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RESEARCH ARTICLE

A Research on Blockchain Technology: Urban Intelligent Transportation Systems in Developing Countries

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ABSTRACT Blockchain technology has been widely used in finance, transportation, education, medical treatment, network security, management science, and other industries due to its decentralization, high reliability, and traceability characteristics. Unlike other studies on Urban Intelligent Transportation Systems (UITS) in the past, we present a model framework of the Urban Intelligent Transportation Systems (UITS) applied by blockchain in developing countries. After a detailed elaboration of the situation of three representative Urban Intelligent Transportation Systems (UITS) in China, blockchain technology has been applied to build a new architecture model of the big data platform for urban intelligent transportation, as well as the design concept and conceptual model for the new generation of the Urban Intelligent Transportation Systems (UITS) in developing countries. Finally, this paper elaborates on the critical direction of future development, areas of concern, and open research challenges, which researchers and urban intelligent transportation designers could explore to further advance in this field.

INDEX TERMS Blockchain, blockchain architecture, intelligent transport systems (ITS), urban intelligent transport systems (UITS), developing countries, security.

I. INTRODUCTION

The core technology of blockchain began to appear from the late 1980s to the early 1990s [1]. Satoshi Nakamoto proposed the concept of Bitcoin based on the core technology of blockchain [2]. As an emerging technology, blockchain has carried out applicability research based on its characteristics of decentralization, high reliability, and traceability. The blockchain is a universally acclaimed innovation based on distributed ledger technology [3]. Melanie Swan defined the development of blockchain technology at three levels [4]: blockchain 1.0 (currency interconnection),

mainly bitcoin and other virtual currencies; Blockchain 2.0 (asset interconnection) takes smart contracts as the primary feature and can develop decentralized application DAPP as required; Blockchain 3.0 (Internet of Things), the application field of blockchain technology extends to education, government management, medical care, transportation, etc. It can confirm, measure and store the property rights of the valuable information in the blockchain and quickly establish credit, making the work more convenient and efficient [5].

The application of blockchain in transportation is crucial because public blockchain technology has become increasingly important. Transportation is considered the backbone of cities. It provides essential mobility services for people's daily life and logistics goods [6], [7], [8]. The gradual automation, digitalization, and intellectualization of transportation is the inevitable trend of transportation development. Apply intelligent technology to the transportation field to achieve the development goal of networked vehicles [9]. The story of intelligent transportation cannot be separated from the innovation of advanced technologies such as big data analysis, artificial intelligence, and information technology. However, integrating these emerging technologies has also

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brought a certain degree of security risk to Intelligent Transportation Systems and caused social attention to the network security of Intelligent Transportation Systems. Currently, the cross-regional sharing mechanism in the Intelligent Transportation Systems network is not perfect, the cooperation efficiency between departments is low, and there are a series of network security problems such as massive data sharing and storage, information acquisition and information acquisition and tampering, and user privacy disclosure [10].

Blockchain technology is introduced into the intelligent transportation network to solve the above problems. The data under blockchain technology is authentic and can not be tampered with. It can provide technical support for storing, sharing, traceability, and anti-attack traffic data. Blockchain offers technical support for the construction of the transportation field, such as using blockchain technology to share traffic congestion, road traffic flow, and other data information to solve the problem of information blocking and data integration difficulties in transportation, combined with edge computing and other technologies, it is applied to the Internet of Vehicles to improve the overall safety and synergy of the system and provide safety guarantee for transportation. At present, Intelligent Transportation Systems (ITS) have become one of the key topics of academic research and also in some international standardization organizations, such as the Internet Engineering Task Force (IETF) [11] and International Standards Organization (ISO). The success of blockchain technology is conducive to solving problems such as network security of Intelligent Transportation Systems (ITS). ITS can be traced back to the 1970s. It is the direction of the future traffic system [12]. The essential underlying technologies of Intelligent Transportation Systems (ITS) include electronic sensing technology, intelligent control technology, data transmission technology, etc. [13], [14], [15] ITS aims to provide more convenient and safer travel and transportation modes for drivers, riders, and pedestrians.

Intelligent Transportation Systems (ITS) have attained huge fame. However, problems and new challenges in developing countries are still facing, especially when combined with blockchain technology, such as open issues in security and privacy.

