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Constructing Internet Plus New Infrastructure in Cities

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Abstract: Internet Plus New Infrastructure is an essential component of the Internet Plus initiative. This study analyzes the demand, development, and problems of the Internet Plus New Infrastructure mode. In addition, the study proposes that establishing the Internet Plus New Infrastructure mode requires addressing the effective aggregation, integration, and application of massive data and ensuring realtime processing and response with high concurrency, low latency, and high security and reliability of network services. The study also demonstrates the typical construction path for the Internet Plus New Infrastructure mode, that is, addressing the efficient integration and effective use of city data by constructing data middle offices and providing both high-throughput and high-quality services with "information high-speed rail stations." Furthermore, the study analyzes concepts and technical prerequisites of the data middle offices and information high-speed rail stations, which are the core infrastructure of the Internet Plus initiative. Finally, to promote the Internet Plus initiative in China, the study recommends measures to design the Internet Plus New Infrastructure mode in cities, from the perspective of planning, policy implementation, and flexible operating models.
Keywords: Internet Plus; new infrastructure; data middle office; information high-speed train; high-throughput computing

1 Introduction

The development of information technology (IT) has transformed human society from the IT 2.0 era represented by the Internet to the IT 3.0 era represented by the Internet of Everything [1]. The *Guiding Opinions of the State Council on Actively Promoting the Internet Plus Action* was released in July 2015. Since then, various industries, such as government administration, education, medical care, retail, finance, energy, and agriculture, have been deeply integrated with the Internet. New application to smart government services, medical care, and transportation has surfaced in multiple cities. However, the persistent development of fifth-generation mobile communications (5G), artificial intelligence (AI), blockchain, edge computing, and other technologies have driven Internet Plus toward a new stage. This is manifested in commercialized 5G and blockchain technology, dominant edge computing technology, and large-scale applications of AI in speech and facial recognition.

In March 2020, China proposed to expedite the construction of new infrastructure, such as 5G networks and data centers, the essence of which is to strengthen the infrastructure of information technology and design a robust framework for social governance, industrial upgrading, and further development of the digital economy. On one hand, the number of network users and network connection devices will enjoy continued growth, combined with an increase in the amount of data, which requires the network to incessantly enhance bandwidth and data processing throughput. On the other hand, Internet Plus will enable the penetration and transformation of consumer

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Internet into the industrial Internet. Therefore, to transform and upgrade many Chinese enterprises, factory production and business management should become contactless, collaborative, and intelligent, and the interconnection of large-scale production equipment, more precise real-time control, and integration and utilization of massive data should be realized. Particularly during the prevention and control of the novel coronavirus pandemic, specific scenarios, such as telecommuting, remote collaboration, online education, and telemedicine, have become essential for the high throughput and low latency of massive data and network transmission.

Whether it is from the perspective of application demand or technology promotion, China’s Internet Plus technology has entered a new stage of development, with a series of demands and changes. How a city builds a new type of Internet Plus infrastructure to adapt to new needs and changes is clearly a topic with high research value. Based on the analysis of demand and development status, this paper summarizes and proposes typical construction paths for urban Internet Plus infrastructure, such as the construction of data middle offices and “information high-speed rail stations.” Further, the paper provides methods and suggestions for the development of “Internet Plus” new infrastructure.

2 Requirements

An urban Internet Plus infrastructure is essential for responding to the data processing and intelligence needs of the Internet of Everything era, such as, the demand for interconnection and interoperability of massive equipment, the demand for massive data integration, sharing, and circulation, and the demand for massive requests for high-throughput processing and real-time response.

2.1 The demand for interconnection and interoperability of massive devices

As more devices are connected to the mobile network, new services and applications are successively emerging, and data traffic is increasing, which challenges the network. The development of 5G addresses this challenge. In the 5G network, the data transmission rate can reach up to 10 Gbit/s, which is 100 times faster than the fourth-generation mobile communication technology (4G), while the network delay and response time are less than 1 ms. Therefore, 5G introduces an era of Internet of Everything. According to a report released by the Global System for Mobile Communications Association (GSMA), the total number of global IoT connections reached 12 billion in 2019, and it is estimated this number will reach 24.6 billion by 2025 [2].

