart cities.

With their critical capabilities in 5G network, big data and cloud computing, telecommunication operators have an irreplaceable role to play in building the infrastructure of smart cities. Given the challenges in smart city development, how do telecommunication operators efficiently provide network infrastructure and connectivity services, foster a new ecosystem where stakeholders build, govern and share the benefits together, and develop smart applications with ecosystem partners? This is an essential question for telecommunication operators to consider when participating in smart city development in the 5G era.

1. Smart city development in the new era

1.1 The context of smart city

Urbanization is one of the most important social economic phenomena in today's world. As of now, 50% of global population live in cities. As urbanization picks up speed, this figure is expected to exceed 70% by 2050. As more people flock to cities, new mega-cities and city clusters begin to take form. At the same time, problems such as traffic congestion, pollution, resource scarcity and lowered quality of life become more prominent, making sustainability a shared concern of city managers. The concept of smart city was conceived in such context. It advocates for the use of advanced technologies, particularly IT technologies, to achieve sustainable city development, and promises to be a best solution for sustainability to city managers.

Meanwhile, information and communication technologies are burgeoning around the world. Key technologies like 5G network, IoT, cloud computing, big data analytics, and next-generation geoinformation system, once novel concepts on paper, are being experimented on and implemented in real applications. This has spawned new usage scenarios and innovative management models, bringing more possibilities to smart cities. As information technologies mature, the condition becomes ripe for digitalization and smart management of the city, which can effectively solve urbanization-related problems, laying a solid foundation for smart city development.

1.2 Updates on overseas and Chinese smart city development

Since the end of the 20th century, with rapid urbanization around the world, the sprawling of cities has made urban planning and management an increasingly difficult job for governments to do. This is the context where countries or regions turned to smart city, which went through three stages of development. In 2012, smart city initiatives were dominated by large technology companies, who focused on the issues of city operation in various verticals by providing tools and technical solutions. However, their interests in technologies blinded them to the real needs of city development. It was not until 2014 that leading governments took over the steering wheel and put great efforts into overall planning and technological application, which improved the quality of city operation. Since 2017, governments have actively involved the private sector and constantly explored new and niche areas, ushering smart city development into a new stage. Up till now, there are over 1,000 ongoing smart city projects around the world.

Figure 1: Development history of global dmart cities and where they are

Smart city 1.0: Technology-driven
1999-2012

Features: led by IBM, Cisco and other major tech companies, focusing on problem-solving in different urban operation verticals through IT means

- **In 1999, Singapore announced its Intelligent Island initiative,** aiming at promoting the use of IT in areas such as urban energy consumption, traffic congestion and environmental pollution
- **In 2007, France initiated comprehensive development plans for Greater Paris,** one of which was reforming Paris' closed traffic network through intelligent management of bicycles with "Public Bicycle Management System"
- **In 2010, for the Portugal PlanIT Valley Initiative,** Cisco was tasked to develop an IoT ecosystem of connected smart devices and then integrate it into urban development process to tackle energy and waste management issues

Smart city 2.0: Government-led
2014-2016

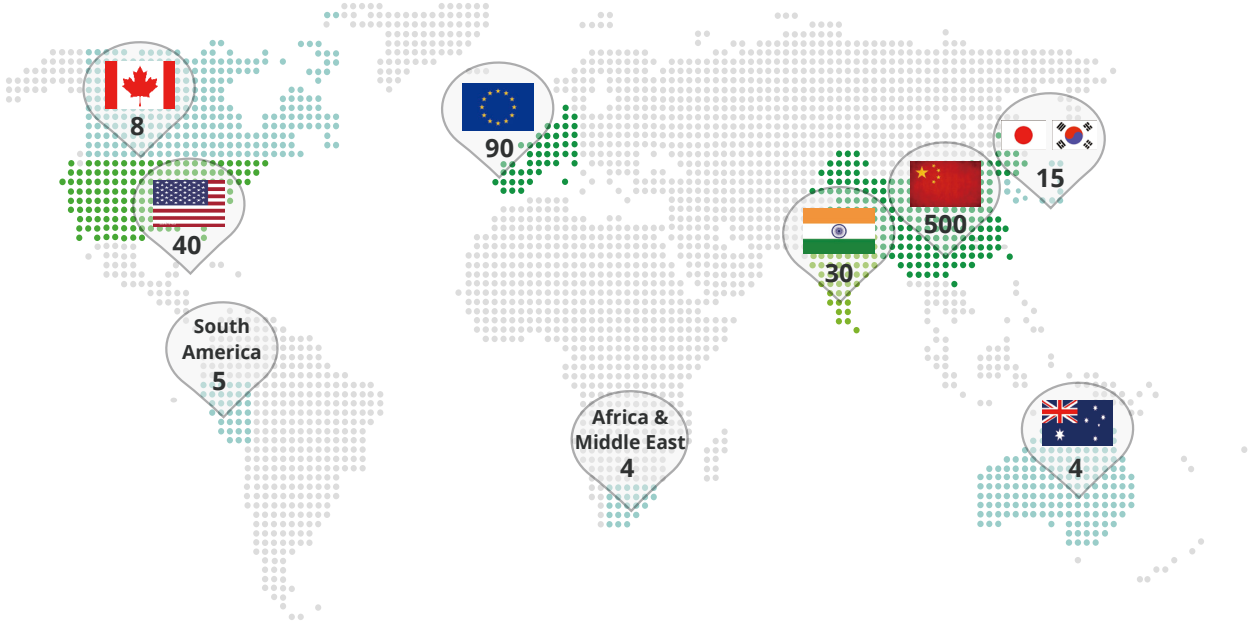
Features: based on urban development requirements, governments formulate plans on the overall use of technological solutions to improve municipal operation efficiency

- **In 2013, London, UK** launched its first citizen-centered smart city plan to make city operation more efficient through the use of technologies
- **In 2014, the Korean government** put forth the idea of "Big Data for small problems" with an aim of building a people-centered, IT-driven smart city teemed with creativity
- **In 2015, the US government presented a new "smart city" proposal** with active plans for intelligent transportation, power grid and broadband to tackle urban transportation and energy issues
- **In 2015, India planned on building a hundred smart cities with PPP model.** Its government announced a 7.5 billion-dollar investment scheduled in the next five years for such development

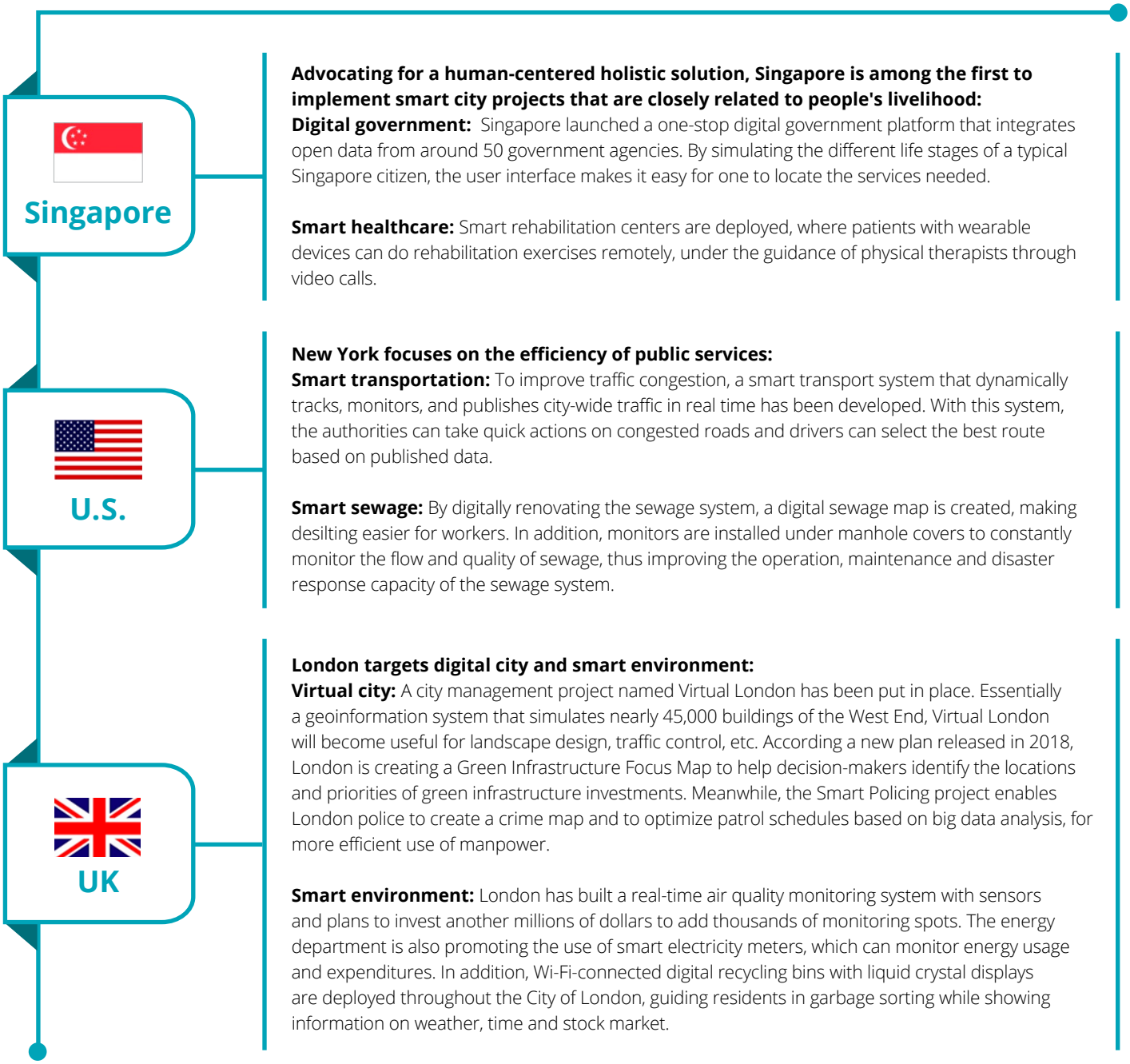
Smart city 3.0: Society-backed
2017-now

Features: Governments give guidance and encouragement to citizens and companies for participating in the smart city development, serving the public through the use of data

- **Since 2016, Vienna has worked with local energy company WienEnergy** to encourage citizens to buy modules from the company and become investors of "citizen solar power plants"
- **In 2017, Amsterdam introduced competitive tendering for public utility projects in its smart city plan** to incentivize companies to participate in the building and integration of intelligent transportation and smart grid systems
- **In 2018, London announced the "Smarter London Together" roadmap** to improve life in city by allowing companies to participate in R&D activities and apply new digital technologies in smart city development
- **In 2019, Canada announced a plan to build a smart city in Toronto with a billion-dollar investment co-funded by companies,** which will be used to bring in necessary technologies and equipment



In selecting which application scenarios to execute, leading countries would refer to top-level design and consider the current development, needs and future positioning of a city, before deciding upon its goals, types of projects and priorities, allowing the city to cultivate its unique features.



Advocating for a human-centered holistic solution, Singapore is among the first to implement smart city projects that are closely related to people's livelihood:
Digital government: Singapore launched a one-stop digital government platform that integrates open data from around 50 government agencies. By simulating the different life stages of a typical Singapore citizen, the user interface makes it easy for one to locate the services needed.

Smart healthcare: Smart rehabilitation centers are deployed, where patients with wearable devices can do rehabilitation exercises remotely, under the guidance of physical therapists through video calls.

New York focuses on the efficiency of public services:
Smart transportation: To improve traffic congestion, a smart transport system that dynamically tracks, monitors, and publishes city-wide traffic in real time has been developed. With this system, the authorities can take quick actions on congested roads and drivers can select the best route based on published data.

Smart sewage: By digitally renovating the sewage system, a digital sewage map is created, making desilting easier for workers. In addition, monitors are installed under manhole covers to constantly monitor the flow and quality of sewage, thus improving the operation, maintenance and disaster response capacity of the sewage system.

London targets digital city and smart environment:
Virtual city: A city management project named Virtual London has been put in place. Essentially a geoinformation system that simulates nearly 45,000 buildings of the West End, Virtual London will become useful for landscape design, traffic control, etc. According a new plan released in 2018, London is creating a Green Infrastructure Focus Map to help decision-makers identify the locations and priorities of green infrastructure investments. Meanwhile, the Smart Policing project enables London police to create a crime map and to optimize patrol schedules based on big data analysis, for more efficient use of manpower.

Smart environment: London has built a real-time air quality monitoring system with sensors and plans to invest another millions of dollars to add thousands of monitoring spots. The energy department is also promoting the use of smart electricity meters, which can monitor energy usage and expenditures. In addition, Wi-Fi-connected digital recycling bins with liquid crystal displays are deployed throughout the City of London, guiding residents in garbage sorting while showing information on weather, time and stock market.

During the building of smart cities, network infrastructures face many requirements in terms of bandwidth, network coverage and speed. Besides physical infrastructure, communication network is often regarded as another important infrastructure in the smart city plan overseas. With the emergence of new 5G technology, many countries are actively upgrading their networks, hoping to drive smart city initiatives via commercial 5G deployment.

Singapore

The Intelligent Nation 2015, published in 2006, proposes the building of a fast, widely covering and secure infocommunciation infrastructure that achieves 90% home broadband coverage.

In the Intelligent Nation 2025 master plan that was published in 2014, the core ideas become Connect, Collect and Comprehend, which stress the importance of data analysis and sharing on top of telecommunication network and sensor network. The objective of Connect, in particular, is to build a nationwide telecommunication infrastructure that is secure, fast, economical and expandable.

According to the Infocomm Media Development Authority in 2019, two independent 5G networks will be launched in Singapore in an effort to strengthen its network facilities.

To avoid the subsequent problem of data integration, in its top-level design, Singapore unified IoT designs and sensor standards as early as 2015 to support the interoperability and interworking of data across various facilities.

U.S.

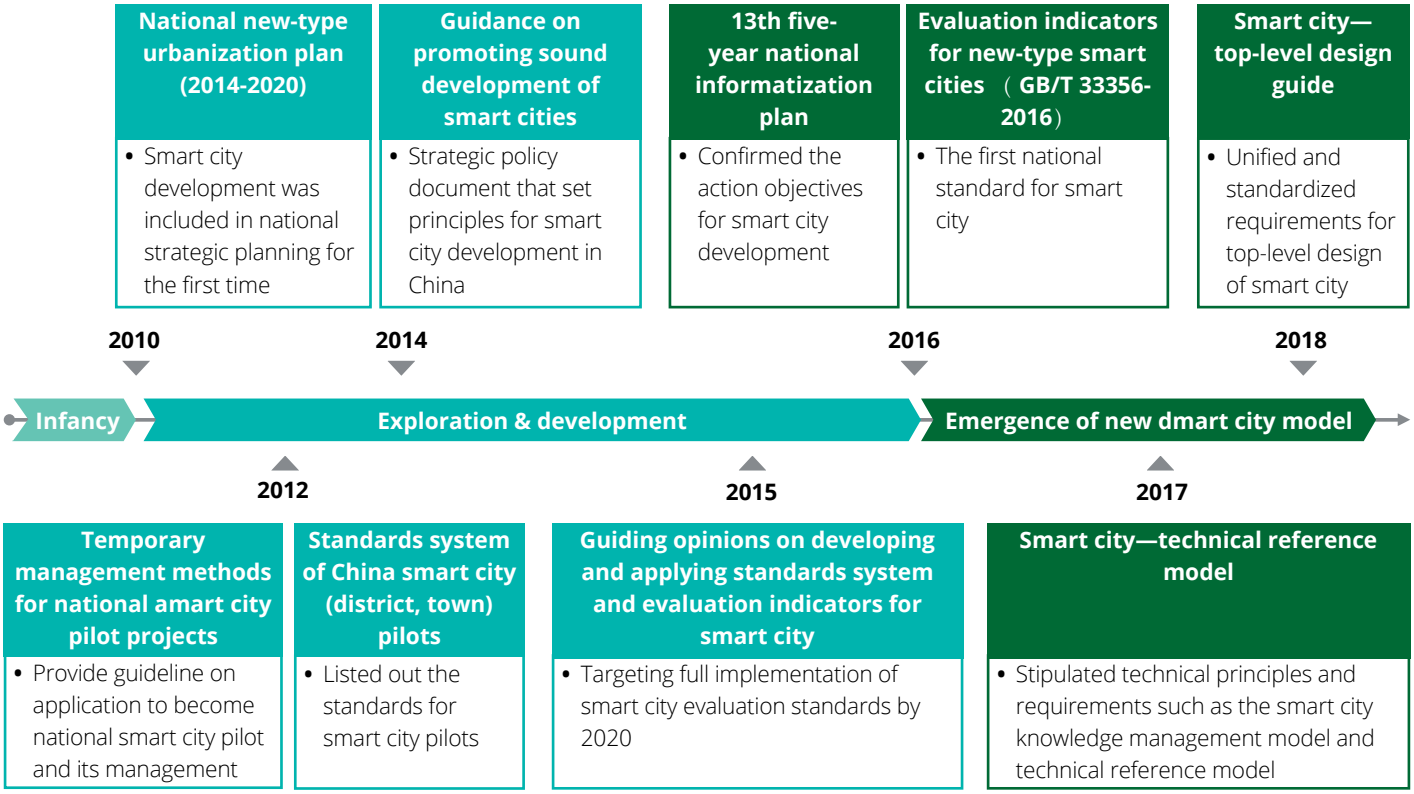
In 2009, the city of New York launched Connected City initiative, which proposed to expand broadband and digital service coverage. The OneNYC 2050 published in 2019 highlights the plan of the city to accelerate broadband roll-out for improved coverage, build 500 public network centers, open more free public Wi-Fi hotspots, develop a mechanism to fend off network risks and provide fast, easy-to-use and secure network services. Furthermore, **in 2019, New York supported the 5G pilot programs by telecommunication companies such as T-Mobile to facilitate future network upgrading.**

UK

In 2018, **the mayor roadmap Smart London Together was published, in which one of the five missions was to build world-class connectivity by promoting 5G projects, enhancing public Wi-Fi in streets and public buildings, achieving full fiber to the home in new real estate developments,** etc. In addition, a city-wide network security strategy has been drafted to improve the security of telecommunication networks. **London became one of the first UK cities to enable 5G services in 2019, which marks a step forward in its ability to provide network services.**

In China, smart city development is marked by three stages: infancy, exploration and the emergence of new smart city models. Prior to 2010, the smart city initiatives in China were mostly technology driven, lacking in top-level design and consistent planning. The focus of the infancy period was digitalization, backed by urban network and data infrastructures, with the adoption of remote sensing technology, geoinformation technology and global positioning system for data collection and monitoring.