A. CONTRIBUTION AND COMPARISON WITH RELATED RESEARCH ARTICLES

This paper mainly contributes to the existing knowledge in three broad ways. First, this paper studies the Urban Intelligent Transportation Systems (UITS) of China, a representative country in the developing countries, focusing on the current structural models of Intelligent Transportation Systems in Guangzhou, Shenzhen, and Foshan, analyzes the advantages and disadvantages of the structural models of Intelligent Transportation Systems in the three cities. It is conducive to the overall understanding and reference of other developing countries, especially for government officials in developing countries with relatively weak professional skills. Second, a new network architecture of the big data platform for urban intelligent transportation has been built based on blockchain technology. By taking advantage of the advantages of blockchain, such as decentralization, distributed computing, big data sharing, and incentive mechanism, the problem of independent management and transmission of data by various organizations of the traditional urban intelligent transportation data network architecture has been solved, thus promoting data sharing. Third, improve Urban Intelligent Transportation Systems (UITS) in developing countries, and propose a top-level design architecture model based on blockchain traffic cloud. However, based on the literature review, no paper has addressed detailed aspects of improving urban transportation intelligent systems (UITS) in developing countries based on blockchain technology. This lack of comprehensiveness motivates us to contribute through this research on the current situation of Urban Intelligent Transportation Systems (UITS) in developing countries and the future development of Intelligent Transportation Systems based on blockchain technology in developing countries.

Many survey articles have been written in the recent past with only a focus on specific ITS technology, application development, key success factors, etc. Some papers have also presented the applications of the traditional ITS model, etc. Strengthening the data security of ITS is also studied in some papers, including [16], [17], [18], [19], [20].

However, on the other side, the contribution of this research is as follows: To study the Urban Intelligent Transportation Systems (UITS) in developing countries, select the Intelligent Transportation Systems of three representative cities in China as the research objects, including the research system architecture, functions, advantages, and disadvantages. Moreover, a new network model architecture of the big data platform for urban intelligent transportation has been built based on blockchain technology. Finally, optimize the structure of Urban Intelligent Transportation Systems (UITS) in developing countries, and build a top-level model framework based on blockchain traffic cloud.

Ultimately the goal of this research is to acquaint researchers and urban transport system designers in developing countries with the urban intelligent transport system architecture based on blockchain technology and the detailed intelligent transportation system architecture model of major cities in China, a typical representative of developing countries.

B. ORGANIZATION OF THE SURVEY

The organization of the survey is as follows and shown in Figure 1. Section II discusses the background concepts as preliminaries to understand better this paper's core, followed by Blockchain and Intelligent Transportation Systems (ITS) characteristics. This section also highlights Blockchain technology and Intelligent Transportation Systems (ITS) challenges and issues. Section III presents the structure model of Intelligent Transportation Systems (ITS) of the three cities in China, a typical representative of developing countries in detail. In section IV, we propose a big data platform structure

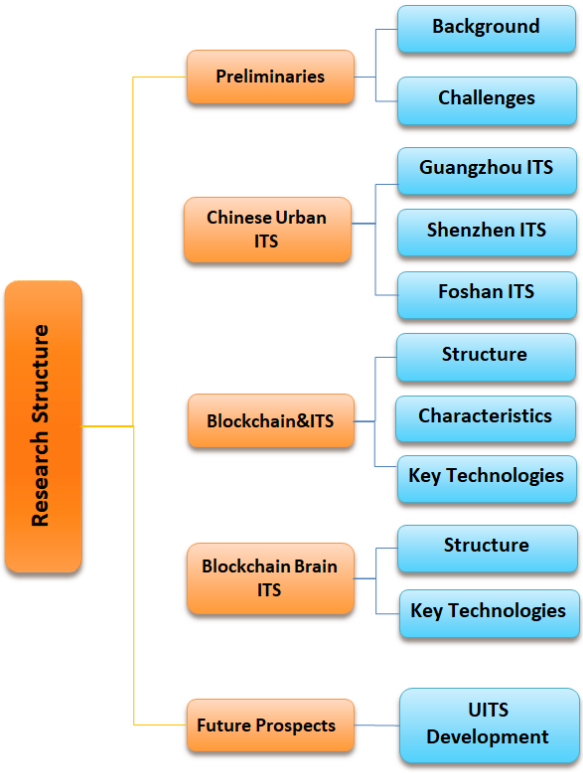

FIGURE 1. Structure and contribution of this research.

for urban intelligent transportation based on blockchain technology. The research and innovation in constructing a new generation of urban intelligent transportation brain systems based on blockchain technology are highlighted in section V. Section VI describes the open research issues learned from this research and the literature review to carry out in the future, and finally, Section VII concludes the research.

II. BACKGROUND AND CHALLENGES

This section first presents the basic concepts of Blockchain Technology and Intelligent Transportation Systems (ITS) then discuss the characteristics and issues of the status of Urban Intelligent Transportation Systems(UITS) in developing countries.