2.2 Demand for integration, sharing, and circulation of massive data

The challenge brought forth by the Internet of Everything era is in the explosive growth of data, in addition to managing, governing, and applying these big data [3]. According to the International Data Corporation's forecast, the total amount of global data in 2025 will reach 175 ZB, of which China’s data volume share will be 48.6 ZB. Thus, China will become the country with the largest data volume in the world [4]. With the continuous advancement of China’s big data, data as a production factor has become a driving force for the high-quality development of China’s economy. The *Opinions of the Central Committee of the Communist Party of China and the State Council on Building a More Complete Factor Market Allocation System* issued in April 2020 clearly stated that data should be used to multiply other factors, and the market for data factors should be cultivated. Data contains economic and commercial value, but its value can be realized only by flowing, integration, sharing, mining, and application. Thus, resolving problems, such as data sharing, repeated construction, and “data islands,” has become a challenge that a city must face and overcome.

2.3 The demand for high-throughput processing and real-time response

The continuous development of 5G, the Internet of Things, and smart cities has improved the digitization of the entire society, and the generation, amount, and processing methods of data have changed. Data circulation speed, cost of use, aggregation ability, and control ability are poised to become decisive factors measuring the competence and competitiveness of various industries [5]. New urban applications, such as smart driving, telemedicine, and industrial control require real-time guarantees and precise control. Traditional big data centers or cloud computing centers are facing tremendous pressure. These centers cannot meet the high throughput, high concurrency, strong real-time, high-security and reliability requirements of big data processing in the Internet of Everything era.

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3 Development status and problems

3.1 Development status

3.1.1 5G enters the commercial stage

Currently, 5G has entered the commercial stage in China, and more than 40 cities, including Beijing, Shanghai, Fuzhou, and Hefei, have entered the first batch of pilot projects. In June 2019, the Ministry of Industry and Information Technology officially issued 5G commercial licenses to China Telecom Corporation, China Mobile Communications Corporation, China United Network Communications Corporation, and China Radio and Television Network Corporation. In October 2019, the three major operators of China Telecom Group Co., Ltd., China Mobile Communications Group Co., Ltd., and China United Network Communications Group Co., Ltd. announced 5G commercial packages, and officially launched 5G commercial packages in November, marking China's official entry into 5G Commercial era. According to China Academy of Information and Communications Technology, by 2025, the commercial use of 5G in China will directly bring about 10.6 trillion yuan in total economic output and indirectly drive total economic output of 24.8 trillion yuan [6].

3.1.2 Cloud computing model is mature, AI is widely used

After years of development, cloud computing has transformed into a mature model and has been widely used. Cloud computing provides on-demand services and is measurable. It enables resource pooling, is flexible, and is widely used in government and enterprise management. In China, Alibaba Cloud, Tencent Cloud, Huawei Cloud, and Inspur Cloud have made great progress. Simultaneously, with the improvement of computing power, the increase of data volume, and the enhancement of deep learning capabilities, AI is now widely used in industrial production, government services, finance, education, and other fields. AI performs multiple functions, for example, facial recognition, voice assistance, intelligent decision-making assistance, and multi-scene interactive systems.

3.1.3 Edge computing is in the ascendant

The increasing sensors and smart devices and growing informatization in various industries ensures a steady growth in the amount of network data. This places higher requirements on the bandwidth and rate of data transmission and higher requirements on the high precision and real-time response of data transmission. However, the current smart service model relying on cloud computing has real-time and delay jitter problems [7]. The development of urban Internet Plus new infrastructure necessitates the resolution of the way in which massive terminals and smart applications directly connect to the cloud. Edge computing can realize local data storage and processing closer to the edge of the network, localize processing and response to simple requests, build a "local intelligent ecology," and provide cloud computing services [8].