Figure 2: The development trajectory of Chinese smart cities



In the exploration phase that began from 2010, China published development plans for smart cities and announced several rounds of pilot cities for experimentation. The policies published then were dominated by plans, guiding opinions, project management methods and so on. It was also during this time that the problems of information silo, repeated development and homogeneity began to surface.

In 2016, the government clearly pointed out in its 13th Five Year Plan that a new type of smart cities should be developed and that priorities should shift from spreading the ideas to doing the work. With the release of smart city evaluation models and national standards, a system of standards for smart cities began to form in China. In particular, the Smart City -- Top-Level Design Guide published in 2018 unifies the requirements of top-level design, with the design concepts and realization process clearly explained. According to the document, digital technologies that make cities smarter will safeguard the development of smart cities. By creating digital twin cities that are parallel to the real world, simulation can be run to guide smart city development.

In recent years, China has obviously picked up its pace in smart city development. Among the many smart applications, one of the more well-

developed ones is smart government. With digitalized government operation and streamlined process, dealing with the government is made much easier for the people. As a core driver to smart government, government cloud has come a long way with the staunch support of national policies. According to the 2019 White Paper on Cloud Computing by the China Academy of Information and Communication Technology, as of 2018, government clouds have achieved full coverage of the 31 provincial administrative regions, with 75% coverage of prefecture-level administrative regions. In the same year, the State Council required further promotion of the "Internet + Government Services" in its Guiding Opinions on Accelerating the Development of a National Integrated Online Government Service Platform. The National Government Service Platform, launched in 2019, connects the government service platforms of 31 provinces (districts, cities) and some 40 State Council departments, with access to over 3 million services provided by local governments, significantly boosting government efficiency via process optimization and platform interconnectivity.

Other than smart government, smart transportation is another area that is being actively explored by a few cities. Smart transportation deploys IoT for full awareness of transport operation and engages big data analytics and cloud computing to generate appropriate handling strategies and traffic dispatching strategies, for a safer transport system with higher efficiency and fewer accidents. For example, the city of Jinan has optimized the signal timing for downtown crossroads. By monitoring real-time traffic and analyzing congestion data, congested roads that need immediate attention are highlighted and the projected handling results are shown. In Hangzhou, the smart transportation system assists the police in processing accidents. Sensing devices such as cameras perceive the accident scenes and send collected information to the back-end system for analysis, which will then reach a decision and share with the police to achieve smart police dispatching.

Figure 3: The smart city policies and years of publication by local governments

In Xiong'an New Area, a brand-new town, **smart city initiative is being rolled out in parallel with infrastructure construction**, giving birth to a new model and template. With a focus on four areas: **government service, public well-being, livability and industry development**, the Xiong'an smart city initiative will demonstrate various application scenarios with its ongoing pilot programs across many areas:

Xiong'an Citizen Service Center: As an administrative agency of the Xiong'an New Area, the Xiong'an Citizen Service Center serves many functions, including display of the overall plan of Xiong'an, government services, convention venue and office space. In walking the talk on environmental protection, the Xiong'an Citizen Service Center has prohibited fossil fuel vehicles from entering the premises since its first day of operation, and has put into use unmanned supermarket and autonomous vehicles, embodying its "green, modern and smart" visions.

Smart environmental protection: To put into action the idea of "greening before city building", Xiong'an embarked on its Millennium Forest Project in 2017. Every single one of the over 12 million trees in the forest comes with a QR code ID for the purpose of full life cycle management and tracking, enabled by a smart platform that incorporates big data, block chain, cloud computing and other technologies.

Blockchain: According to the Guideline for Planning of the Xiong'an New Area in Hebei Province, Xiong'an must clearly define its industry development priorities and take the lead in studying, developing and testing blockchain technology. As of now, Xiong'an New Area has tried out many blockchain applications. For example, in the Millennium Forest Project, blockchain technology is applied in fund monitoring. By binding the salary card numbers of tree-planting workers to a block chain system, the flow of money can be dynamically documented and tracked. Another case in point is the blockchain platform on the compensation and resettlement funds for demolished houses. Launched by the Administration Committee for the Xiong'an New Area, the blockchain-empowered platform supports full process management of original demolition and requisition files, compensation and resettlement funds, ensuring transparency in the flow of money.

Having completed its top-level design for digital and smart city, Xiong'an is now embarking on large-scale implementation. It is also busy deploying city-wide smart infrastructures including urban IoT, telecommunication facilities, full-coverage and application of 5G technology.

Looking to the future, the Xiong'an New Area will continue the construction of world-leading infocomm infrastructures and deepen the development of City Brain, an overall situation-aware smart city management model based on data analysis, decision-making and governance, to create fast-responding, efficient and coordinated solutions for the refined management of transportation, security and environmental protection.

In response to the calling of the central government, directly-governed municipalities such as Beijing, Shanghai and Tianjin, sub-provincial cities such as Nanjing, Hangzhou and Guangzhou, prefecture-level cities such as Hefei, Yinchuan and Suzhou and county-level cities such as Kunshan, Jiangyin and Yuyao have joined the smart city rally and engaged in smart city initiatives with different priorities based on their distinctive economic and industry niches.

Suzhou, a National High-Tech Industrial Development Base and one of the central cities in the City Cluster of Yangtze River Delta, is leading the rest of the country in smart city development, industry upgrading and many other fronts. In 2012, the Suzhou government published the Smart Suzhou Planning, which marks the beginning of the city's exploration in many fields:

Smart logistics: Suzhou Industrial Park Comprehensive Bonded Zone, China's first comprehensive bonded zone, is applying IoT, RFID license plate management, video surveillance examination and other smart technologies in building a mobile examination system that collects and transmits information on on-site examination and logs in examination results, in order to improve the quality and efficiency of examination and drive smart logistics forward.

Smart government: As a national economic and technological development zone, Suzhou Industrial Park is home to the first specialized government cloud on a comprehensive geographical coordinate platform. Within the park, a private e-government network covers over 400 nodes, facilitating the migration of e-government to a cloud-based model. Boasting three major databases: geographical information database, legal entity database and population database, with coverage of multiple departments, Suzhou Industrial Park offers seamless connection with multiple nearby airports, ports and airline companies in support of automatic verification and write-off for trade as well as paperless customs clearance.

Smart pipeline network: The comprehensive pipeline corridor located in Taihu New Town, Wuzhong District, Suzhou, is one of the first national pipeline corridor projects and a key national engineering project. Based on monitoring needs, sensors of various types are installed in the right locations along the pipeline corridor. BIM, IoT, mobile connectivity, AI and big data are combined in developing a smart management platform for the corridor, greatly improving the ease of maintaining and repairing power, telecommunication, gas and water facilities. This system also serves the purpose of disaster relief and earthquake prevention, to some extent.

One of the first Chinese cities to begin smart city planning and development is Yinchuan, which has deployed six modules in smart security, smart government, smart transport, smart environmental protection, smart health care and smart tourism to resolve its long-standing problems, greatly enhancing urban management and people's quality of life.

Smart public transportation: To solve the issues of public transportation, Yinchuan connects a geoinformation system with real-time traffic data to predict traffic volume in real time. In addition to releasing a real-time bus tracking app for citizens, in all of its BRT platforms, Yinchuan has installed LED displays with information on the location of the next bus, making it easier for passengers to track bus operation.

Smart environmental protection: Online monitoring devices for water, gas and sound are installed in the smart communities and key enterprises of Yinchuan to collect raw data for future use in environmental protection. These devices are online 24 hours a day, tracking and gathering data in real time on water quality, air and noise. Collected data will be routed to the Yinchuan Smart Environmental Protection System for real-time tracking and analysis.

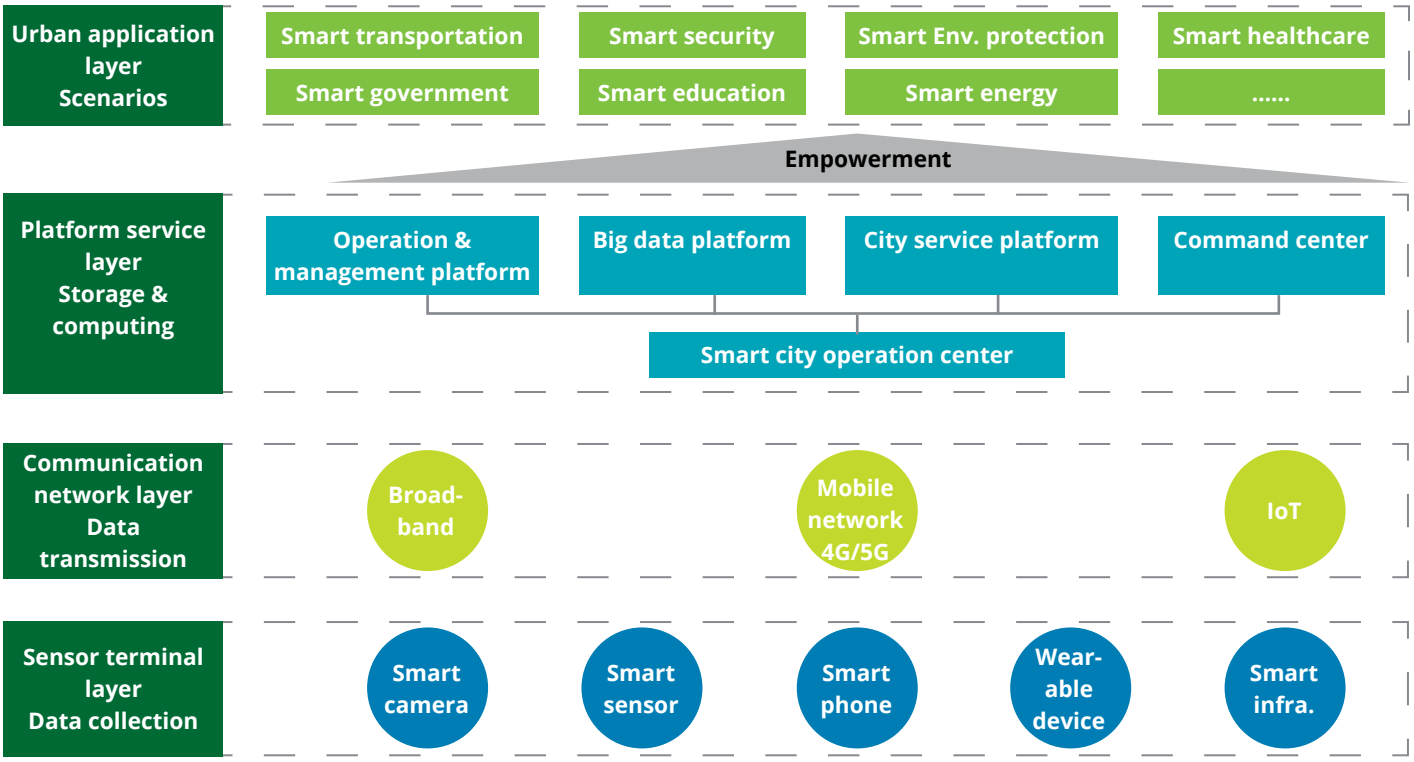
Smart healthcare: In the outpatient lobbies of the Yinchuan First People's Hospital and People's Hospital of Ningxia Hui Autonomous Region, smart guidance robots have replaced information desk nurses in receiving patients, giving directions and information. Enabled by big data and AI technology, the robot doctors employed by Yinchuan Tumor Treatment and Diagnosis Center can quickly come up with one or more customized treatment regimens for patients and kindly provide the source of relevant literature and successful cases for patients and attending physicians to consider.

1.3 5G Brings new momentum to smart city development

1.3.1 5G-led ubiquitous sensor network as a cornerstone in smart city development

The overall architecture of a smart city consists of four layers: **terminal sensor layer, communication network layer, platform service layer and city application layer**. The operational data perceived at the terminal can be obtained by modifying traditional infrastructures (i.e. water, electricity, gas, road, transport hub, etc.) through the use of technology so that they become smarter and more digital. Communication infrastructure, which includes fixed line broadband, mobile network, IoT, private network and others, serves as a pipeline for information and data transmission. Data platform infrastructure is used to store, exchange, analyze and process data and information. The combination of communication network with basic technologies, such as cloud computing and AI, gives birth to or optimizes many general technologies, which can then be applied to different industry verticals to empower the various application scenarios in a smart city.

Figure 4: The overall architecture of Chinese smart city



Judging by the trajectories of smart city development in China and the rest of the world, communication network deployment is one of the priorities for many countries. Terminal data collection, data transmission via communication network, data storage and computing are all indispensable to realizing smart city applications. Among them, communication network has a particularly important role to play as a channel linking data collection with data processing.

With the extensive application of IoT terminals in infrastructure, massive data are driving smart cities onto a deeper level, from parallel development in the early days to the current system integration. This means fixed line broadband and 4G network alone for data transmission can no longer fully meet the needs of future smart city scenarios, given their disadvantages such as high installation and replacement costs, low flexibility, low bandwidth of wireless network and long latency.

The 5G-based ubiquitous sensor network will become the cornerstone of smart city and one of the key infrastructures for the Internet of Everything, where people, machines, and things become deeply integrated. Featuring ultra-high speed, ultra-low delay and massive connectivity, 5G will provide all-round support to the innovation and development of smart city. At the same time, through integration with next-generation information technologies, including AI, big data analytics, cloud computing and IoT, 5G will profoundly alter every aspect of the city, including production, people's daily life and city governance.

High bandwidth, low latency and massive connection

As an upgrade to existing communication network, 5G network will meet the needs of smart city applications for high bandwidth and low latency in mobile networks, while enabling the connection of massive small, low-cost sensors, which will provide basic guarantee for data-driven decision-making and governance on a large scale. Transmitted through the 5G network, the massive data generated by smart cities will be processed and analyzed using next-generation information technologies, including AI and cloud computing, to unleash greater potential in a variety of vertical segments and application scenarios of smart cities.

1.3.2 The unique ability of 5G network to meet the differentiated needs of smart city

What can 5G actually do for a smart city? More than a simple upgrade of the 4G network, 5G is a revolutionary network of the future. The 5G-based ubiquitous sensor network plays the role of a bridge connecting all things together, reaching all areas of the city like a neuron network, prepared serve demands that are rapidly changing, diverse and personalized. Crowned as the foundation of smart cities, how 5G network should be built becomes a question of utmost importance.

Most traditional network equipment is communication device with integrated software and hardware, unable to support a network designed to accommodate continuous application innovation. To break such limits, in recent years, operators around the world are committed to "network reconstruction" with software defined network (SDN) and network function virtualization (NFV) using general IT equipment.

5G enables the Internet of Everything and diversified applications, which will in turn drive its core network to embrace SDN, virtualization, cloud and smart technologies. Compared with the current communication network, a major change of 5G is **a service-based architecture at its core network**, where network elements are software-hardware decoupled through NFV to achieve system-as-a-service and hardware pooling, allowing the 5G network to flexibly allocate resources based on needs.

In addition to architectural change, with network slicing and edge technologies, the 5G network will become better at providing customized and user-friendly services, integrating network with business, and flexibly deploy on demand.

Key service capabilities of 5G network

Network slicing: A key feature of 5G standalone (SA) core network with virtualization technology, 5G network slicing can categorize resources and functions by logic, edit or customize network functions, and orchestrate network resources, creating on demand independent, isolating virtual networks on the same infrastructure for different application scenarios. With the sharing of 5G network, scarce spectrum resources are saved, and industry-specific private networks are set up.

5G + network slicing enables the private use of public network by different industries within the smart city.

Virtual private network: Wireless access to shared public network via end-to-end network slicing is a low-cost, quick-turnaround solution for industry clients who have temporary needs or have requirements that can usually be served by the public network.

Main application scenarios: Network slicing can be used to quickly configure a large broadband network for high-definition event streaming on the media.

Integrated private network: Wireless access to multiplex 5G public network on authorized spectrum, with customization on the network side for the right reliability and business separation, can fulfill the SLAs for industry clients who need more than what the public network can offer.

Main application scenarios: Hospitals and traffic hubs, where patients and passengers need access to the public network, while staff and merchants need private networks. User data can be separated at the terminal level. Or, physical and virtual private networks can be merged to meet differentiated needs, by setting up independent internal core network or multiplexing the air interface of public network.

Physical private network: A private network physically isolated from the public network on dedicated frequency with wireless equipment can meet the needs of industry clients that expect high reliability and privacy. This solution supports flexible customization, with high reliability and complete isolation.

Main application scenarios: Physical private networks for government agencies and industrial parks via the setup of independent network facilities.

Edge computing

Computing systems with edge devices are created with 5G-based AI and edge computing technologies to locally process massive data, instead of sending them to the core network, to save bandwidth and reduce latency. This will give rise to a clearly-structured and highly efficient cloud service system to enable the intensive development, rapid deployment and quick response of smart city applications. On one hand, 5G + mobile edge computing effectively reduces network workload as only processed data is transmitted. Quick, local processing for high definition video surveillance, AR/VR, connected vehicle and other applications will reduce access delay and better serve the clients' needs. On the other hand, with the powerful 5G network, extensive data are collected from intelligent terminals, analyzed with AI at the edge and sent to the respective data platforms with fast feedback.

Latency-sensitive businesses (Internet of vehicles, remote control, etc.), and businesses requiring high processing capacity of massive data (video monitoring and analysis, etc.)

By moving content and computing power further down the line, and by offering limited network support, the 5G network will transform from a connecting pipeline to an information service enabling platform.

Ability integration to create edge ecosystem

1.3.3 Smart edge system built on 5G and other technologies for collaborative intelligence

Traditional urban intelligence, often in the form of smart vertical systems, is decentralized and fragmented across various sectors, with disconnected data often ending up in information silos, or even "smart silos". **The prevalence of 5G network, and the integrated development of new ITs, including big data, AI, IoT and cloud computing, will break the traditional limitations and reconstruct the urban intelligence system into a new integrated framework featuring 5G+terminal perception, edge computing and central decision-making.**

The integrated development of 5G and AIoT (artificial intelligence + Internet of things), MEC (mobile edge computing) and IOC (intelligent operation center) is a common thread connecting the multi-layered intelligent scenarios, empowering city intelligence. With 5G + AIoT, the Intelligence of Things will come to life, which covers all terminal perception nodes (i.e. cameras, smart lighting poles, monitoring devices, etc.) based on demand, fulfills the devices' high requirement of network capacity and collects massive data in full domains from the connected and real-time urban "nerve endings". 5G + MEC gives rise to edge intelligence, which can move the cloud-side AI processing closer to local data. This new infrastructure of cloud-edge coordination will facilitate the seamless connection between urban perception and urban intelligence. For example, in video surveillance, real-time processing of video stream at the edge has lower cost and faster response than uploading to and processing by server, or local processing by camera. With data integration as its core, 5G + IOC enables central intelligence and facilitates data sharing and interactive collaboration to create value and incubate innovative applications. IOC, the key to smart cities, is capable of integrated data operation, which includes data collection, storage, computing, mining and presentation. The 5G network can reach downwards to connect the cloud foundation and upwards to house development capability and application, empowering massive data and reshaping the urban intelligent system.