A. BACKGROUND AND CHALLENGES OF BLOCKCHAIN TECHNOLOGY

Blockchain is an innovation mode and application of distributed data storage technology, P2P network, encryption algorithm, smart contract, consensus mechanisms, and other information technologies in the Internet era [21]. The birth of blockchain cannot be separated from Bitcoin. The Bitcoin system has been the most influential and well-known application case of blockchain technology. Broadly speaking, blockchain technology is a new distributed infrastructure and computing paradigm that uses blockchain data structure to verify and store data, uses distributed node consensus algorithm to generate and update data, uses cryptography to ensure the security of data transmission and access, and

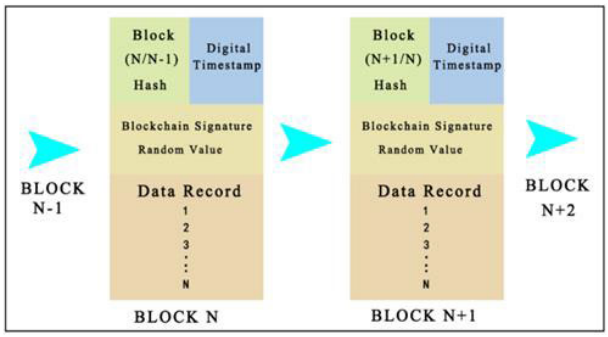

FIGURE 2. Blockchain structure diagram.

uses smart contracts composed of automated script code to program and operate data [22]. Each block contains the data to be recorded, the current block of the root Hash, the previous block of the root Hash, the timestamp, and other information. The blockchain is formed by linking the root hash values of the front and back blocks according to the timestamp sequence [23], [24], [25]. The structure of the Blockchain is as follows and shown in Figure 2.

Blockchain has the characteristics of decentralization, sequential data, collective maintenance, programmability, security, and anonymity [26]. The various operation processes of blockchain data are based on the distributed system structure. Pure mathematical methods are used instead of the central mechanism to establish the trust relationship of each node, forming a decentralized distributed system. Each block has a timestamp, which adds a time attribute to the data to achieve data verification and traceability [27]. Each distributed node jointly participates in data maintenance and verification under the specific incentive mechanism and determines the specific new block into the chain through a consensus algorithm. The blockchain system provides a flexible script code system to support users to in creating smart contracts or other DAPPs according to their needs. The encryption is based on the principle of asymmetric cryptography, and the security of the system is guaranteed with the help of the consensus mechanism of the distributed system [28]. The transaction process does not need to pass the public identity, which has the characteristics of anonymity.

In recent years, blockchain has developed rapidly, and its application scenarios have quickly grown in other fields besides the financial area [29]. The United Nations,the United States, the United Kingdom, Japan, the IMF, multinational banks, securities companies, and other countries or institutions actively explore and promote the research and application of blockchain technology [30].

As a distributed ledger technology, blockchain overcomes the disadvantages of traditional centralized ledgers, such as low storage efficiency, low credibility, and vulnerability to single-point attacks. The technology ensures distributed sharing, multi-party consensus, tamper resistance, and traceability. Distributed ledger (a shared ledger or distributed ledger technology) is a replication consensus that shares and synchronizes digital data geographically distributed

across multiple websites, countries, or institutions. No central administrator or centralized data storage [31].

At present, there are still many problems in the practical application of blockchain technology [32], [33]. For example, the distributed storage architecture has high hardware requirements for each physical node, the blockchain system throughput is small, the transaction information processing rate is low, the consensus mechanism still has vulnerabilities, and the smart contract may be attacked. These problems still restrict the application width of blockchain technology in practical scenarios, and the key to solving these problems is to build a good blockchain development environment in all fields [34].

B. BACKGROUND AND CHALLENGES OF URBAN INTELLIGENT TRANSPORTATION SYSTEMS(UITS)

Intelligent Transportation Systems (ITS) is the application of communication, electronics, machinery, vehicles, control, information, and other technologies to the transportation industry, and the ability to correctly, flexibly, and rapidly understand and propose solutions to maximize the efficiency of transportation and improve traffic conditions [35], [36], [37]. Intelligent transportation can provide better transportation information services for the public, enhance the safety and environmental protection of transport, improve transportation efficiency, and provide more effective means for transportation management [38].

The development of Urban Intelligent Transportation Systems (UITS) went through the ITS 1.0 era in 2005, the ITS 2.0 era in 2015, and the current ITS 3.0 era. It is reconstructs the system service concept and mode with the new technological transformation. Urban traffic managers have started to use big data to drive the innovation and upgrading of traffic management and services. Intelligent travel, intelligent logistics, intelligent assisted driving, etc., have become intelligent transportation's innovation and development direction [39]. Many developed countries, including the United States, Japan, and Singapore, are vigorously developing automatic driving and vehicle networking technology and improving the automation and intelligence of urban traffic management through investment in the construction of intelligent transportation facilities [40].