3.1.4 New applications such as smart driving and smart factories appear

With the rapid development of technologies such as AI and big data, autonomous driving and the Internet of Vehicles are increasingly emerging. At present, Chongqing, Wuhan, Changsha, Beijing, Shanghai, and other cities have planned and tested unmanned road sections. The continuous demand for car–road–person collaboration has enabled a driverless car to collect hundreds of gigabytes of data in one minute. Additionally, the efficient information interconnection between machines and equipment in smart factories can realize dynamic real-time data perception among production equipment, materials, and personnel. This can not only fulfill the factory's 24-hour monitoring requirements and complete tasks, such as energy consumption optimization and automatic production decision-making, but also addresses personalized customization and flexible production. In addition, operators can remotely understand the real-time dynamics of production and participate in the command or coordination of the production process.

3.2 The problems ahead

3.2.1 Data islands still exist

Currently, planning and design of the city's information infrastructure is insufficient, the mechanism to induce multi-subject interest coordination is not mature enough, and the information system construction lacks a standard model. These factors have led to a lack of public platforms and sharing channels among government departments, enterprises, and between governments and enterprises in China. Thus, many cities face the problem of "unwilling to share, dare not to share, and don't know how to share" their data [6], and shared or open data cannot be associated and integrated due to lack of format standards, data quality issues, and so on.

3.2.2 Urban localization data processing urgently needs to be strengthened

The advent of the Internet of Everything era brought along a dramatic increase in the amount of data generated by urban information infrastructure and large equipment, bringing higher data transmission bandwidth requirements. Simultaneously, new applications, such as intelligent driving, remote control, and collaboration, also introduced higher requirements for the real-time and accurate data processing, and traditional cloud computing models can no longer effectively cope [4]. Large amounts of data and requests need to be processed locally and responded in real time. To a large extent, a smart city needs to be equipped with a localized big data center with efficient processing capabilities.

4 Typical construction path

The construction of a new urban Internet Plus infrastructure is a system project. From the perspective of infrastructure, the construction content covers smart terminals, backbone networks, 5G base stations, data centers, cloud platforms, smart application systems, and so on. From the perspective of the full lifecycle of big data, it involves device interconnection to data collection, data aggregation to data fusion, data sharing to data circulation, and data processing to data application. However, an urban Internet Plus infrastructure is built to ensure the continuous growth of the convergence, integration, sharing and application of massive amounts of data and provide a safe and reliable platform, with efficient processing and real-time response-ability to hundreds of billions of network application requests. The data middle office can effectively respond to the surge in urban data and promote the effective use of data. The “information high-speed rail station” can serve as the foundation of the data center, providing high-throughput and high-quality services.

4.1 Data middle office: the core infrastructure for the city’s Internet Plus

The city’s construction of Internet Plus infrastructure is based on gathering and applying the city’s big data while satisfying efficient interconnection. To solve the problems of data sharing, “data islands,” data governance, and data utilization, many cities in China have started building data middle offices.

The concept of data middle office has not yet been unified. ThoughtWorks proposed that the data middle office is a capability platform between the rapidly changing and innovative front-end system and the record-based back-end system. It aggregates and manages cross-domain data, abstracts and encapsulates data into services, and enables the realization of the logical concept of business value. Fu et al. [10] believe that the data middle office is a set of sustainable “put data into use” mechanism, a strategic choice, and an organizational form. It is based on a novel business model and organizational structure and supported by tangible products and implementation methodology, capable of building a set of mechanisms that continuously transform data into assets and serve the business.

The preliminary stage for building data middle offices is to address slow changes in core data models and rapid changes in application requirements. Through the establishment of data middle offices, the unified collection and aggregation of data and the standardization, capitalization, and service of data can play influential roles in meeting the diversity of user needs and support application variability. Through the construction of data middle offices, we can achieve urban public data precipitation and sharing services, which can quickly respond to the dynamic needs of users and support foreground applications. In addition, the reliability and stability of the data middle offices is satisfactory, and it can guarantee standardization, timeliness, and efficiency. The overall technical architecture of the data middle office is shown in Fig. 1, which is divided into the following modules [10].