5G combines with other technologies for collaborative intelligence

Artificial intelligence (AI)

As a city upgrades its production, lifestyle and city management with smart technologies, strong demand will be generated for a new generation of AI technologies, products, services and solutions. The 5G era fulfills the demand of smart cities for concurrent access to numerous intelligent devices and realizes millisecond-level response in device interaction, facilitating diverse AI applications to achieve the Intelligence of Things.

In smart city applications, deep learning, as a type of AI, is gaining fast traction. As AI technologies, such as robotics, language recognition, image recognition and natural language processing, become woven into the ubiquitous connections of smart city, city managers will be in a better position to make informed decisions and provide intelligent public services.

New connected terminals and the Internet of things

As smart city development deepens, in addition to computers, smart phones and smart cameras, a wide variety of smart terminals are being deployed on a large scale, including smart robots, smart electricity meters, smart manhole covers and smart industrial modules. As a new-generation network infrastructure and the cornerstone of the Intelligence of Everything, 5G and the wide connectivity it enables will facilitate the deployment of intelligent terminals and achieve ubiquitous connection among people and things. Through perception devices and connected things, data and information will be captured to form a massive peripheral nervous system of the city, providing solid support for digital twin city and giving city managers access to timely and accurate information.

Big data analysis

Data represent a strategic resource of the future, and will be generated in large amount by the smart terminal sensors deployed across the city. With high bandwidth and mass connectivity, 5G powers the entire process of big data analysis, including data acquisition, data fusion, data modeling and data mining, to extract value from mass city data and provide effective and timely support to city managers in city management and decision-making.

Cloud computing

Cloud computing offers flexible computing and usage-based fee model, allowing information and resources to be coordinated and shared to the fullest extent on the "cloud". With cloud computing technology, physically dispersed computing power can be integrated and used for data storage and processing at the lowest possible costs, with the highest possible returns. With the high bandwidth of 5G, more data can be stored on the cloud. With its low latency, data uploading takes less time. With its enhanced load capacity, more IoT devices can connect to the cloud. Such a cloud-edge collaboration will improve the efficiency of business operation.

Block chain

5G connectivity brings massive amounts of end-to-end information exchange, especially in large-scale business applications that pose higher requirements for security. The integration of 5G and the distributed ledger technology that underpins blockchain can be applied to information authentication, location and identification management, as well as spectrum sharing, etc. It will change the business model and architecture of future networks and drive a transformation from information network to value network, extracting values inside the network and information assets.

2. 5G unleashes the potential of smart city applications

On June 6, 2019, China issued its first commercial 5G licenses, and kicked off commercial 5G services on October 31. With the deployment and commercialization of 5G networks, how to enable vertical industries with 5G strengths has become one of the most discussed topics during smart city development, as an important application scenario of 5G. 5G empowers a number of areas including city governance, industry growth and citizen services. Thanks to favorable policies and maturing infrastructure, an increasing number of innovative pilot applications have been carried out in transportation, security, environmental protection, healthcare and other verticals, which both benefit from and contribute to the development of 5G network.

Figure 5: 5G smart city envisioned

Category	Application	Typical scenario	Function required
Smart governance	Smart government	• Major public emergency response • Online one-stop government services • Identification by facial recognition	
	Smart Env. protection	• Environment monitoring • Smart garbage bin	
	Smart security	• UHD real-time monitoring • Robot patrol • Drone patrol	
	Smart transportation	• Remote/self-driving • Infotainment on hi-speed train • AR-assisted Navigation • Smart traffic planning	
Smart Industry	Smart power	• Real-time grid monitoring • Smart allocation of energy • Remote grid maintenance	
	Smart logistics	• Fully automated warehousing • Autonomous driving transportation • Drone delivery • Real-time tracking of goods	
Smart living	Smart healthcare	• Auto collection of health data • Remote surgery • Remote diagnosis & treatment • Super ambulance	
	Smart education	• Immersive teaching & learning • Remote interactive learning	
	Smart household	• Furniture IoT, remote control • Immersive entertainment	

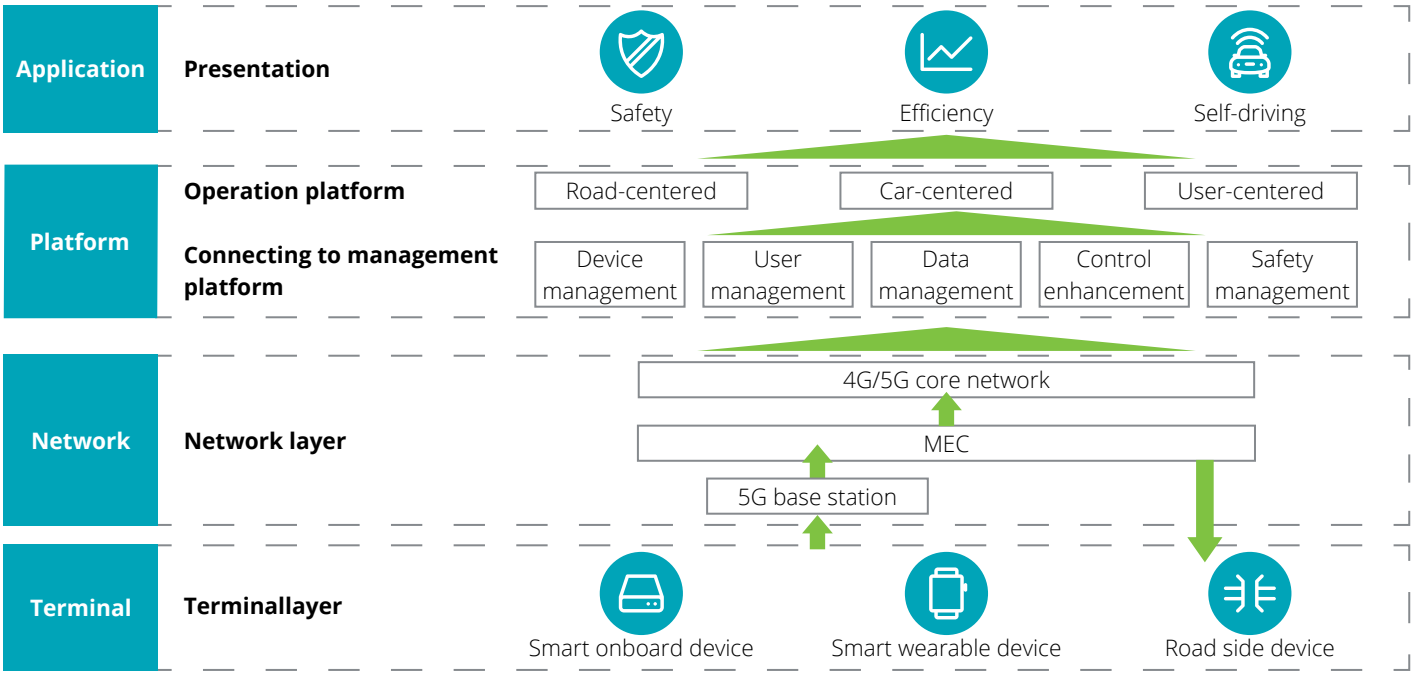
Legend eMBB mMTC uRLLC

As the concept of smart city becomes more popular, with the development of technologies and infrastructure, there has been a rising variety of smart city applications, covering all aspects of government affairs and citizen services. To elaborate how 5G enables industries, this paper chooses five areas that are closely related to people's daily life, with intuitive user experience. They are **smart transportation, smart security, smart environmental protection, smart healthcare and smart governance.**

2.1 5G+smart transportation —enhanced safety and road efficiency

By enriching the technical arsenal for achieving V2X, 5G technology can give birth to an integrated "cloud-application-terminal" network for communication, supervision and decision-making, as well as a new transportation architecture, paving the way for innovative transportation applications. With upgraded 5G technology, the application scenarios of smart transportation will expand from remote vehicle control and platooning on enclosed or specified roads, to open road autonomous driving and eventually to traffic management as a whole.

Figure 6: The architecture of 5G smart transportation system



5G remote vehicle control: away from danger and threat

Remote vehicle control is among the most typical smart transportation applications enabled by 5G technology. When the control room is connected to a vehicle through the 5G network, driver will be able to remotely control the vehicle to accelerate, decelerate, turn or change lane. With this technology, drivers no longer need to physically work in dangerous places like mines and disaster-hit areas. Instead, they can remotely drive their vehicles into the target location and perform tasks, avoiding unnecessary injury or casualty. Remote vehicle control requires high uplink bandwidth, as images and data from the vehicle must be transmitted to the control room in time. In a 4G network, the uplink bandwidth is usually below 50Mbps, resulting in low video definition and long delay in the driver's end. For example, image transmission between Beijing and Shanghai usually lags for over 100ms and breaks up often, posing significant safety risks.

In a 5G network, where uplink bandwidth can reach up to 100-200mbps, the delay of image transmission under the same conditions can be reduced to less than 30ms, enhancing the feasibility of remote vehicle control.

5G vehicle platooning: efficient and eco-friendly driving

Based on telematics and preliminary autonomous driving, the vehicle platooning function allows two or more vehicles to line up at preset distances and follow a lead vehicle automatically. The lead vehicle can be manned, driver-assisted or unmanned, while the rest of the fleet are unmanned. This will be useful to logistics fleets traveling on enclosed roads like highways. Platooning frees up more lanes for other vehicles, thus optimizing overall road use and relieving traffic pressure. In addition, in the close space in between platoon vehicles, a vacuum zone with reduced air resistance is formed, which effectively reduces fuel consumption and carbon dioxide emission, thus making it a more eco-friendly driving method.

Delivery trucks equipped with in-vehicle cameras, radars and other devices can collect information of the vehicle and the surrounding environment, while the on-board unit (OBU) is in charge of vehicle-to-vehicle and vehicle-to-road information exchange. After the on-board unit uploads real-time information through 5G network, the back-end platform will make decisions and issue commands, informing the lead vehicle driver of road conditions and assisting in vehicle operation. The following vehicles can automatically accelerate, decelerate, brake or turn according to specified order and rules, in sync with the lead vehicle. According to manufacturer test results, with a 5G V2X solution, the lag of end-to-end inter-vehicle command transmission is within 5ms, which is hardly possible with 4G.

5G autonomous driving: hands-free driving for better travel experience

The C-V2X technology overcomes the limitation of single-vehicle intelligence, such as high modification cost and multiple blind spots. Cameras, radars, sensors and roadside units (RSUs) are deployed along a street to collect detailed information of the surrounding vehicles, pedestrians and road conditions, which will then interact with the OBUs for information alignment. In emergent or challenging situations, i.e. merging at intersection or collision risk within line of sight, a warning will appear on the on-board computer, assisting it to make accurate autonomous driving decisions. At the same time, the information collected will be transmitted to the back end through 5G network, processed and analyzed by a cloud platform, to figure out the optimal speed, fuel consumption and routing for maximum efficiency. Since the V2X technology connects different vehicles to a unified cloud platform for management and operation, and the RSUs allow collected data and information to be shared across vehicles, the average cost of autonomous driving can be reduced.

Autonomous driving requires massive data transmission in real time, information processing and decision-making within milliseconds, all the while driving at high speed, which is far beyond the capability of 4G networks. Going forward, 5G will combine with single-vehicle intelligence and C-V2X to enable application scenarios, such as vehicle-road collaboration, collision within or beyond the line of sight, precise parking and smart routing strategy, to achieve fully autonomy in driving and greatly improve the travel experience of people.

5G traffic management: improving the traffic system for higher efficiency

A large number of cameras, microwave radiometers, weather detectors, intelligent signal lights and electronic road signs will be installed along city roads to capture real-time information on wet or icy road, unfriendly weather, road construction and maintenance, accident-induced congestion, etc. These roadside devices will be connected with on-board units, with the information of both sent via 5G to a smart traffic cloud platform for analysis. The platform, which will share decisions with vehicles and pedestrians through 5G and C-V2X networks, assists the authorities in issuing warnings on bad weather conditions, road construction, speed limit and congestion, monitoring traffic rule violations and centrally managing traffic flow.

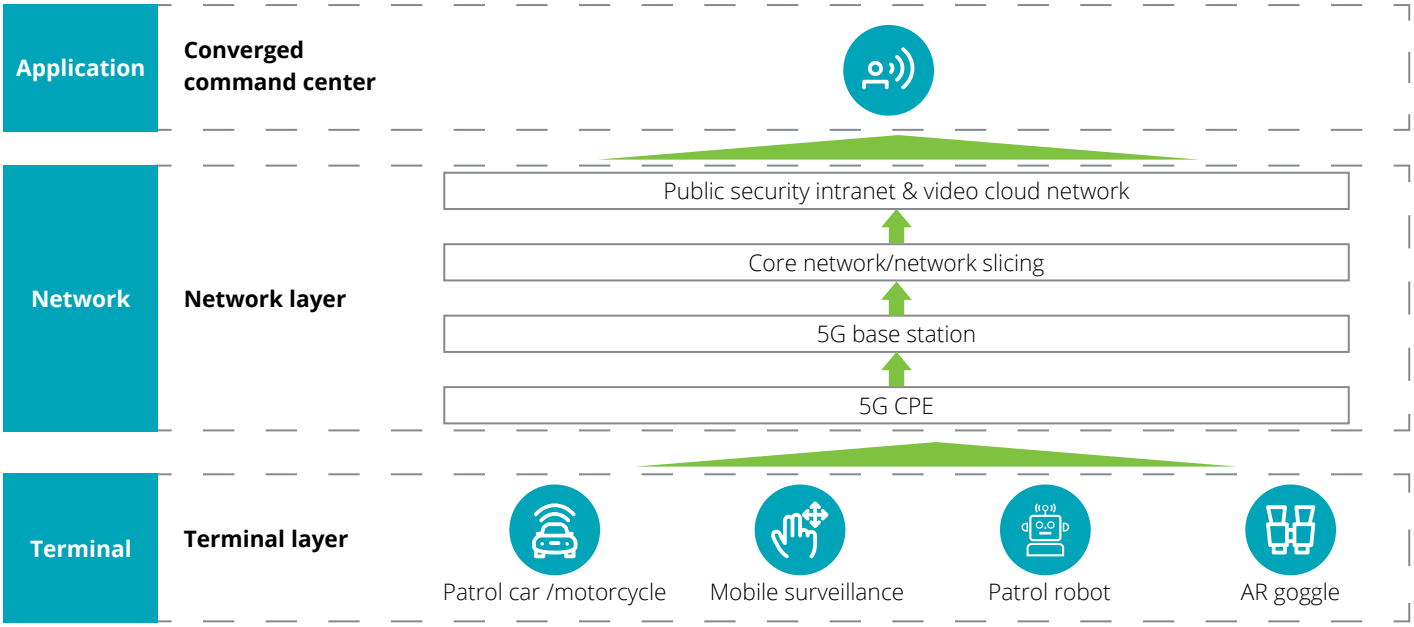
In addition, smart traffic management involves high volumes of data, often of various types, which is beyond the capability of a central cloud platform in terms of latency, efficiency and other aspects. With road-side edge devices, the collected data can be processed and transmitted locally, significantly reducing delay especially in scenarios that require fast decision-making, such as emergency braking and roadside parking. Meanwhile, the central cloud platform pools together all types of information for dynamic route planning and driving behavior analysis. The network slicing technology divides the physical 5G network into multiple virtual networks to flexibly address different application scenarios based on business needs. The application of these technologies will optimize the smart traffic management system, with enhanced safety and efficiency.

2.2 5G+smart security: efficient city protection anywhere, at anytime

With the development of artificial intelligence, VR/AR, high-definition image recognition and other technologies in recent years, the monitoring devices distributed across the city are increasingly equipped with high-definition feeds and intelligent technologies. As they connect to the network in large quantity, massive amounts of data will be generated. Yet, the existing 4G network is unable to accommodate these data.

With high bandwidth, 5G supports ultra-high-definition video transmission with low latency, which comes in handy during the remote control of mobile patrolling devices, such as drones or robots, and during emergency response. The mass connectivity of 5G technology can empower a city-wide security monitoring system, including the monitoring of dangerous goods and important materials.

Figure 7: 5G network slicing empowers a secure and integrated wireless police system



5G patrolling robots: maintaining public security at lower labor cost

A patrolling robot can cover a road of 800-1,000 meters long and work for 7-8 hours non-stop. Equipped with a pan–tilt–zoom camera, a panoramic video camera (6-7 channels) and thermal imaging equipment, the robot can capture multi-channel HD videos and images and via the 5G network, send to the police platform in real time, where facial and behavior recognition will be performed with AI algorithms. In addition, images and videos of the surrounding environment will be used to optimize the robot's route. With laser radar, GPS and various sensors, the robot can automatically avoid obstacles and pedestrians and patrol with autonomous navigation. In the process of patrolling, the robot can also interact by voice with police officers in the back-end monitoring room or in the nearest police post in real time, assisting them in emergencies or police duties.

Thanks to the high bandwidth and low latency of 5G network, the public security authorities are able to evaluate the surrounding environment with the HD videos and images uploaded by robot, send command to the robot or even remotely control it in real time. However, the 4G network supports the transmission of 720p video only, which is not clear enough for facial recognition. With 5G roll-out and the maturing of patrolling robots, the city will become a safer place, with significant cost saving in patrolling manpower.

5G AR mobile policing: smart devices for coordinated law enforcement

Based on the 5G network, AR mobile policing uses wearable equipment that integrates innovative AR and AI technologies, such as mobile police terminals, body cameras, on-board mobile devices and wearable devices, connected with a back-end information management platform, to provide strong technical support for law enforcement, crime fighting and the protection of people and their properties.

Innovative AR helmets and glasses, in lieu of the traditional law enforcement equipment, allow wearers to see in real time a 3D or panoramic view of the site from the first-person perspective of a law enforcement officer. The captured high-definition videos and images will then be uploaded in real time via 5G network to a central cloud platform or edge server. The AI recognition and analysis system can quickly interpret the video stream and images received, extract face and vehicle information and check against the various databases in industry users' business systems to identify suspicious individuals, vehicles with traffic violations and so on. With 5G's large bandwidth and low latency, it takes less than 2 seconds to complete AI recognition, which will boost policing efficiency and quality at all fronts.

5G UAV: holistic patrolling in special terrains

UAVs can be dispatched quickly and flexibly, which is particularly useful in special locations that are beyond human access, but can be quickly reached by the highly mobile drones. At present, most of the UAVs encrypted and controlled via Wi-Fi can only fly within the line of sight, but once connected to the 5G network, they can cover a wider area and are less likely to have their signal intercepted by hackers. Only point-to-point control is currently available for UAVs, due to the data link limitation of private protocols. With connection to the 5G network, multiple UAVs can be controlled by one control center, reducing the number of operators and equipment cost.