(1) Data aggregation. Collect and aggregate data from all levels of society across the city, such as the data of various commissions, offices, and bureaus of the government system, using real-time access or offline batch import to aggregate large amounts of heterogeneous, multi-source data.

(2) Data development. This is primarily used by data developers to process data and algorithm modeling, such as providing tag libraries for business systems.

(3) Data system. After data aggregation and data processing, the data is categorized into applications, constituting a basic data warehouse. The basic data system includes label data, post-source data, application data, and unified data warehouse.

(4) Data asset management. Data asset management includes data asset catalog management, metadata information collection, data blood relationship detection, data lifecycle management, data quality, and data standards.

(5) Data service system. Data service is formed by transforming data into a service capability and encapsulating

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the data model according to application requirements. The data service system provides application system, data application interface, service creation, service authorization, call management, and so on.

(6) Data operation system and security management. After processing, the data middle office packages the data into a public data product or service. The data operation system and data security management are the basis for the continuous operation of the data middle office.

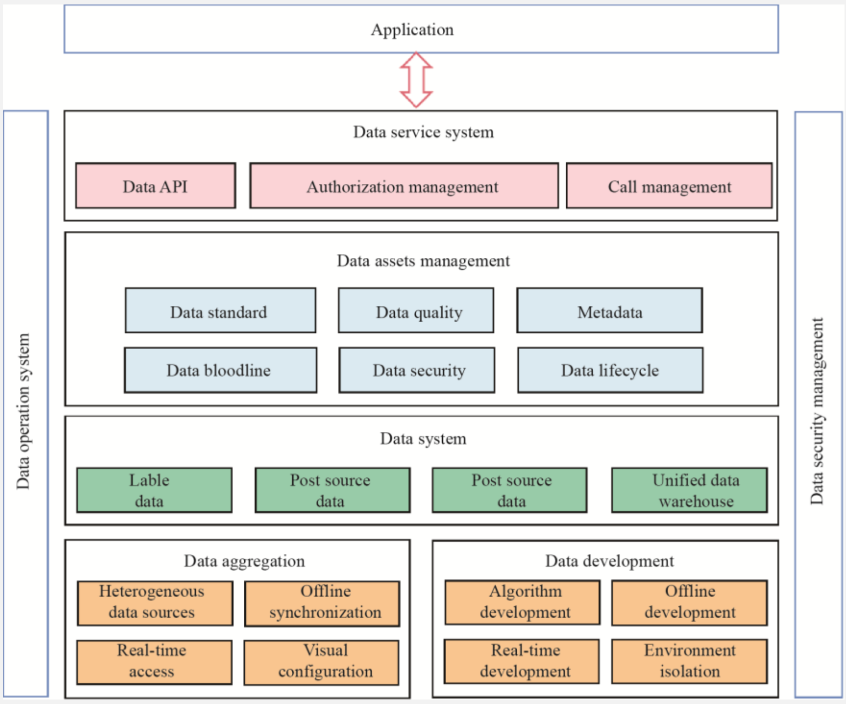

Fig. 1. The architecture of the data middle office [10].

Fig. 2 shows the overall structure of the station in the city data. Guizhou Province is a pilot demonstration area for developing big data in China. As the provincial capital city, Guiyang is at the helm of the country in terms of open government data and big data development and application. Currently, the city is starting the construction of a block data (city) integrated service platform, with the construction of a data middle office as the essence. As the middle layer of the application's front-end and the back-end of the business information system, the data middle office includes a data resource platform, an algorithm platform, and a computing resource platform. It not only supports the ever-changing front-end application system, but also efficiently and stably combines the heterogeneous multi-sources of the entire city's data and capitalizes, standardizes, and serves data.

The Guiyang block data (city) integrated service platform incorporates government data sharing and exchange platforms, third-party data platforms, and urban government systems and real-time data, such as data pertaining to medical, education, urban management, public security, emergency response, and ecology, through the construction of data middle office. For government and enterprise big data scenarios, it provides all-element and all-time-space data of people, things, and things in the city to form a unified data service platform and data asset management platform across the city.

4.2 Urban "information high-speed rail station": the foundation supporting the data middle office

In the era of the Internet of Everything, the "human–machine–things" ternary world is deeply integrated. To function with today's systems, intelligent processing should increase the computing capability by thousands of times without increasing the energy consumption [11]. Text-based structured data is gradually being replaced by unstructured data, such as pictures and videos, which is a significant reason for the rapid growth of data traffic. To address this demand, the information processing capacity of the new urban data center should support the newly added 100-billion-level terminals and massive information processing requests. The "information highway" has been unable to address the big data computing needs of the Internet of Everything in the 5G era. To resolve this challenge, the Institute of Computing Technology, Chinese Academy of Sciences proposed the "information high-speed rail" plan, the basis of which is the computing demands for the ternary integration of "human–

machine–things," providing higher throughput, more real-time guaranteed, highly secure, and reliable information services. This plan addresses the globally controllable and efficient processing method of big data acquisition, transmission and processing in the era of Internet of Everything. Additionally, it creates a unique type of information infrastructure. The content of the "information high speed rail" plan entails building a stable and reliable cloud-network-side system with a complete Internet Plus infrastructure, using high-throughput core chips, high-throughput cloud servers, smart routers, super base stations, intelligent measurement and adjustment system, and so on. Further, the plan aims to build an "information high-speed rail" network and computing hub across the country to achieve full chain coverage from core chips to application scenarios. Among them, the construction of "information high-speed rail station" is the core content and primary task.

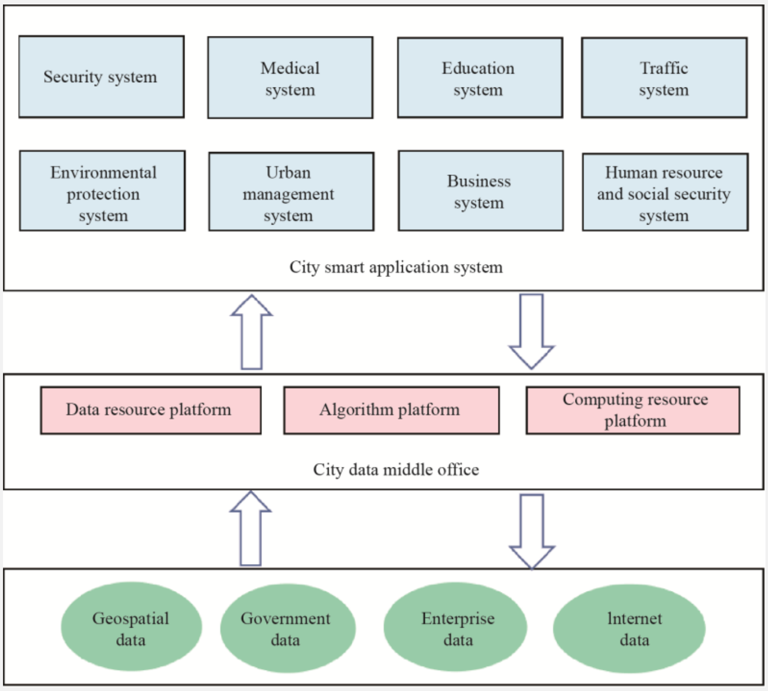

Fig. 2. Urban data middle office construction.

4.2.1 The significance of developing information high-speed rail

(1) Information high-speed rail is more suitable for China's national conditions

The United States launched the "Information Superhighway" project in the 1990s, which propelled the prosperity of the Internet worldwide. Similar to highways in the United States, China has used high-speed rail to solve the problem of transporting one billion people. This is based on the centralized high throughput and transmission rate. Grounded on the same national conditions, to meet China's informatization and intelligence needs, it is necessary to build an "information high-speed rail." The key features of "information high-speed rail" are high-throughput computing and high-quality services. High-throughput computing pursues fast, numerous, and stable calculations, while high-quality services pursue guaranteed computing and networks, like high-speed rail.