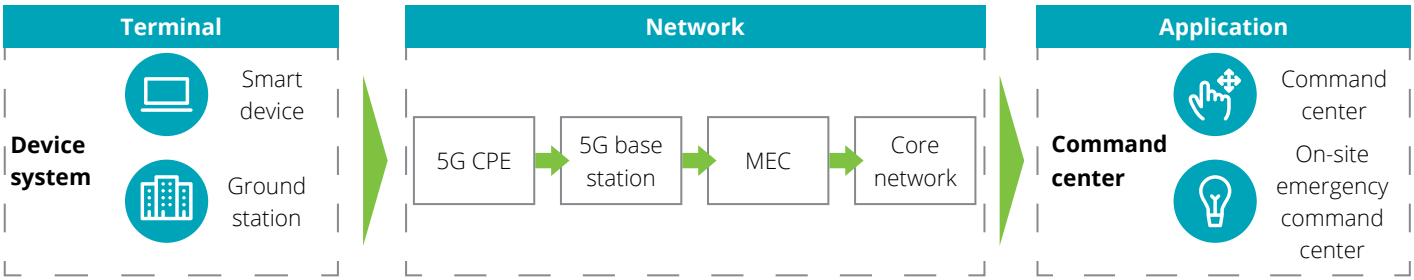
With the high bandwidth of 5G network, UAVs will be able to transmit the ultra-high-definition videos beyond 4K that are captured by HD cameras for subsequent AI recognition. The images and data captured on site can be sent to a back-end command platform in real time for the reference of the command staff, or to a ground control vehicle, where on-site feeds are displayed on a screen on board for remote command.

2.3 5G+smart environmental protection to empower supervision

Environmental governance, as an important foundation for a nation to realize sustainable development, is not being fully served with traditional monitoring methods that are insufficient in regional coverage and frequency. Yet with the maturing and application of 5G technologies, a new era of environmental protection and regulation will commence.

The mass connectivity of 5G means environmental data across the whole city can be pooled into the government database for holistic management. With its high bandwidth, 5G supports the transmission of high-definition images, with improved information identification and utilization. Its low latency will ensure real-time transmission of information so that the authorities can respond in time. This particular feature also fulfills the network transmission requirement of smart devices so that they can demonstrate their value in on-site monitoring. With devices like drones and unmanned vessels, which are highly mobile and fully autonomous, staff can receive accurate monitoring data in the comfort of their rooms.

Figure 8: The technical framework of 5G smart environmental protection



5G water body monitoring: multi-dimensional management

In 2017, 7000 kilometers of water bodies were polluted and turned dark-colored and odorous, which was around 150% the length of the Yangtze River, according to the National Platform for the Treatment and Supervision of Urban Polluted Water Bodies. Given the challenges of water pollution prevention and treatment in China, smart environmental protection is regarded as a matter of urgency.

Water body monitoring requires regular collection and analysis of water environmental information and images on water quality and so on. However, water bodies are generally too large to inspect manually at a fast pace, and some areas are beyond human reach. Although highly mobile UAVs are available, they mostly only fly in pre-set routes without real-time data transmission due to the limitations of 4G network, and are thus unable to adapt to unexpected incidents. The potential of UAVs is yet to be fully captured. With the limitations of 4G lifted, the 5G network enables real-time, high-definition transmission for smart mobile devices such as drones and unmanned vessels, which can replace humans in air, water, and underwater monitoring.

In the process of monitoring, drones can carry different cameras to obtain the images needed; high-definition cameras and water quality sensors onboard the unmanned vessels can collect data and analyze water quality during patrolling and send data back to a testing platform; in combination with sonars, UUVs can explore underwater terrains, and investigate potential issues. When these devices are used in junction, a three-dimensional water management system will be ready. The low latency and high bandwidth of 5G network enables real-time transmission of high-definition images, greatly enhancing control precision over drones and unmanned vessels. A smarter water management system not only saves manpower and resources, but also allows comprehensive, real-time and accurate inspection.

2.4 5G+ smart healthcare: reform towards a fair, accessible and universal healthcare system

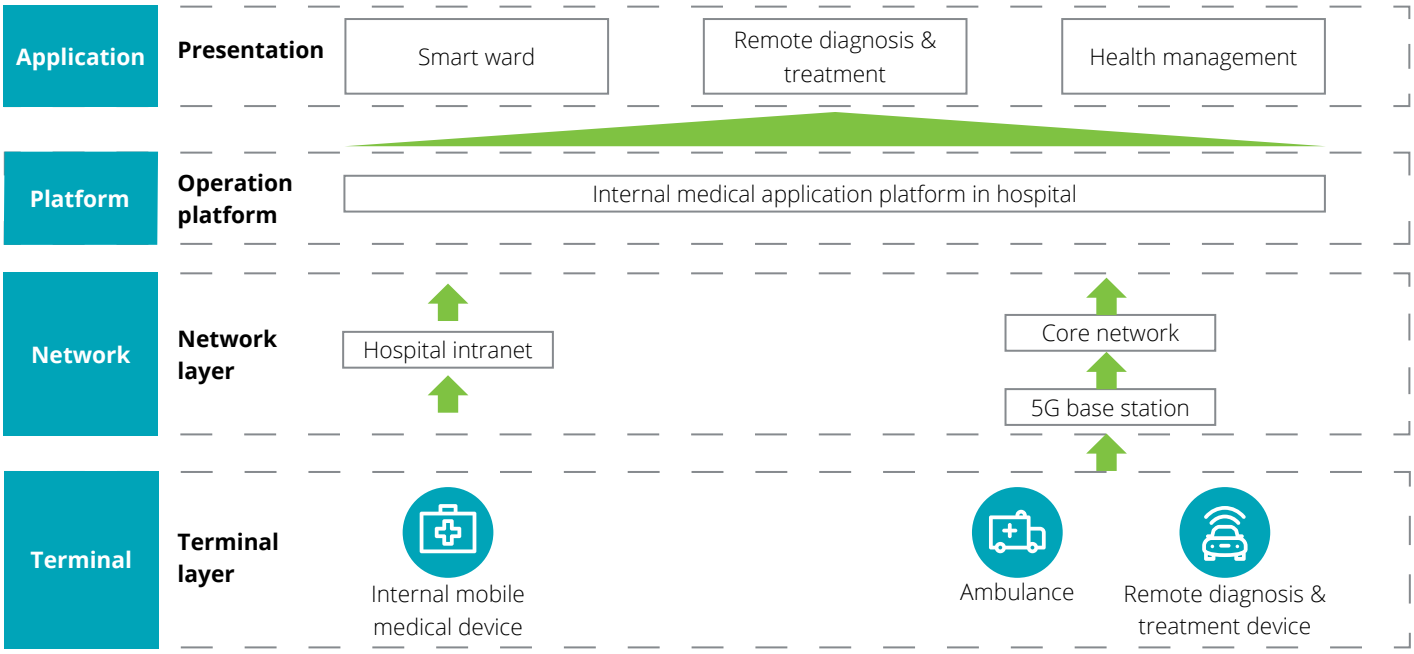
Compared with big cities, the quality of medical services in many remote areas is far from satisfactory, prompting patients to travel across provinces for treatment. As people become more health conscious, the trend is expected to grow. According to the National Healthcare Security Administration, in 2018, 1.32 million inpatient visits were made to non-local hospitals, 6.3 times that of 2017. Patients seeking cross-province treatment need to pay for not only the treatment, but also the travel expenses. People's demand for high-quality medical services in their areas of residence is a strong driving force for the rapid development of smart healthcare.

Leveraging the IoT technology, smart healthcare enables the interaction among patients, healthcare professionals, hospitals and medical devices. In particular, remote diagnosis and treatment, based on high-definition image transmission with low latency, enables physicians to diagnose and even treat patients remotely, promising to solve the problems above.

However, 720p or 1080p videos streamed over long distances via 4G network are severely choppy and fail to meet the requirements of telemedicine. With the fast 5G network, 4K or even 8K medical images can be quickly shared, improving diagnostic accuracy and enabling remote HD consultation. The high-definition and low-latency data transmission can spur the application of robotic arms, with which experts will be able to diagnose and treat patients remotely, saving patients the trouble of traveling, expanding access to high-quality healthcare resources to lower-tier regions.

In addition, with China's vast territory, large population, frequent movements of people and complex demand, the efficiency of information exchange is of utmost significance, especially for patient diagnosis and treatment and epidemic screening. The COVID-19 outbreak in early 2020 put to the test China's epidemic prevention and control mechanism and its public health emergency response system. 5G network is superior to 4G in its high speed, low latency and massive connectivity, which, when combined with general technologies such as big data, AI and cloud computing, provides an effective, real-time data solution, and inspires innovative methods and ideas for the screening and treatment of contagious diseases.

Figure 9: The technical framework of 5G smart healthcare



5G Telemedicine: breaking the limits of time and space between physicians and patients

During the process of diagnosis and treatment, physicians rely not only on their own experience, but also on a variety of medical devices. Due to the limited speed of 4G, physicians are not able to operate medical equipment remotely. Nor can they receive high-definition images of patients in real time. Consequently, telemedicine is yet to be fully realized.

In the case of ultrasound examination, which is highly reliant on the physician's experience, the dynamic footage generated from an abdominal screening may easily reach 2GB in size, way too big to be transmitted in real time, of high definition, via 4G network. However, even the loss of one frame could lead to misdiagnosis. With the support of 5G network, remote ultrasonic diagnosis was realized in Guangzhou in 2019. Over the low-latency, high-bandwidth 5G network, high-definition images captured by cameras on the patient's end are sent in real time to the physician, who then controls a robotic arm to remotely examine the patient. The low latency ensures fast response of robotic arms, allowing physicians to work as if with their own hands. The ultrasound images are displayed clearly and smoothly in front of the physician to facilitate the diagnosis process, which only takes around 20 minutes. With further development of 5G, remote consultation will become more widely adopted and cover a greater variety of departments.

Remote surgery requires low-latency and high-bandwidth networks, which can be fulfilled by 5G. A physician can sit in front of a machine, receive real-time high-definition video footage transmitted from the patient's end, and remotely manipulate a scalpel and other surgical instruments via a robotic arm. During the operation, even the texture and pulsing of an organ are clearly visible to the physician, as if he or she is in the same room with the patient. In 2019, China Unicom partnered with two hospitals in Beijing and Fujian, and completed the world's 5G-based remote animal surgery, where a physician in Beijing successfully performed liver lobectomy on a piglet in Fujian.

Remote surgery relieves patients from the burden of travelling and the extra expenses incurred, and, more importantly, saves the precious time and gives them a better chance of survival.

5G outdoor first aid: saving time and lives

It has become common practice to set up several medical stations on sites of major events. In case of medical emergency, the patient can receive a preliminary diagnosis at the medical station before being sent to the nearest hospital for further diagnosis and treatment by ambulance. This means the medical station, ambulance and hospital need to exchange patient information. If not done right, in the case of complex conditions, additional hospital transfer may be needed, delaying diagnosis and treatment.

Using the 4G network, hospitals are now able to receive data from ambulance respirator, but with delay. In the 5G era, multi-party communication among the medical station, ambulance, nearby hospital and remote experts, will become possible, saving time to save lives beyond the boundaries of physical space.

With 5G, any medical emergency will be first attended to by an onsite medical station, where staff will transmit patient imaging and information to a nearby hospital, and order an ambulance to take the patient in. The 5G network will ease the delay in respirator data transmission under 4G and allow the connection of more devices such as ultrasound, so that patient can be fully examined on the ambulance. From there, the ambulance will transmit real-time image and information to the hospital in high definition and with low latency, so that physicians can get updated, prepare to receive the patient and guide the ambulance medical staff on first aid. Upon arrival at the hospital, the patient will be sent straight to the next stage of treatment. If needed, experts from afar can also join the consultation and advise on operation. All of this not only saves the invaluable time for rescue, but also enables the selection of suitable treatments.

5G epidemic prevention and control: precise monitoring, real-time communication and risk mitigation

When a virus spreads wide and fast, the key to outbreak containment is to quickly identify the virus carriers among the population, which heightens the importance of information collection in public areas on body temperature, travel and contact history and so on. Compared to 4G, 5G bandwidth supports the real-time transmission of massive amounts of high-definition images and dynamic data (including 4K thermal image, travel trajectory and close contact tracing), to a command center screen or a cloud platform for data tracking and monitoring. This allows quick body temperature checks in crowded places, such as airports and train stations, and reduces staff risk by avoiding direct human contact.

Severe epidemic outbreak poses a huge challenge to the ambulance network responsible for transporting confirmed cases, while HD remote diagnostic devices and mobile testing devices enable the timely diagnosis and treatment for patients en route. With high bandwidth, low latency and strong mobility, 5G provides stable communication signal in real-time diagnostic data transmission. Ambulances equipped with 4K monitoring equipment can send high-definition videos and the patient's vitals to the command center in real time. If needs be, the command center can initiate a three-way 5G video call with the vehicle and hospital experts for seamless connection between first aid and hospital treatment.

To contain the COVID-19 outbreak in early 2020, tens of thousands of healthcare practitioners were sent to Wuhan from all across the country to ease the staff shortage on the frontline. Yet close contact with patients for long periods of time exposed them to high physical and mental risks. Smart robots, when empowered by 5G, can reduce the workload and safety hazards of medical staff during triage, disinfection, cleaning and drug delivery. By taking over the time-consuming routine disinfection, the limited number of medical staff can be freed to provide more complex care that requires human intervention.

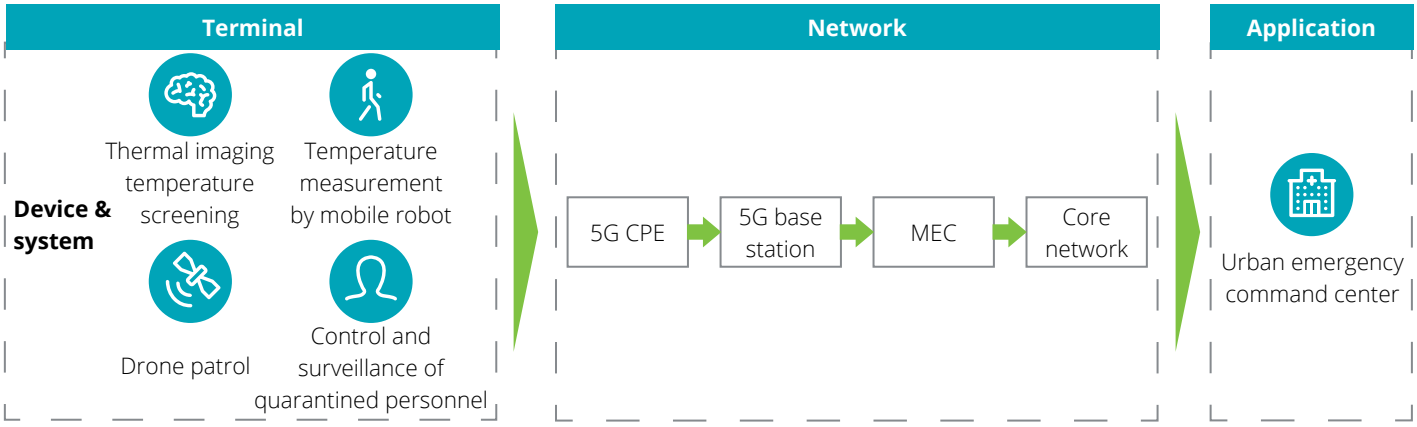
2.5 5G+ smart governance: a smart toolbox for emergency response

As urbanization advances, the public become more aware of public services, social governance, public security and other aspects of urban governance, and are raising diverse requests and challenges to city managers in refined governance, service and regulation. During special times, such as epidemic outbreak, disaster and terrorism attacks, how to quickly respond to these public emergencies in a safe, open and fair way, while maintaining city functions is a test to the wisdom and competency of government officials.

In times like this, 5G and the ubiquitous network derived from its integration with IoT and big data can convert the physical city into a digital twin, with detailed and comprehensive big data, including dynamic and static data, government and societal data, historical and deducted data, assisting the government in its response. This new data-driven emphasis will imbue official emergency event management, e.g. forecasting and early warning systems, 'smart' assessments, joint emergency actions and policy supports, with a much greater degree of AI-based decision-making. On the one hand, 5G, cloud computing, AI and other such new information technologies could be incorporated into high-risk settings, e.g. areas in the midst of an outbreak. Digital information technologies, such as AI-powered smart devices, could be deployed to real locations in lieu of traditional manpower to reduce staff risks whilst enhancing productivity via new methods of e.g. 'digital pandemic control' or 'digital disaster control'.

On the other hand, 5G's prodigious bandwidth promises to empower a host of new online applications, helping governments maintain routine urban services to safeguard residents' lifestyles amidst major emergencies, e.g. by providing online government services, video conferences, education live streaming, and so on.

Figure 10: A technological framework for the smart control of severe pandemics using 5G



Emergency management in a 5G city: a city's ubiquitous 5G network coverage provides a strong basis for an improved emergency response

The highly contagious nature of the new coronavirus-induced pneumonia outbreak in Wuhan alongside the added mass migration that occurs during the Chinese New Year served to spread the disease throughout China very rapidly and posed a severe challenge to containment efforts. Pandemic control demands that potential urban cases be screened, rapidly diagnosed, and isolated whilst such data must also be quickly organized and dispatched to an emergency command center for analysis and to generate subsequent responses and strategies. An extensive municipal 5G network could allow for a rapid, comprehensive urban sensing system to monitor a pandemic's status and issue alerts; this level of data sharing could raise the coordinated effectiveness of the urban response across different areas, departments, and domains, its speed and efficiency - transforming the municipal management model from passive threat response to proactive early warning management.

The addition of 5G to thermal imaging and temperature information technology may help to resolve issues around screening for infectious diseases in public locations with significant foot traffic and turnover, thus forming an effective first line of defense in containment efforts. Inefficient traditional temperature screening techniques in public areas, such as in subway stations, airports, and train stations, invite queues and then crowds, which is unhelpful for containment; at the same time, close contact between testing staff and suspected cases also raises the risk for employees.

Solutions such as 5G + thermal body temperature sensors are easy to roll out, contact-free, facilitate rapid passage, can help reduce duplicate testing over time, improve screening efficiency and reduce risks to staff. In addition, 5G bandwidth is easily capable of rapidly transmitting video and other relevant data in real time to monitors or a city's emergency command cloud platform to create a data record or carry out supervision. Cloud-based big data management could facilitate contact tracing when and if a larger outbreak occurred.