(2) Information high-speed rail adapts to the Internet of Everything in the 5G era

The application of high-throughput computing in the data center serves the Internet, Internet of Things, and other Internet of Everything scenarios in the 5G era. Its characteristics are as follows: diverse tasks, small amount of calculation, huge number of concurrent tasks and data scale, and real-time processing needs [12]. Compared with traditional high-performance computing, which aims at attaining peak speed or high speed, the core of high-throughput computing is to pursue high-throughput, implying maximum computing and including three core elements: high throughput, high utilization, and low latency [13]. High throughput refers to the number of tasks completed per unit time or the number of requests responded; high utilization refers to the high utilization of the system's core components (central processing unit, storage, network, etc.); low latency refers to the time required for users to request a response short.

(3) Information high-speed rail is the foundation of urban data middle office

The urban data middle office integrates all aspects of a city's data, supports many application systems, and

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adapts to constantly shifting application requirements. In the future, urban public computing power facilities will need to face new demands introduced by hundreds of billions of end devices. Thus, it is necessary to provide computing and transmission capabilities with higher throughput, higher intelligence, higher determinism, lower latency, and lower power consumption.

The current public computing facilities provided by cities are mainly supercomputing centers and cloud computing centers, as shown in Table 1. The supercomputing center is characterized by "fast calculation," similar to an airplane, expensive, fast, and short in completion time. The cloud computing center features "cheap calculation," which is similar to cars and benefits the public. It can achieve low-cost travel in most travel scenarios. However, both airplanes and cars have a clear defect: in the case of low traffic, both can ensure better service quality; once the traffic load rises rapidly, it is easy to cause congestion, the completion time increases dramatically, and guaranteeing the quality of service becomes difficult. The high-throughput center aims to break through the previously mentioned limitations and achieve "compute as much as possible" under high load conditions, similar to high-speed rail. High-speed rail is the best solution for the current transportation tools, effectively guaranteeing the quality of user service based on high load and utilization [14].

Table 1. Comparison of urban public computing facilities [14].

Type	Supercomputing center	Cloud computing center	High throughput computing center
Characteristics	Fast	Low-cost	Much
Analog traffic	Airplane	Car	High-speed rail

Therefore, as shown in Fig. 3, the "information high-speed rail station" can be used as a foundation to support the city data middle office, effectively managing many future requirements for safety, order, and control, such as the rapid increase of urban data, large-scale interconnection, real-time response, and precise control.

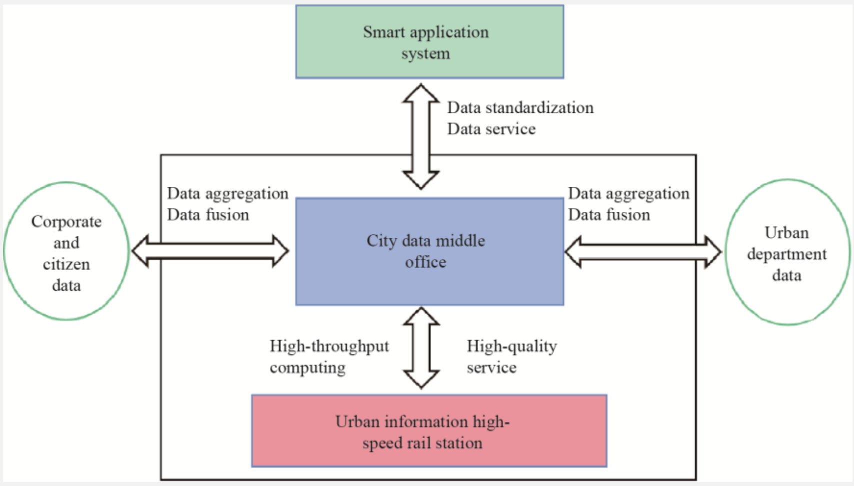

Fig. 3. Construction of an urban information high-speed rail station.