The pandemic 'big data' produced via a ubiquitous 5G network would be of enormous convenience to contact tracing, identifying pathways for transmission, forecasting growth models, and such other tasks involved in containing a pandemic.

5G community management: The flexible rollout of wireless high-definition video monitoring and security patrol bots could strengthen containment supervision at the community level and help community staff organize and manage isolation and distancing.

The long incubation period of the novel coronavirus necessitates a rather lengthy process of isolation and contact tracing across a fixed set of locations once suspect cases emerge as well as potentially the demarcation of entire streets and neighborhoods into isolated zones in heavily affected regions; at the same time, many cities throughout China were enforcing closed-off management on neighborhoods against the threat of contagion, restricting outbound or inbound trips - fewer trips from, or the careful monitoring of visitors to, each area. It would be extremely time and labor-intensive to run traditional manual patrols in the local community under such circumstances, encumbering the timely supervision of local districts or isolating individuals and increasing the potential risks from having frequent contact with suspect cases.

A 5G-based wireless high-definition surveillance solution could take full advantage of its relatively simple wireless roll-out and bandwidth with high definition cameras +5G CPE (fixed wireless access devices and equipment) or high definition cameras with in-built 5G communication modules, and could be rapidly affixed to makeshift hospitals, e.g. mobile cabin hospitals, community isolation checkpoints, road checkpoints, and other such areas to generate real-time, free-flowing, and high-definition visuals to quickly update officials on current isolation measures and containment efforts, the needs of isolating individuals, and could be used to safely and effectively ensure their intended effects.

The deployment of **smart patrol bots that can execute contact-free body heat screenings and remote visual commands** could measure the temperatures of individuals in containment zones in real-time and feedback flagged data to the back-end to generate early warnings; the bots could efficiently, flexibly, safely, and reliably complete many of the daily management activities associated with the containment zone, e.g. by reminding travelers to wear a face mask who are currently without.

Cloud services for a 5G city: To facilitate the continued and regular operation of municipal and residential services during citywide emergencies

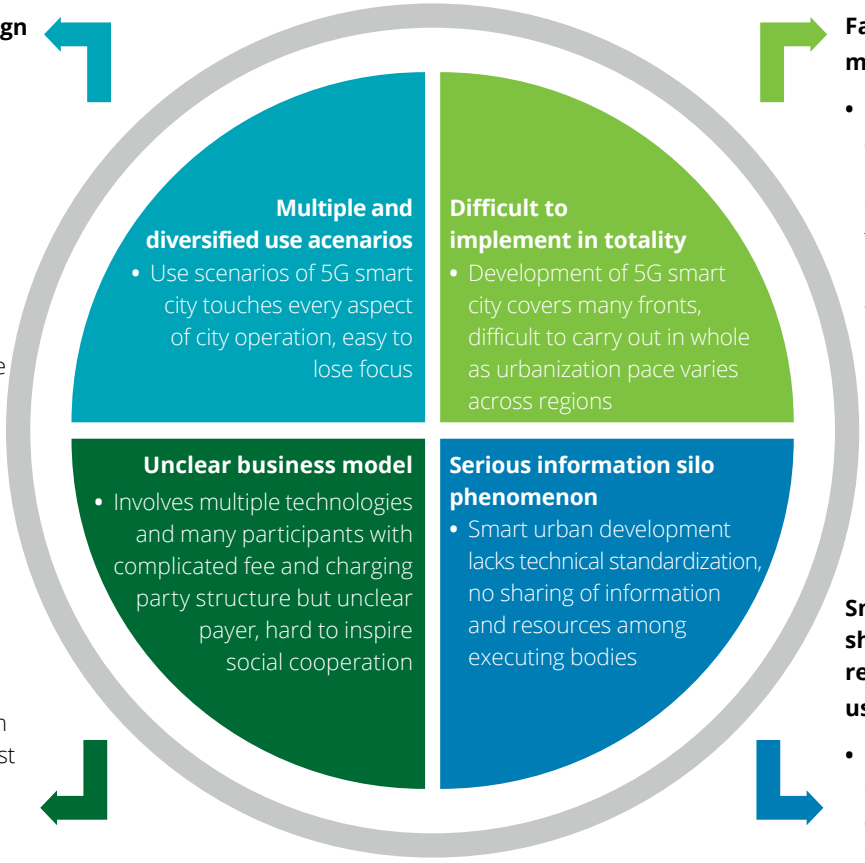
A single integrated set of online government services for everyday affairs based on 5G+ cloud services, blockchain or other such technologies promises to break down interdepartmental barriers between government offices in enabling truly secure data sharing. Corporate or civil matters could be carried on normally during extraordinary pandemics while distancing, significantly assisting in the national fight against the pandemic.

Online video conferencing and educational streaming based on a flexible roll-out of 5G and the 5G network promises to meet the huge demand for network resources on the part of emergency command centers, remote corporate offices, online class interactions and so forth.

Online medical services, such as remote medical inquiries, remote consultations, online diagnoses, imaging consultations, and information uploads based on a 5G network could forestall contact risks for residents seeking regular medical or hospital checkups in extraordinary times.

3. Building a smart city with 5G elements: main challenges and pathways to implementation

Figure 11: The main challenges associated with building a 5G smart city



To lead by top-level design and issue city-specific policies

- Government should be responsible for overall planning guided by top-level design, formulate development plans and determine order of execution based on the resources available in the area

Fast landing of smart micro-unit

- Make management and services of urban unit digital, smart and convenient according to area specificity and industry resources available

Build, manage and share together through innovative model

- Attract stakeholders from different verticals to invest in areas of interest by having business models that enable co-building, co-managing and benefit-sharing for a steady development process

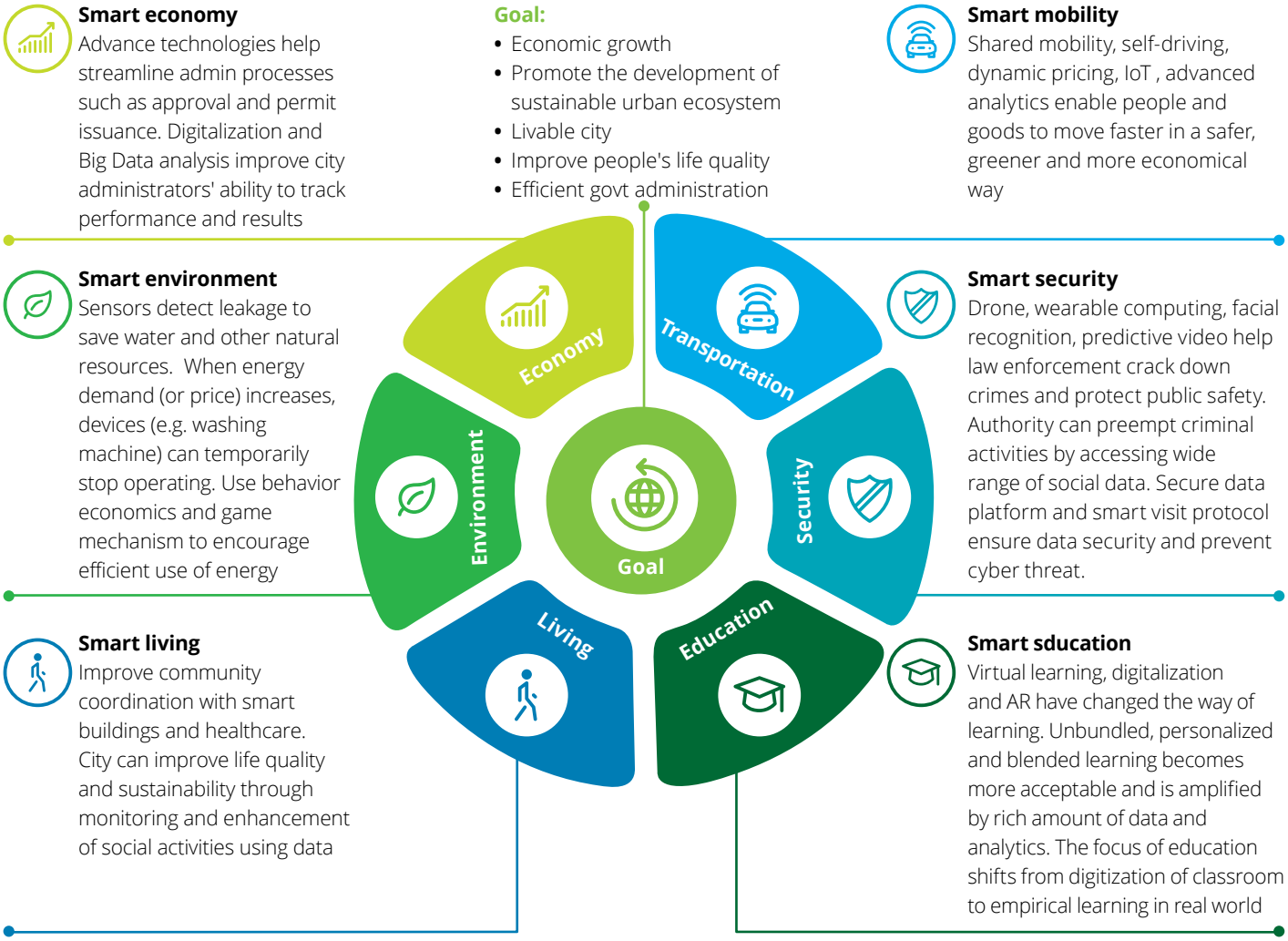
Smart city operators shall consolidate resources for efficient usage

- Break technology and organization silos to achieve interconnectivity of data, information and other resources and make use of which to provide city services

3.1 The quantity and disparate nature of potential applications: top-down design-led, tailored city implementations

Conceptually, these new smart cities cover six major municipal functions, including local economy, transportation, safety, education, lifestyles, and environment. Further technological innovation in each function will give birth to an increasing array of niche markets. Furthermore, the enormous degree of content and number of domains involved in building a smart city obligates each department and local government to tailor their plans and policies to their individual circumstances.

Figure 12: Municipal capabilities associated with the smart city



However, in the actual rolling out of their local applications, some have opaque top-down design or unclear objectives, some recycle smart development plans of other cities that do not actually fit their own needs or not consistent with their urban features, resulting in project duplication, resource wastage, **and loss of focus.**

The government must step forward with a top-down, overarching plan that clarifies the general objectives of a rollout and **prioritizes top-down-led implementations** to address these issues; furthermore, this plan will also need to take a city's current circumstances, resources, needs and difficulties into account for a **uniquely tailored approach** with an order of priority.

Top-level design refers to the comprehensive assessment and evaluation of every level and element of a specific project, the examination of its fundamental questions and a panoramic review whereby only the pursuit of top-down solutions can effectively sidestep potential issues of e.g. data silos, duplication, insufficient scalability and government guidance. A smart city built and driven by the government as a master planner executing top-down designs must take the following key factors into account:

Clarify your objectives: The government must confirm the specific details and objectives associated with the smart city's development at different phases of its construction prior to commencement, and formulate progress frameworks and relevant approval criteria at each phase. Only clear objectives and the configuration of a schedule can keep the rollout on track and efficient.

Develop an ecosystem: Although government departments are the most relevant stakeholders in smart city development, there is tremendous financial and operational pressure on the governments that are operating in traditional silos. The development of a 5G-connected smart city calls for the participation of multiple stakeholders in solution design. Therefore, stakeholders such as governments, enterprises, tech start-ups, academic institutions as well as NGOs should come together in creating a partnership ecosystem.

Coordinate technical architectures and standards: Since a smart city usually requires multiple technologies and scenarios, governments should be responsible for basic technical coordination and integration, including that of the system architecture, data governance, technical interoperability and network security, and for the unification of core architectures, implementation plans and data standards.

Policy to remove obstacles: Various stakeholders are involved in the development of a smart city, which requires the government to mediate among various parties with policies, to reduce conflicts during smart city development. Take the indoor installation of base stations as an example. With higher frequency, 5G signal does not penetrate as far as 4G signal, which sometimes requires base stations to be installed inside buildings. However, property owners have expressed varying levels of acceptance for such practice. As a result, operators who want to set up base stations inside buildings will have to negotiate with a large number of owners and almost always, end up paying a fee. In its top-level design, governments can take this into consideration and issue guiding policies to clear the obstacles for the deployment of network and other facilities, thus expediting infrastructure development. Since similar conflicts of interest may be widely present among stakeholders, the top-level design by the government can help identify and solve potential issues with targeted policies.

This is why top-level design, which plans a smart city layout with holistic thinking and utilizes technology to improve city operation, should be the first step in a smart city initiative. To devise a top-level design, city managers should first define the following three fundamental objectives: more competitive economy, more sustainable city development and better quality of life for citizens. Specifically for economic competitiveness, this means attracting and retaining talents for enterprises, promoting innovation and entrepreneurship, and encouraging the public and private sectors to provide services and financing. With regard to sustainability, the shared vision of smart cities is the conservation of energy and natural resources, asset recycling, and emission reduction. In terms of quality of life, the forces driving smart city forward are the pursuits of health, safety and education, higher operational efficiency and better civic services.

The top-level framework of smart cities should cover six major fields: transportation, economy, environment, life, education and safety, with six key elements: intelligence, autonomy, integration, real time, ubiquitousness and openness. Led by this framework, future smart cities will become more integrated and better at cooperation for maximum value.

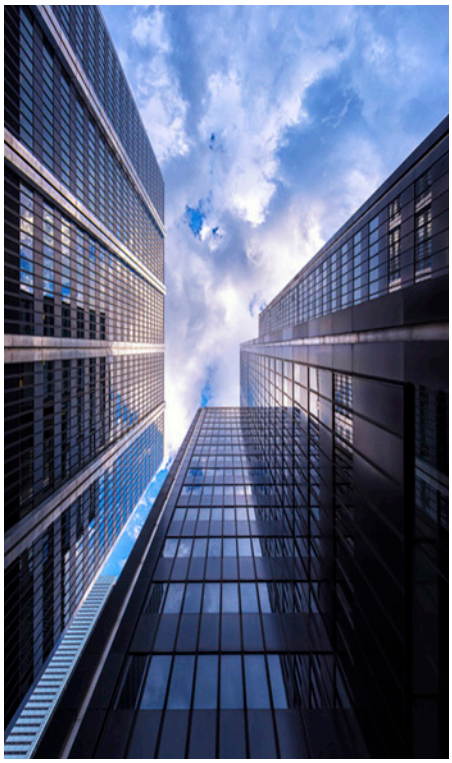
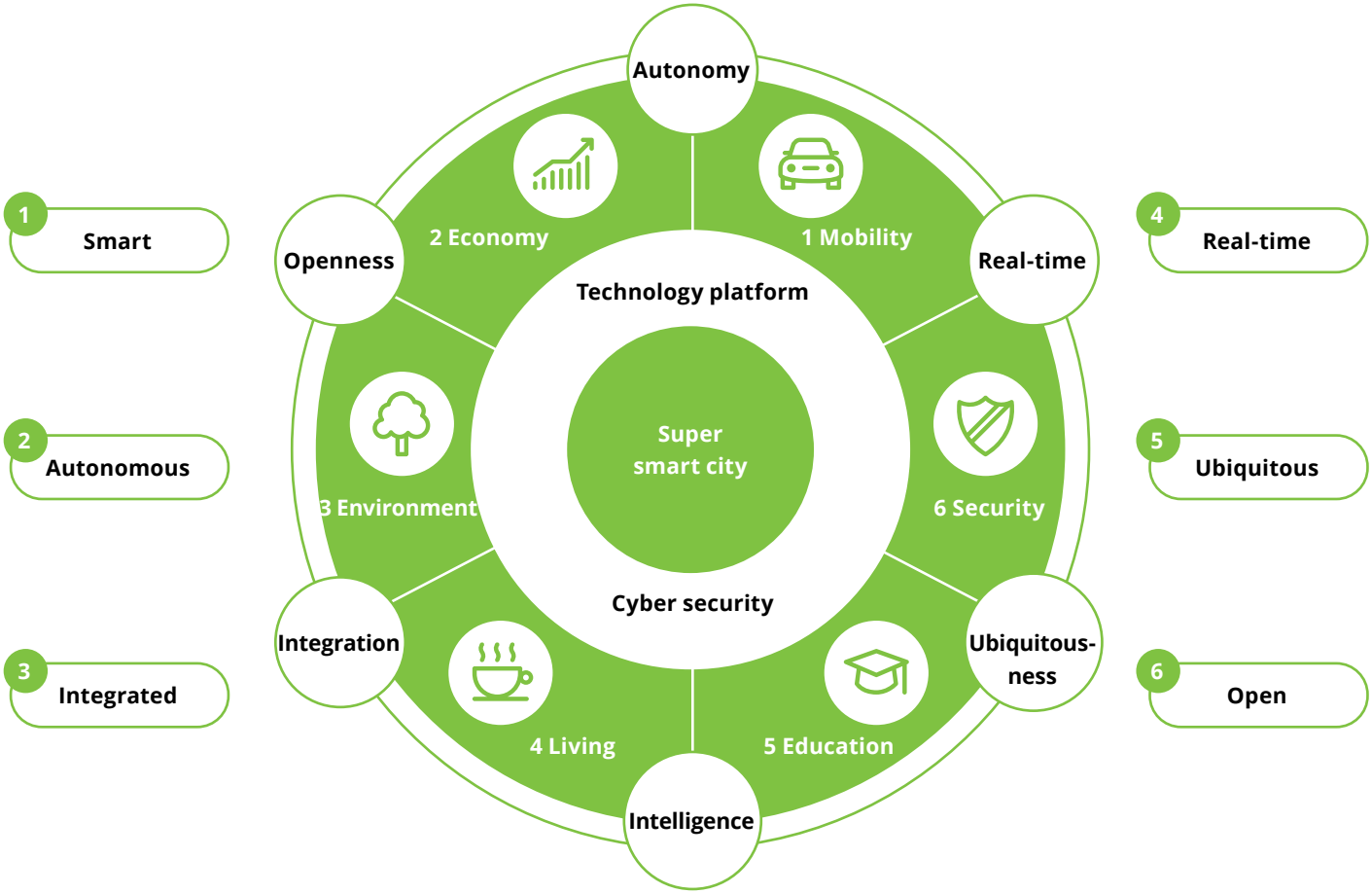


Figure 13: The Theoretical Framework of Smart Cities by Deloitte



Smart cities are different from traditional cities in that city managers are assisted in sound decision-making, fine management and rapid response, thereby improving city competitiveness, thanks to the following six key elements:

Intelligence: In a smart city, AI makes decisions for humans. Currently, AI technology has been implemented in many fields, such as finance, medicine and security, with more diverse application scenarios to come. In future smart cities, AI will make decisions, instead of humans, with technologies such as big data analytics.

Autonomy: In a smart city, interconnected things, such as smart cameras and smart street lights, operate independently without human control. Distributed data makes it possible for the Intelligence of Things to operate on its own. The application of 5G + AI allows things to analyze the data that they collect and perform functions adapted to different scenarios.

Integration: In a smart city, all general technologies are integrated and new applied technologies are combined with specific scenarios, so that the value of the whole becomes greater than the sum of its parts.

Real time: In a smart city, information, decisions and even behavior can respond to changes in the environment in real time, which will dramatically increase efficiency and solve the issue of delay in traditional cities. With 5G, the problem of latency will go away for good.

Ubiquitousness: In a smart city, where everything is connected via the 5G network, information can be collected, transmitted and used anywhere at anytime.

Openness: In a smart city, information open for sharing will become the norm, giving everyone easy access to shared information.

3.2 Challenges in execution: rapid implementation of smart city micro units

Although the planning of a 5G smart city should adopt a top-down approach, with a focus on top-level design, the reality of different regions and their levels of development should also be taken into account to make sure that the plan and subsequent policies are well adapted to each city. Yet during implementation, a bottom-up approach should be taken, working from small pilots to larger application. Considering that different city units have different needs and levels of intelligence, the model of 5G smart cities is yet to validate and that investment pressure needs to be dispersed, the development of 5G smart cities should follow a bottom-up approach with clear priorities, under the guidance of a top-level framework.

According to local resources and industry niches, smart cities micro units can be created, as benchmarks and demonstration projects. **Defined as a unit in a geographical sense, a micro unit can refer to anything from buildings and parks to communities, neighborhoods and towns. They have almost all the basic functions that a city has to offer, only with fewer stakeholders, capable of driving highly integrated application of new communication technologies and smart technologies to the largest extent. Through the integration of business, data and technical capabilities, city unit management and services will become more digital, intelligent and convenient.**

The following areas should be considered when creating smart micro units:

Differentiated development to cater to different needs

Different city units may present different needs for smart development. Areas with dense population and industry clusters tend to benefit the most from smart city initiatives, while less populated areas have no urgent needs for them. Meanwhile, to develop 5G smart cities, city units need to reach certain levels in financial strength, technical capability, infrastructure maturity, management expertise, understanding and acceptance of the idea. Only when city units really want smart city initiatives and are ready in the above-mentioned areas can they make progress in the development of 5G smart cities in a steady, smooth and efficient way. However, as different areas and industries in a city often grow at different speeds, it is difficult to tick the boxes for demand and readiness at the same time. In that case, a reasonable and feasible solution is to drive smart city initiatives at different speeds in different city units to match their levels of demand and readiness.

Different industries develop by different models

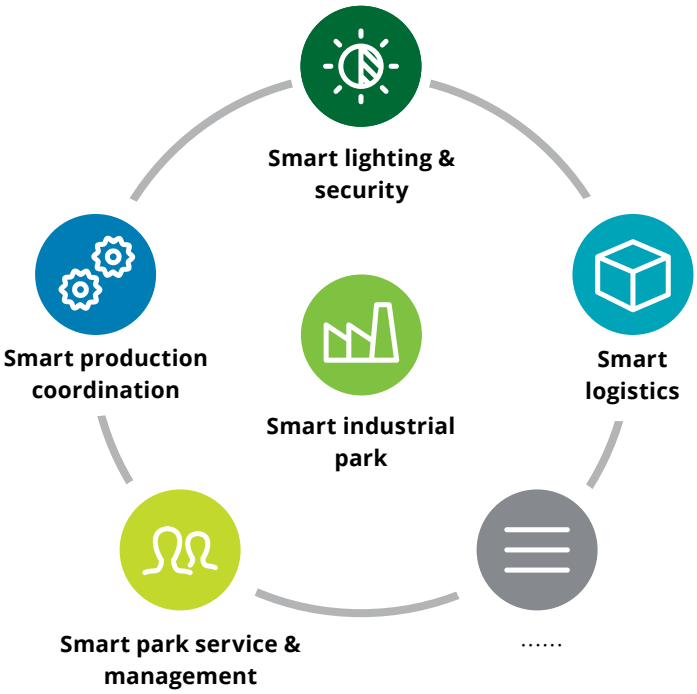
As the development of 5G smart cities is still in its early stage, the many concepts and business models for innovative vertical application are still new and will need to be validated before large-scale adoption. Each with their own characteristics, different industries have demonstrated different needs and problems in the pursuit of 5G-enabled intelligent development. This requires network builders to cooperate with stakeholders from various industries to develop suitable and targeted solutions, rather than simply copying from old experience. Therefore, a bottom-up approach to smart cities development based on industry characteristics will not only effectively reduce the risks of large-scale deployment, but will also establish benchmark models for different industries that may be later promoted to more areas of application.

Smart industry park trends and features of smart industry parks in the new era:

1) The Intelligence of Things, featuring ubiquitous connections, where humans, machines and things are deeply connected and integrated based on 5G+IoT; 2) Data-driven. As the connector of physical parks and digital parks, the IoT, by amassing large volumes of data in real time, will drive the quantitative and qualitative change of data, which will serve as a cornerstone in super smart parks; 3) Fusion of the virtual and real worlds, where a digital twin of the physical park is created in cyberspace with digital technologies, forming a ubiquitous cyber-physical system with a tripartite structure of park personnel, the physical world and digital space. The virtual and the real world will interact and fully integrate; 4) Smart technology driven, where smart technologies such as AI, data intelligence and machine intelligence are applied in industry parks for higher operation efficiency, lower operational costs, better decision-making and governance.

The connotation and value of smart industry park in the new era: The 5G smart park is an advanced form of industry parks that arise from the deep integration of people, machines and things. Based on a new generation of information technologies, including 5G, AI, blockchain, cloud computing, edge computing, big data and IoT, equipped with communication networks of ultra high speed and large capacity, the smart park possesses a data-driven brain capable of multi-dimensional perception and intelligent decision-making, which can create a digital twin to precisely map and interact with the physical space. With the fusion of the virtual world and the real world, park operators, businesses and employees will enjoy precise personalized services 24/7, covering all factors and all scenarios, to effectively improve the efficiency and user experience of the park, maximize net returns and achieve sustainable development.

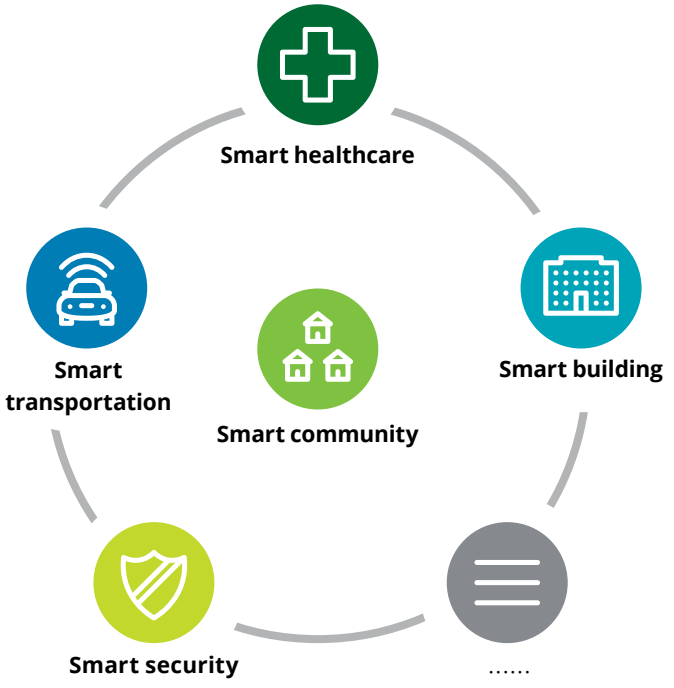
Figure 14: Smart city micro units: application in smart industry parks



Smart community

Trend of smart community development in the new era: 1) Communities are moving towards three value coordinates, which are focus on people, ecology and digitalization; 2) The future convergence with digital communities, where vertical information systems evolve to embrace digitalization and visualization; 3) Innovative application scenarios will continue to grow in future communities, including applications in neighborhood, education, entrepreneurship, construction, transportation, emission reduction, service and governance; 4) Coordinated development between industry and ecology, where the communities best at aligning industry growth with eco-friendly practice shall prevail.

Figure 15: Smart city micro units: application in smart communities



The connotation and value of smart communities in the new era: Smart communities uphold the ideals of humanism, intelligence and service, highlight the importance of quality of life and follow the values of people-orientation, ecological protection and digitalization. With shared governance in harmony, eco-friendly development and shared intelligence as their basic construct, smart communities are backed by technical means such as 5G, big data, IoT and AI, and are working to realize intelligent industries, efficient management, human-centric services and a low-carbon environment. By coordinating various services, they create application scenarios in neighborhood, education, healthcare, entrepreneurship, construction, transportation, emission reduction, service and governance, and develop new functional micro units that are futuristic, but also bring a sense of belonging and comfort.

3.3 Unclear business model: innovative model for shared development, shared governance and benefit sharing

The massive scale of investment and unclear business model prevent a synergy from forming in smart cities. The investments and developments on 5G smart city scenarios can be categorized into two types: network deployment and the deployment of IoT devices and solutions for specific scenarios.

Network deployment refers to the construction of core 5G networks, base stations, etc. Compared with 4G, 5G has higher frequency and transmission rate, but with smaller coverage radius, which means the number of 5G stations will be 2-3 times that of 4G stations, as they need to be more closely located with each other. In 2018, the total number of 4G base stations in China reached 3.72 million. It can then be inferred that to reach the same coverage as 4G, the number of 5G base stations would easily exceed 10 million. If the cost for building one 5G base station is 600,000 RMB, the total investment would be over 1 trillion RMB.

Apart from base stations, supporting devices and software are required for data collection, transmission, storage and processing. As different usage scenarios require different devices and software, the initial investment also varies.

Self-driving bus: The development of self-driving bus includes two steps: the physical modification of buses and the development of a backstage management platform. The transformation of a normal bus to a self-driving bus would cost up to one million RMB. Considering the potential impact from future technology maturing, it is estimated that the modification cost per bus could be lowered to 50,000-80,000 RMB. According to the Shanghai Statistical Yearbook, there were around 180,000 buses and trams in Shanghai by the end of 2018. A 60% fleet modification, together with the development of a new management system, would push the total investment to nearly 10 billion RMB.

Street patrolling robot: Patrolling robots are often sold together with management software and supporting devices in a package that costs 200,000-400,000 RMB. They are most commonly deployed in crowded commercial districts. To patrol a 1000-meter long street around the clock, two robots are required. Take the 12 commercial areas of Shanghai as an example. To cover the total area of 59 square kilometers, around 4000 robots will be needed to perform 24-hour patrolling in major streets, which would cost around 2 billion RMB.

Water body monitoring: To perform three-dimensional monitoring in air, at water surface and under water, over 3 million RMB worth of monitoring devices will be needed, including drones, unmanned vessels, unmanned underwater vehicles, control systems and mounts. In the case of Shanghai, which has over 40,000 rivers stretching 28,000 kilometers, a monthly inspection in full would need at least 23 sets of devices, which would cost over 60 million RMB.

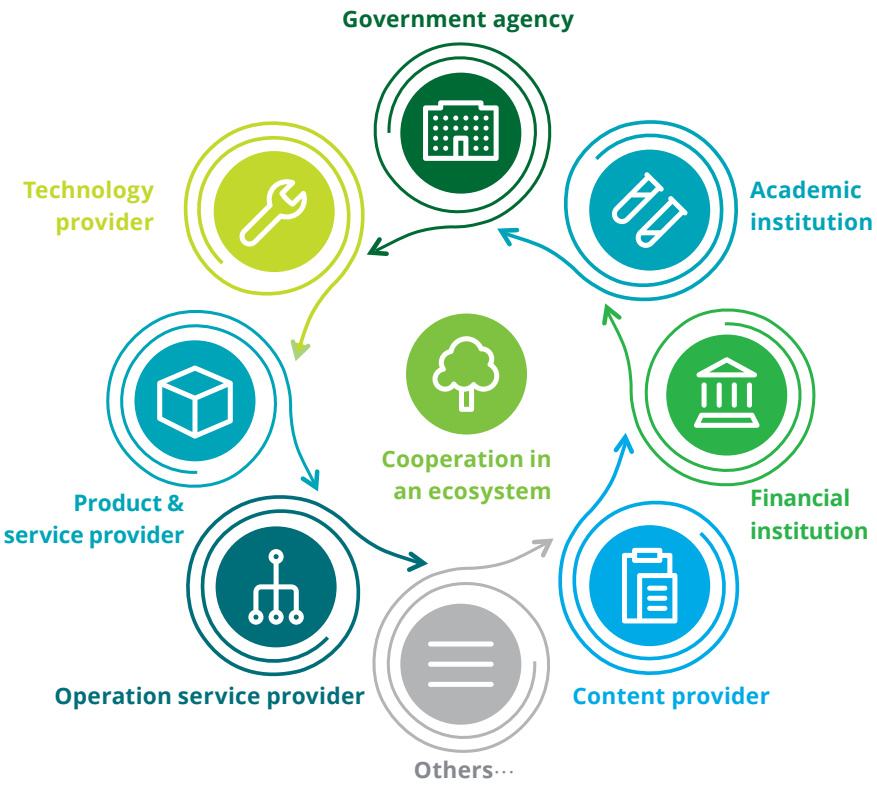
Remote ultrasonic diagnosis: A color ultrasonic scanner with robotic arms costs around 3 million RMB and a 5G base station costs 800,000 RMB to be deployed in the ultrasound room, which put the total cost at 3.8 million RMB, for only one department.

This shows the tremendous initial investments required by many smart city applications, which are often beyond the affordability of a single company or government department. Therefore, one of the challenges today is how to create an innovative investment and financing model.

Besides, the value chains related to smart cities are often quite long, with a large number of stakeholders and the involvement of financial returns and implicit social returns, adding to the difficulty of business model design. If people are unclear about who should invest, who can reap the returns and how the returns will be calculated, the whole society won't be mobilized to form a synergy.

Payer unclear: Applications such as smart security and smart environment protection, which are designed to serve people in their daily life and to improve the urban environment, belong to the scope of public utilities, with citizens being the main beneficiary. However, these services are provided in a relatively open environment, so it is difficult to quantify when and where an individual citizen has used how much of the service, making it impractical to bill the user directly. In this case, governments or related institutions usually need to bear the initial investment. Although governments can recover the cost via indirect charges such as taxes, the challenges remain. On one hand, accurate calculation of the due tax is tricky. Without strictly charging based on actual usage, disputes may arise. On the other hand, even in this model, the cycle of investment recovery is long.

Figure 16: The many participants in smart city development



The complex involvement of multiple fee chargers: Since smart cities often involve huge investments and various types of infrastructures for deployment, development projects are usually undertaken by multiple parties. A variety of cooperation models exist: A company may be assigned a whole region to be in charge of, or a specific type of infrastructure in one region, with other infrastructures undertaken by other contractors, or it could be a combination of both. Take self-driving cars as an example. Two operators may be responsible for the construction of 5G base stations in two neighboring cities, while roadside units and sensors are put in place by local transportation departments. In that case, when a car drives from one city to another, the expenses incurred will need to be split four ways, but it is difficult to determine the respective amounts.

The development of a smart city has bearing on every industry and every aspect of life. Each brings projects that are complex, systemic with daunting workload, huge investment and a large number of participants. To effectively promote smart city initiatives, in addition to a good top-level design, a sound business model is necessary. This will secure the funds needed and clearly spell out the responsibilities and returns of all stakeholders.

Clear division of interests along the value chain

The development and operation of a smart city involves multiple stakeholders, including the government, operators, solution providers, content and service providers and end users. This is a process marked by three stages: the initial stage of infrastructure construction, the mid-stage of the building of data processing facilities and the late stage of service platform development. Along the way, an extensive value chain is involved, including telecommunication equipment manufacturers, system integrators, data collectors and analysts, telecommunication operators and data service providers. As a novel concept with a long value chain and multiple stakeholders, smart cities raise a challenge to the design of business models, because of the ambiguity around questions like who should invest, who can reap the returns and how the returns will be calculated. One of the main focuses of smart city development, therefore, is to figure out who are part of the value chain and to clearly define their responsibilities and interests, in order to coordinate resources accordingly.

An innovative business model that advocates for shared development, shared governance and benefit sharing will attract stakeholders from different verticals to invest in their areas of interests, which can lift the financial pressure off of the government and pave a smooth road ahead. Furthermore, by having some skin in the game and with the promise of future returns, vertical stakeholders will be more motivated in development and operation.

Seeking diverse sources of value

Smart cities may receive funding from the public or private sector, in the form of debt or equity, depending upon future cash flow of the project. The traditional model where the government pays is not suitable for the massive investments of smart cities. Therefore, innovative models should be invented to attract different sources of capital with favorable policies and financial returns. Governments can derive value directly from infrastructure investments, in the form of financial returns, or indirectly, through the appreciation of adjacent lands. Governments should seek diverse sources of value and monetize them to pay for specific projects or cover future expenses.

Designing business models based on application scenarios

In early smart city development, the most common model is sole government ownership, because there is usually a need for different areas to collaborate and share data and resources, especially between the government and public institutions. For example, in the medical field, companies alone are not strong enough to drive hospital digitalization. Even though some hospitals are already digitalized, convincing hospitals to share their medical data with companies remains a challenge, which is why the government has to be the one driving the initiative. This model is suitable for adequately funded areas or areas of significant public interests, such as public security, public transport projects. Meanwhile, the government needs to assign dedicated staff to these projects for future maintenance and problem solving.

Another rising model is the cooperation or joint venture between the government and companies, where government grants concession to companies to build infrastructure and operate the applications based on such infrastructure. Companies are responsible for investing, financing, building and operating the project, which shall be returned to the possession of a designated government entity with no charge upon contract expiration. Featuring full coordination between the government and companies, this model does not require the government to put up much fund. While companies make a profit from project operation, they are also doing a service to city development.

The co-existence of multiple models in future smart cities can be anticipated. This is due to the financial stress faced by various governments, which can be alleviated with the participation of social capital and private businesses. At the same time, unlike companies, many governments are inexperienced in project operation and lacking in professional talents. This is another value that companies are bringing to the table, in addition to funding. Thus, government of all levels should issue policies to create a favorable investment environment to encourage further company participation.

3.4 Severe information silo: City resource integration and operation by smart city operators

Smart city 1.0 is characterized by smart application scenarios in various verticals. However, in actual roll-out, the devices and systems supplied by different vendors are often based on conflicting standards, hindering data sharing across systems. The result is information silos or even "smart silos" that arise from a lack of data and information connectivity across various industries and areas. On the other hand, many government-led projects on smart city IT development face the conundrum of data sharing. Because of institutional reasons, the walls standing between various government departments and public institutions are difficult to shatter. Institutional barriers such as fragmented governance, incoordination and information monopoly keep government data mostly within their departments, used only for internal cycles, without being connected and combined with other databases to create a unified database inside the government. Different government departments often have different data sources and structures, housed in their independent platforms. The prevalence of information silos renders the application of such data ineffective.