4.2.2 Key technologies and practical cases

The core technology of information high-speed rail includes the following: high-throughput core chips, high-throughput cloud servers, smart routers, super base stations, intelligent measurement and adjustment systems and other core chips, equipment, and basic software, as well as building a stable and reliable cloud-network-side system. Among them, high-throughput multicore architecture and high-throughput on-chip data path are the key technologies. Considering the characteristics of high throughput, low latency, and high utilization of high-throughput computing, the architecture should be changed from "speed-oriented" to "throughput-oriented." For example, using easily scalable on-chip networks to support energy consumption and congestion awareness to achieve on-chip network balance in high-concurrency scenarios, and on-chip storage that is fine-grained and configurable to adapt to complex data access patterns in high-throughput scenarios.

The first station of China's information high-speed rail, Yancheng High-Throughput Computing Center, officially started construction on July 31, 2019. It aims to create a high-throughput service platform that integrates high-throughput computing technology and practical application scenarios. Additionally, the platform needs to provide high-throughput data processing solutions aimed at responding to user service requests and provide new information technology infrastructure and services with high throughput, low latency, and high certainty for advancing regions and industries. The Yancheng High-Throughput Computing Center has 1000 computing and storage nodes, 30 000 processor cores, and can process 10 million video streams per second, with a power consumption of only 750 kilowatts. It exhibits a super high energy efficiency ratio in practical applications. It supports the following applications and services: 5G connected cars, video big data, network security information processing, big picture computing, artificial intelligence data processing, high-concurrency Internet of Things processing, and so on.

5 Suggestions

5.1 The top-level plan must be forward-looking

In the era of the Internet of Everything, the continuous increase of connected devices, the constant growth of data volume, and the more prosperous application ecology are the inevitable trends in the development of intelligent cities in the future. The planning of the new urban Internet Plus infrastructure must be forward-looking. It must have stability, continuity, and strong scalability to address the inability of providing the future high bandwidth, low latency, strong real-time, High-reliability, and high-quality service. This will avoid the infrastructure from entering the vicious circle of “overturning and repeating construction.”

5.2 City-based policy implementation and systematic construction

Data middle office and “information high-speed rail station,” are the foundations of the new infrastructure of Internet Plus in future cities, and these can support the extensive applications and ecosystems of informatization, networking, and intelligence. However, because each city has different informatization foundations, industrial ecology, and application requirements, all regions should build their own Internet Plus new infrastructure systems based on actual conditions, for example, 1+1+X, that is, 1 information high-speed rail station, 1 data middle office, several industry clouds or supercomputing centers.

5.3 Flexible use of multiple construction and operation modes

Both the data middle office and the city’s “information high-speed rail station” demand “heavy-duty” information infrastructure construction and require large-scale investment. Simultaneously, as an urban infrastructure, its operation is related to the advancement and ecology of related industries. Therefore, each city can adopt different construction modes based on actual conditions, for example, government investment, enterprise construction and operation, or government and enterprise joint investment in construction and joint operation, or enterprise investment and operation, and government purchase of services and supervision.

6 Conclusion

With the advancement of new technologies, such as 5G, Internet of Things, and AI, and new demands, such as online applications, collaborative office, and remote real-time control, China’s Internet Plus growth has entered a new stage. Consequently, several challenges are encountered, including managing the development needs of the Internet of Everything and application of massive data fusion in the new phase of the Internet Plus city, high concurrency and real-time response in remote office, remote collaboration, and other applications. Thus, we propose the construction of a new urban Internet Plus infrastructure. On one hand, a city data center needs to be built to effectively aggregate and integrate city data, make data capitalized, standardized, and service-oriented, and support the dynamic application needs. On the other hand, urban “information high-speed rail stations” need to be constructed to support high-throughput and high-quality data processing needs, which are safely, orderly, and controllable as the foundation of the data middle office, and jointly promote the further development of China’s Internet Plus. In the future, the extensive completion of data middle offices and “information high-speed rail stations” will ensure that the unique Internet Plus infrastructure in China’s cities attains a new level.

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