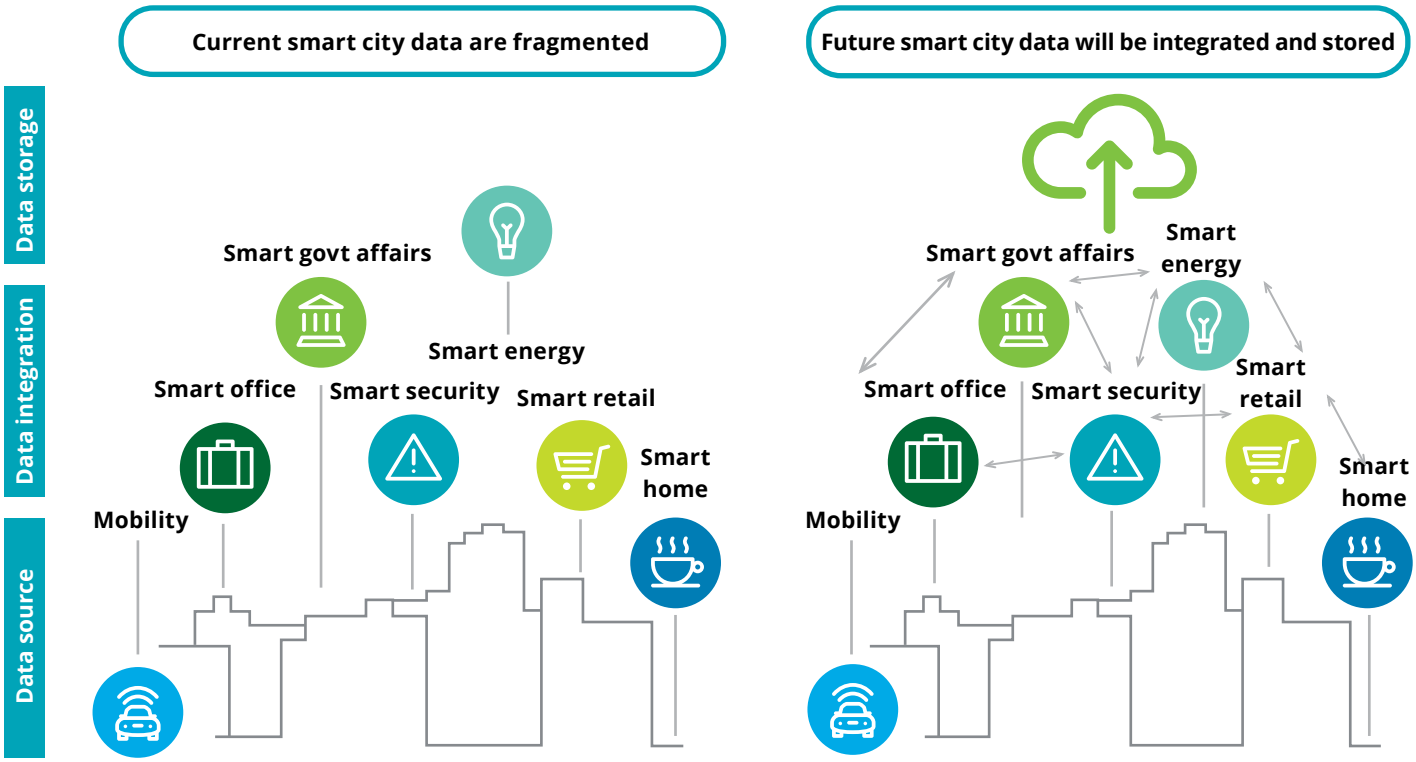
Another problem is the lack of convergence between government data and public data, which calls for the government to step up in data openness. In addition, the government does not yet have in place a sound mechanism for public data collection, which explains their inadequacy in applying public data to innovate smart city applications.

Since most cities do not have consistent criteria for technology assessment, the sharing of information across various systems, given their complicated interconnected relationships, becomes an impossible mission. Over the years, a large amount of data has been picked up by various city systems, which, unfortunately, were developed independently, giving rise to information silos. This is doing a disservice to smart city databases, and hindering the communication and coordination across government departments. As the issue of fragmented governance and incoordination becomes more prominent, it will be more difficult to find the synergy needed to build an integrated service model that encompasses all social elements of a city. Therefore, information coordination and effective management is a challenge plaguing many smart cities.

Smart city operators, as integrators of city resources, creators of operational service ecosystems and leaders of marketized operation, support smart city development during the phases of "planning, financing, building and operation" in a "capital + technology" model, making up for government shortcomings in professional talent, funding, planning, management and operational experience.

The first job of a smart city operator is to digitalize the not-yet-digital city resources and integrate existing digital resources. Based on the link paths of city resources, the second step is to integrate existing government information and resources, followed by integration of city IoT resources and finally, integration of city data. Afterwards, based on the operational platforms of a city, operators should enable access to operational service ecosystems to C, B and G, by utilizing the data resources of the city.

Figure 17: Data integration in future smart cities



The development of a 5G-connected smart city would not be possible without the support of technologies, including core **general technologies** that have achieved key breakthroughs, best represented by 5G, big data analytics, AI, IoT and spatial information technology, as well as **specific technologies** that are developed to meet the needs of specific verticals, also with ongoing progress. Smart cities that have inconsistent planning or data interfaces unmatched with technical standards in the early days may easily fall into the traps of information silo, repeated development and difficulty in technology fusion. For technologies to really work in smart city scenarios, general technologies should be fused and integrated, on which basis specific technologies for specific verticals will be innovated and developed. **The first thing to consider for a city operator during the integration of smart resources is how to enable technology fusion with 5G.**

Fusion of general technologies

The fusion of general technologies refers to the combination of two or more core underlying technologies, such as 5G and AI, so that different technologies can support and call each other for maximum functions. The most typical technical architecture of smart cities, for instance, consists of a terminal layer, which senses and collects data based on IoT technologies, a network layer, which transmits data quickly and reliably via the 5G network, and a service layer, which uses edge computing and AI to process data at the edge and form decisions before sharing them with city operators. In this way, a complete end-to-end chain of data is created. Along this chain, every link should be able to call other links and respond to their feedback, which means to a large extent, the execution efficiency and performance of the entire system depends upon the coordination among the links. To truly realize the fusion and coordination of general technologies, it is necessary to experiment by trial and error in various smart city scenarios.

Innovation of specific technologies

Specific technologies refer to the applied technologies developed to meet the needs of specific verticals that are built upon underlying technologies. A case in point would be C-V2X, a core technology in the vehicle infrastructure cooperative system that China is promoting. Built upon cellular networks, C-V2X is an innovative vehicle communication technology that allows vehicles to exchange information with the outside world in a fast and stable manner. This technology will be ready for use in autonomous driving and other smart transport scenarios upon the implementation of 5G and edge computing. Another example can be found in drone maintenance and rescue. With 4K ultra-high-definition image transmission technology that brings together 5G wireless communication with drone technology, drones can benefit from the high bandwidth and low latency of 5G network and transmit high-definition images to the control terminal in real time, making precise remote control possible. Underlying technologies will only reveal their best value and better serve different verticals when being combined with specific technologies.

Technology fusion and innovation are mutually reinforcing and often happen at the same time. Only by solving the application challenge of new technologies can 5G-connected smart cities go from a concept on paper to real implementation, benefiting the government, businesses and citizens.

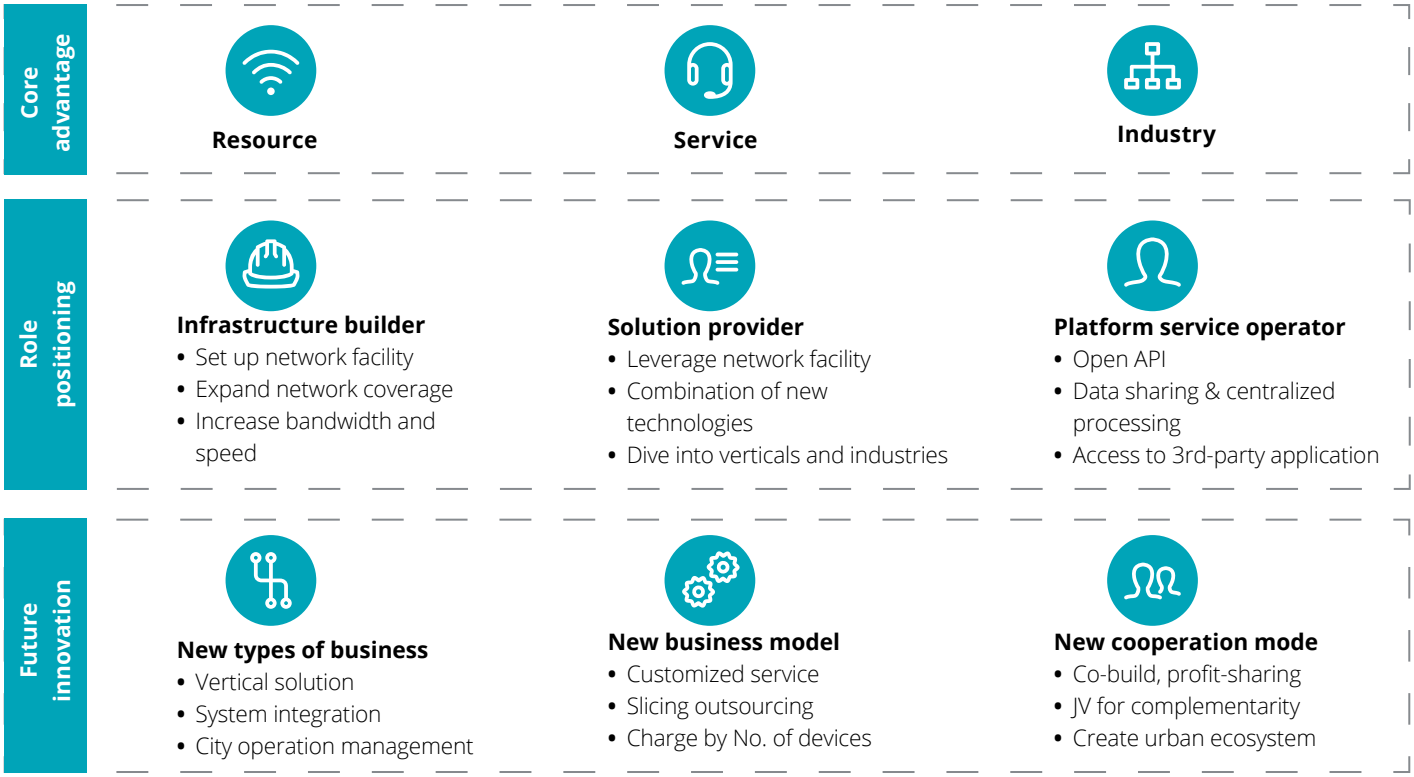
4. Thoughts on the role of operators in the 5G era

Smart city involves many novel 5G-based application scenarios that require the availability of various technologies and infrastructures, posing a high requirement to the comprehensive capabilities of city investors. Given this context, professional city operators naturally emerge. With their in-depth systematic thinking, well-developed frameworks of rules and unified systems of standards, they assist governments in city management and operation and drive the sustainable development of smart cities.

Tapping into their natural advantages in big data and cloud computing as well as their key capacities in 5G network, telecommunication operators will gradually connect the smart devices across the city and create a unified and efficient IoT platform, which will play an indispensable role in smart city infrastructure.

While offering efficient network infrastructures and connectivity services, telecommunication operators and partners of smart city ecosystems will join hands in developing smart applications and ecosystems to usher in a new landscape of co-development, co-governance and co-existence.

Figure 18: Operators in the 5G era



4.1 Unique advantages of operators in the 5G era

Responsible for establishing the communication infrastructures of a nation, telecommunication operators have long dedicated themselves to driving IT application in the national economy and society and supporting the "Internet+" fusion in various sectors. Telecommunication operators enjoy the following natural advantages in facilitating smart city development:

Advantage No.1: Rich resources in network, cloud and data, outstanding resource integration abilities and operational excellence with extensive experience in operational safety and norms

5G network development: As a smart city infrastructure, 5G network is the foundation for the Internet of Everything as well as the pipeline for big data collection and transmission. As network builders and operators, telecommunication operators enjoy a natural edge in network resource, operation and management.

Edge cloud deployment: With growing volumes of data generated by future smart cities, city managers and users will raise higher expectations for the real-timeliness of massive data and information. As an extension of the central cloud at the edge of network, edge cloud is an effective solution to issues of bandwidth waste and long latency. By processing the massive amount of data that the city generates in real time with high efficiency, it can help users accelerate the decision-making process. Since edge computing facilities can be deployed close to or inside base stations to share the land, electricity and other resources with the stations, operators enjoy competitive costs and superior efficiency in edge cloud deployment.

Big data: Telecommunication network is the circulation channel for all Internet-generated data and information. After smart terminals become prevalent, almost every aspect of the life of urban residents is taking place online, generating tons of data that can be used to produce accurate user portraits. With further development of smart cities, the Internet of Everything based on IoT technologies will become a reality, creating tremendous business and social value from the tons of pooled data on people and devices. Therefore, thanks to their network and edge cloud facilities, operators will be one step ahead in data collection and processing.

Advantage No.2: Service capability

As the service provider of telecommunication networks, telecommunication operators have a huge professional service team covering every county, city and province in the nation, capable of offering comprehensive professional services 24/7. They are not only experienced in serving ordinary consumers, but are also well-trained in serving government and corporate clients. After years of training and practice, they have the experience and know-how of working on important projects, a strong sense of confidentiality, and the ability to ensure secure and stable operation of the IT systems of their clients.

Advantage No.3: Industry strengths

In recent years, telecommunication operators have been keen on driving other sectors to transform and upgrade and are closely following the latest Internet developments in popular areas such as government, healthcare, education, tourism, manufacturing, innovation and entrepreneurship circle. This leads them to found their own Internet subsidiaries and to execute Internet-related projects across the country. Take China Unicom as an example. In partnership with Ericsson, Qingdao Port and ZPMC, China Unicom successfully controlled a 5G-connected quayside container crane to automatically handle, pick up and move containers in Qingdao port. This is the world's first case of remote crane control in a real production environment based on 5G network. In Jiangxi province, in its exploration of the idea "Internet + farming", the agricultural incubation base by China Unicom is moving ahead with the R&D and integrated operation of agricultural IT products. Through in-depth involvement in the government top-level design for smart agriculture, by developing, operating and supporting unified and innovative IT products for Chinese farmers, China Unicom is doing its part to empower agricultural transformation and upgrading. In Guizhou, the tourism incubation base by China Unicom is following through on the idea of "tourism + IT" to cultivate core competencies for the travel industry. Three business areas "tourism big data + tourism IT system integration + tourism industry operation" are being vertically developed and the core product Tourism Big Data Platform is now being promoted across the country.

4.2 The positioning of operators in smart cities

The rapid progress of new technologies and the accelerated smart city development have presented to the telecommunication industry major opportunities for growth. To take advantage of the opportunities presented by diversifying application scenarios and increasing number of smart devices, operators should clearly define their roles and positions, fully utilize available resources and provide quality services to all smart city participants. In addition, telecommunication operators have gained an in-depth knowledge of local network deployments and niche industries, thanks to the subsidiaries or branches they set up in various provinces and cities, which allows them to participate in the design and planning of smart cities in the capacity of government advisors and provide tailor-made suggestions.

4.2.1 Network infrastructure builders of smart cities

The foundation of smart cities is the communication of data and information among connected things, which means telecommunication networks are one of the most important city infrastructures. In this area, telecommunication operators, as providers of such networks, have an important role to play. That is, to fulfill the demand for network connection from public utilities and residents and to safeguard the stable operation of smart city applications, as 5G expands network coverage and bandwidth.

4.2.2 Smart city solution providers

With ubiquitous 5G connections among people and things paving the way for the collection, transmission and processing of mobile data, 5G network will become a major pushing force for the IoT. Tapping into their network infrastructures in combination with cloud computing, big data and other technologies, operators can seek cooperation with vertical participants by combining communication networks with downstream applications and provide vertical-specific solutions for various smart city scenarios.

4.2.3 Smart city platform operators

To unleash the maximum potential of smart cities, which involve every aspect of residential life and industry activities, the only way forward is to achieve integration and sharing of city information, data openness, centralized monitoring and cross-departmental coordination. After micro units become connected, the operation and management of an entire city will become far more complicated than that of a single unit. At this time, a smart city operation platform may be set up, on which an operator will take over the job with their professional expertise.

By opening up the API interface, operators will connect the third-party applications on 5G network to the smart city platform and share network resources, data and other operational services with them. For example, a telematics application in the area of smart transportation can be connected to the platform and interact with public transport data. On one hand, this enriches the source of data and information that the transportation department can use to manage public transportation. On the other hand, the telematics application is enhanced from the information that it receives on vehicle location and speed, as it helps improve the efficiency of vehicle operation.

4.3 Key operator innovations in smart city development

4.3.1 New types of business

The top-level design of smart cities in the new 5G era: A new generation of information and communication technologies represented by 5G, AI and edge computing are booming, with the emergence of various new applications. In comparison, the top-level design of many smart cities is lagging behind. The government and enterprise service departments of telecommunication operators are often in close contact with governments at all levels. Relying on their first-mover advantages in 5G network and application, telecommunication operators can fully support those involved in the development of smart cities and micro city units, such as governments and real estate developers, by providing future-oriented, forward-looking top-level design.

5G + vertical solutions: 5G smart cities will spawn innovative applications and business models, driving the demand for customized solutions. The characteristics of 5G deployment and its integration with edge computing mean that operators will have more opportunities to provide vertical solutions for enterprise users in the future. After enhancing their professional capabilities in vertical solution by creating smart city research institutes and 5G innovation centers, or by M&A, joint venture and strategic cooperation, operators can develop customized 5G solutions based on their strengths in network technology and data to offer a one-stop service of "5G network + solution + management" for governments and enterprises.

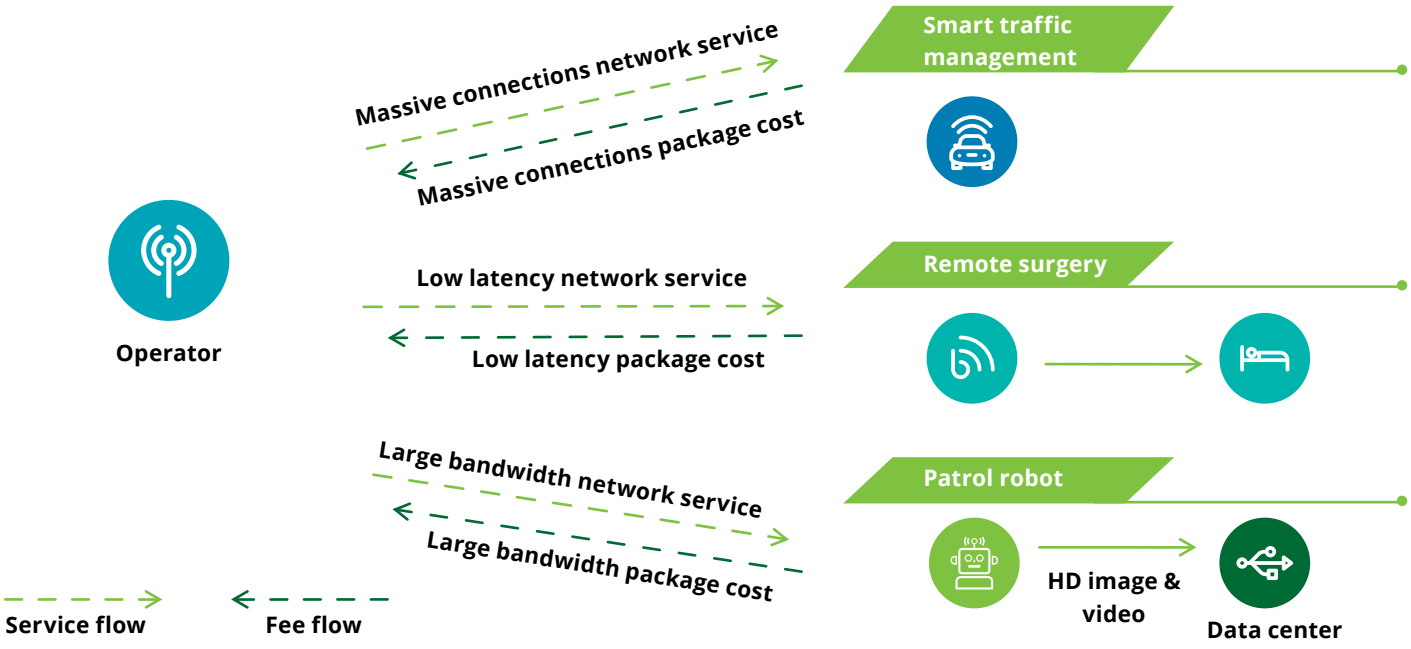
The operation and management of digital twin city: With the commercial use of 5G, the futuristic ubiquitous sensor connection and data transmission network are now part of the reality, driving qualitative transformation from an increasing amount of collected data. With major breakthroughs in information technologies such as perception modeling and AI, cities have entered the era of the Intelligence of Things, where digital twin city, as an emerging technological path for new smart city development, has become a cutting-edge model for smart and sustainable operation. By applying BIM, big data, cloud computing, AI, three-dimensional visualization and other technologies and by integrating the data from micro units and IoT, telecommunication operators can develop a unified operation and management platform of digital twin city that connects governments, enterprises and residents. This platform fully senses the operating status of the city and assists operators in decision-making by providing timely advice. In short, telecommunication operators can serve as service providers operating the smart city platform. Centered around the digital city operation and management platform, they will also provide value-added services to governments and enterprises, such as the operation, support and maintenance of smart cities and micro units.

4.3.2 New business model

In the era of 3G and 4G, the only available fee structure for mobile network service is based on data usage. As 5G technologies mature, business model innovation has not only become possible, but also necessary for operators.

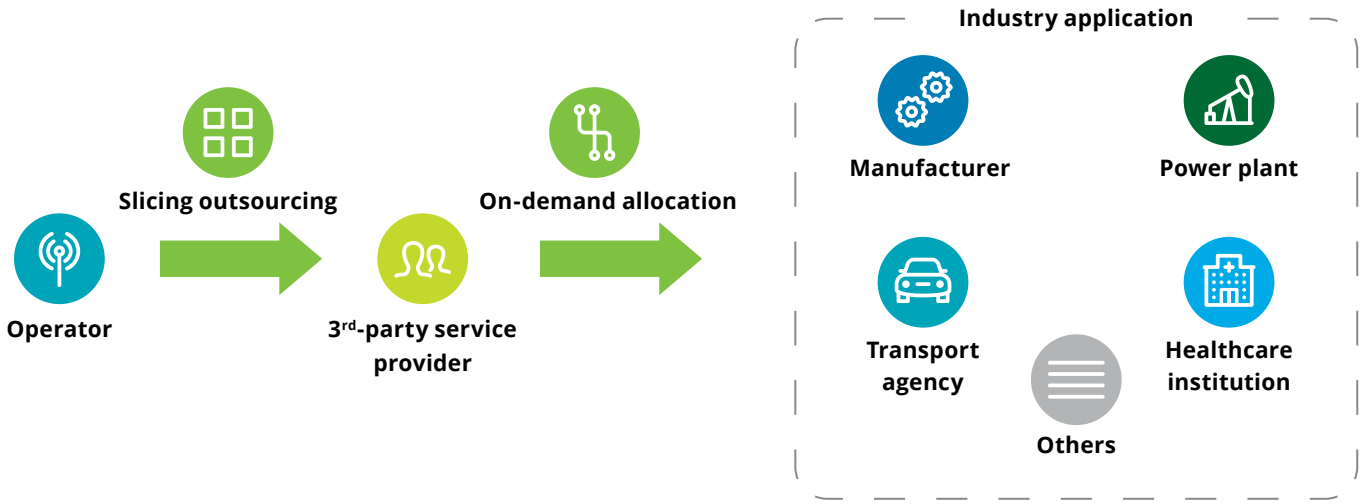
Differentiated services: In the 5G era, NFV, SDN and network slicing technologies bring new possibilities to the services and business models of operators. In addition to charging by data usage, services can be priced based on **use scenario, duration, region, bandwidth, latency and the number of connected devices**, or a combination of any of them. On one hand, this meets the need of customers for customized services, and on the one hand, maximizes the value of 5G networks.

Figure 19: The differentiated service model for operators in the 5G era



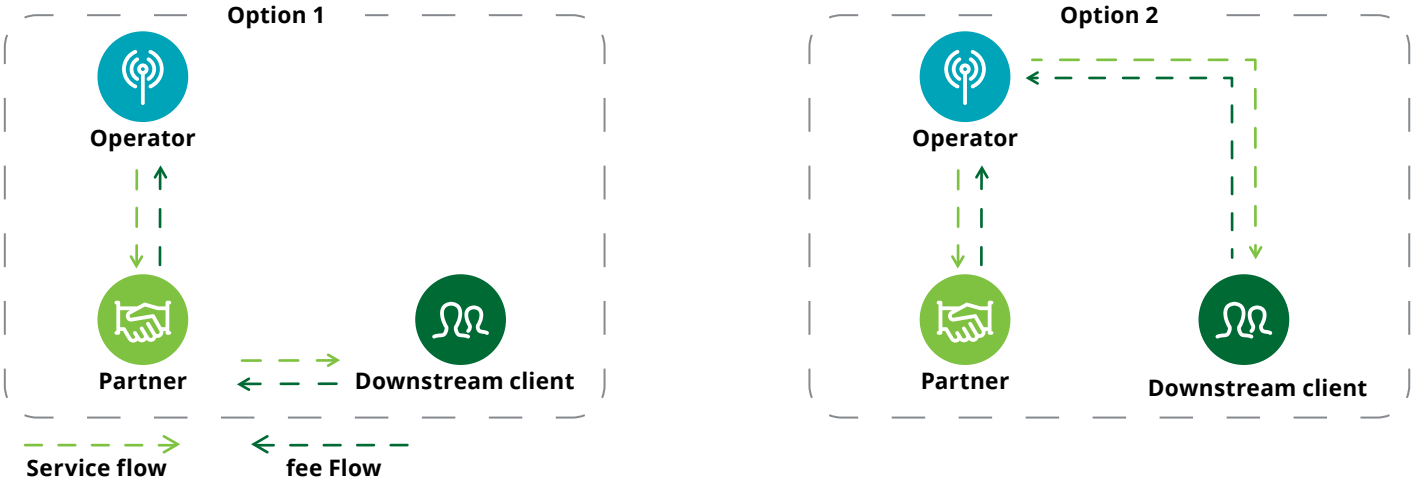
Slicing technology outsourcing: Operators can outsource their 5G network slicing capabilities to third-party service providers, who will then allocate resources to their downstream application users, and design a refined pricing scheme based on speed, bandwidth and the number of connected devices. The advantages of this model include lower operating costs, as they only need to deal with a few network service providers, and lower network operation and management costs.

Figure 20: The network slicing model for operators in the 5G era



Vertical platform/solution: To add more value to their service offerings, operators in the 5G era will need to become more involved in various vertical sectors, cultivating and developing industry-specific 5G applications with profitable business models, building vertical platforms or providing industry-specific solutions. Interested operators may try one of the two ways: One is to sell network slicing service to a vertical partner, who then bundles the 5G network with its own product offerings and sells to downstream clients. The proceeds will then be shared with the operator. The second model is where the operator combines their network expertise with the vertical know-how obtained via acquisition, joint venture or cooperation, and directly sells solutions to industry clients. For this model to work, operators need to strengthen the ability to cooperate with third parties.

Figure 20: The network slicing model for operators in the 5G era



4.3.3 New cooperation model

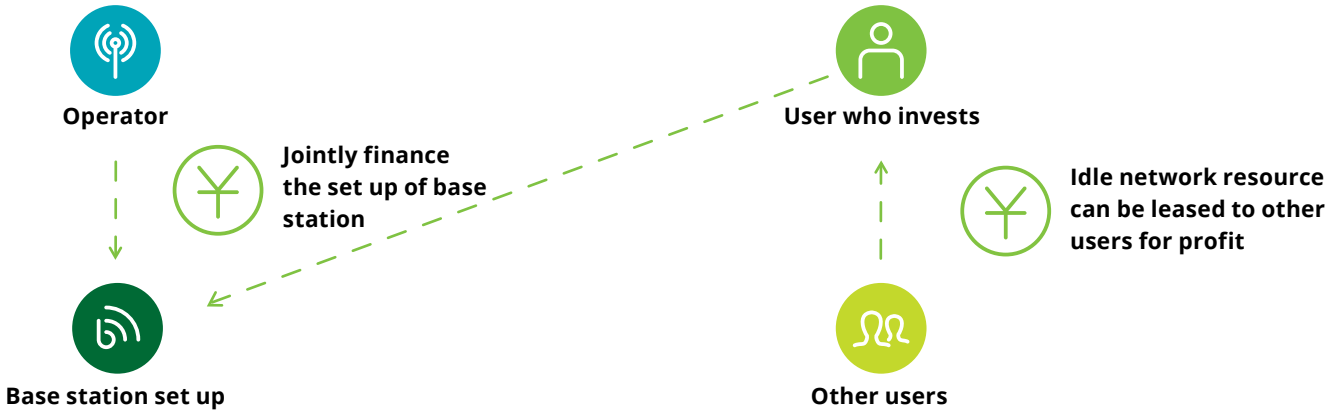
Given the challenges of smart city development, such as the large scale of investment and the complexity of technology integration, it is well beyond the ability of any government agency or company to pull it off on their own. Thus, the future trend will be institution cooperation across different fields in the value chain. Tapping into their network resources and positive brand image, operators can work with industry partners to build up technologies and professional experience and drive smart city initiatives together.

Multi-party participation with revenue sharing: Given the huge cost of 5G network deployment, an innovative cooperation model and a well-designed revenue sharing mechanism must be proposed, to alleviate the financial pressure of all participants while fueling a full roll-out of the 5G network.

Operators can consider cooperating with downstream industry users to jointly fund the 5G base stations needed in city units. In this model, a pricing scheme that sets different rates for internal traffic and external traffic will be designed, giving industry users network access at a discount and allowing the renting of idle network resources to help recover some of the initial investment. For example, operators can build 5G base stations together with industrial parks and open up the network for use by the factories, companies and employees in the park. Factories and companies in the park that have chipped in are eligible for a special discount on the data consumed by their equipment during production and processing, while the data used by workers or outside visitors will charged by the operator, with revenue shared with these companies.

If any network resource is used outside working hours, companies can choose to rent their private networks to other factories or companies in the park for additional income. This will also incentivize more companies to join in the early stage of investment. Alternatively, operators may also consider financing via asset securitization. With their good brand image and business reputation, operators can raise money from the society by securitizing their base station assets to alleviate their financial pressure.

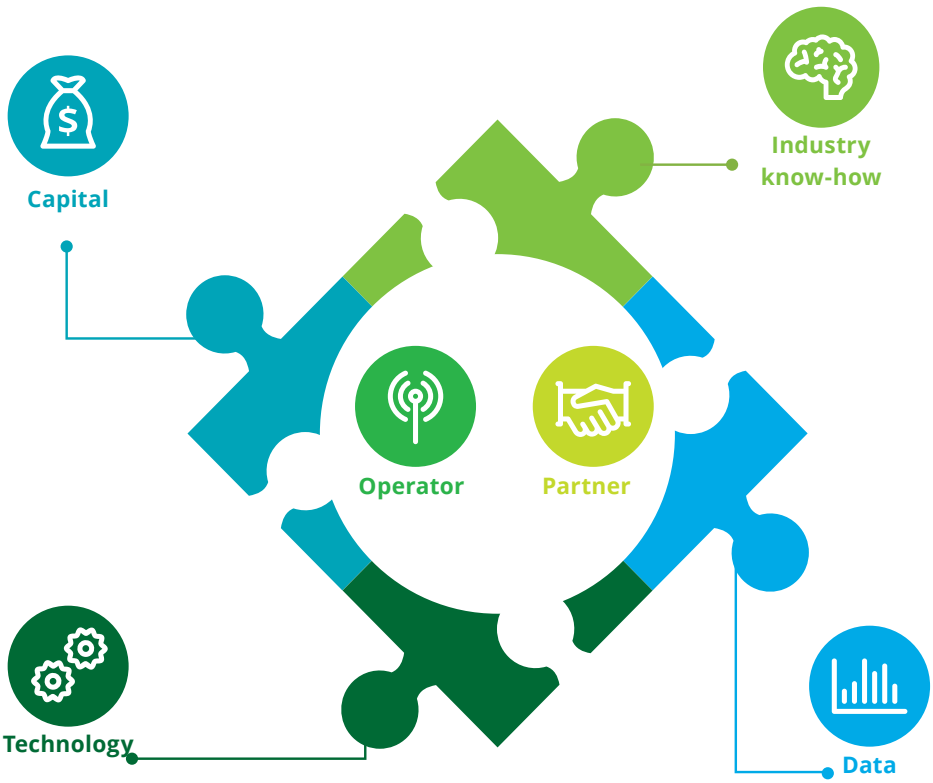
Figure 22: Operators and industry users cooperate to build infrastructure



Forming of joint ventures to draw on each other's strengths: Smart city development not only depends on technological progress and integration, but also requires operators to understand the needs and business logic of each vertical. Therefore, to draw on each other's strengths in technology, market, and resource, the establishment of joint ventures between operators and vertical players has become an emerging model for cooperation. A pre-requisite and basis for this model is the mixed ownership reform for operators.

For example, during its mixed ownership reform, China Unicom has joined hands with Tencent and Alibaba and founded a joint venture with Alibaba named Yunli Intelligence Technology Co., Ltd. to provide cloud services, IT technical services and holistic solutions in government affairs, finance, environmental protection, public security and manufacturing. Yunjing Culture and Tourism Technology Co., Ltd. is the joint venture between China Unicom and Tencent, with tourism big data, smart tourism and operational services as its core businesses. With further integration of smart communication infrastructure + vertical-specific solutions, China Unicom begins to stand out in smart city development. Looking to the future, the founding of joint ventures is set to become one of the most important ways for operators to quickly enhance their competitiveness in different verticals.

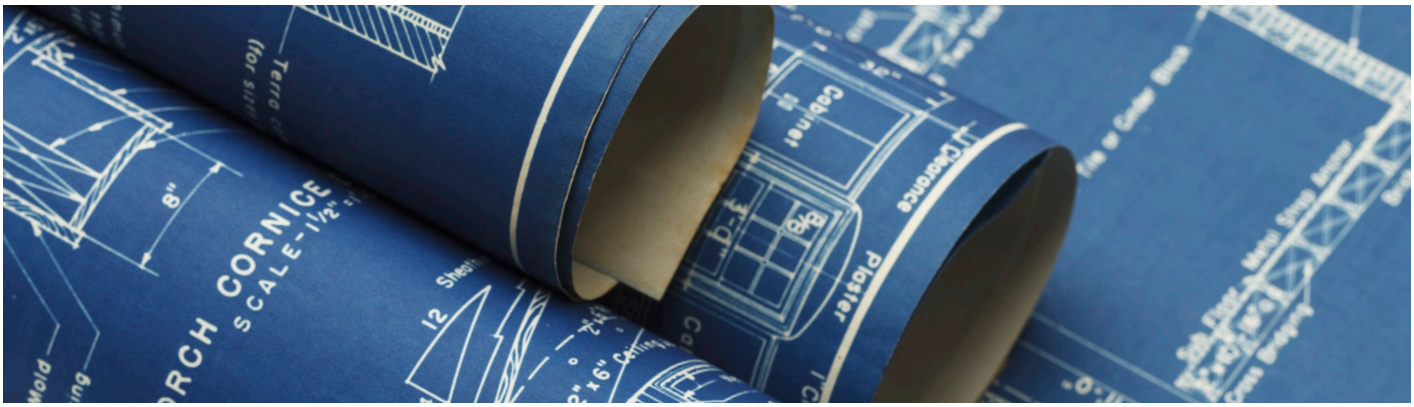
Figure 23: Operators and industry leaders establish joint ventures to pool complementary resources



Acknowledgements

2019 is the first year of 5G commercialization. Seeing an urgent need of the planning and development of 5G smart cities across the country, Deloitte China and China Unicom Smart City Research Institute jointly released the White Paper on 5G-Enabled Smart Cities to study the trends of smart cities in the 5G era. Focused on typical application scenarios of 5G such as transportation, security, environmental protection and governance, the report analyzes the major challenges facing current smart cities in the 5G era, with discussion of implementation options and insights on the role of operators in driving 5G deployment in smart cities.

We are grateful that the drafting of this report was kindly supported by the government and enterprise service department of China Unicom, who provided guidance, China Unicom Network Technology Research Institute, China Information Technology Designing & Consulting Institute, China Unicom System Integration Co., Ltd. and Yunli Intelligence Co., Ltd. for the research materials.



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