In the cities of developed countries in Europe and the United States, intelligent transportation is the construction content of general concern. Its core is mainly reflected in the construction of four systems, as follows and shown in Table 1, intelligent perception (such as an intelligent road), intelligent decision-making (such as intelligent logistics, intelligent parking, customized freight), intelligent operation (such as intelligent traffic control) and intelligent services (full-chain personalized services, such as intellectual connection, customized information, and robot pickup) [30]. This also represents the inevitable direction of future urban intelligent transportation development in developing countries.

At present, when the Intelligent Transportation Systems (ITS) in most developing countries cannot fully realize the intelligent transportation brain and intelligent management system to take over the urban traffic in all directions automatically, traffic managers still need to carry out auxiliary management of urban traffic, and even occupy the main decision-making position [41]. For example, the urban intelligent transportation data mainly relies on the relevant businesses of the transportation bureau and the traffic police bureau, lacks the cross-department, cross-industry data sharing, aggregation of mobile phone signaling data, meteorological data, infrastructure data, railway data, etc., and is difficult to grasp the urban population distribution, land development, urban space, travel rules, etc., which is insufficient to support the traffic management business [42]. Therefore, the gradual transformation of Urban Intelligent Transportation Systems (UITS) in developing countries from semi-automatic to automatic still has a long way to go.

III. INTELLIGENT TRANSPORTATION SYSTEMS IN CHINA

The Urban Intelligent Transportation Systems (UITS) in developing countries and developed countries are quite different and start relatively late [43]. China is a typical representative country of developing countries with a large population, and the management of Urban Intelligent Transportation Systems (UITS) is complex. At present, China has invested more resources in constructing Urban Intelligent Transportation Systems (UITS), and Intelligent Transportation Systems (ITS) have entered a period of rapid development. China's Urban Intelligent Transportation Systems (UITS) is in the stage of system integration, and the whole is in an era of equal emphasis on construction and management [44]. The following describes the Intelligent Transportation Systems of Guangzhou, Shenzhen, and Foshan in China.

A. GUANGZHOU INTELLIGENT TRANSPORTATION SYSTEMS

Guangzhou is the south gate of China. It is an essential central city, international trade center, and comprehensive transportation hub in China, approved by the State Council [45].

At present, facing the needs of urban transport development in the new era, Guangzhou has improved the management system and mechanism of transportation informatization construction and has deeply studied the big data system of urban intelligent transportation. It has built the framework of ''one center, three platforms, and four guarantees'' intelligent transportation big data system in Guangzhou, continuously promoted the integration and application of new generation information technologies such as big data in the field of urban transportation, and carried out a series of meaningful practices in data perception, processing, application, etc., providing some experience for reference for the application of big data in the transportation industry [46].

According to the policies of the ''14th Five Year Plan'' for the Reform and Construction of the Guangzhou Digital Government, Guangzhou has built a ''one center, three platforms, and four guarantees'' [47], [48] urban intelligent

TABLE 1. Key points of urban intelligent transportation systems construction in developed countries.

Project	New York	Chicago	San Francisco	Amsterdam	London	Florence
Intelligent Parking	✓	✓	✓	✓	✓	✓
Intelligent Connection	✓	✓	✓	✓	✓	
Intelligent Traffic Information	✓	✓	✓	✓	✓	✓
Intelligent Traffic Light Control System	✓	✓	✓	✓	✓	
Adaptive Communication Connection Vehicle	✓		✓			
Share Driverless Cars	✓		✓	✓	✓	✓
Intelligent Street Light	✓	✓	✓	✓	✓	✓
Ibeacon Location Information Service		✓	✓	✓	✓	✓
Customized Freight	✓	✓	✓	✓	✓	✓
Robot Pickup	✓	✓	✓		✓	
Intelligent Logistics	✓	✓	✓	✓	✓	✓

transportation big data system, it includes: promoting data perception and sharing, strengthening data transmission efficiency, deepening data mining analysis, and innovating data application services. Among them, ''one center'' refers to the transportation big data center, and ''three platforms'' are the intelligent perception platform, integrated business platform, and innovative service platform. Under the intelligent transportation big data system framework, Guangzhou strengthened data fusion analysis and association mining, built cross-dimensional data analysis capabilities, and drove industry governance and service quality improvement with big data innovation. The following introduces several representative system platforms based on the framework structure of the Guangzhou Intelligent Transportation Systems (ITS) [44]. Figure 3 shows the architecture of Guangzhou Intelligent Transportation Systems [48].

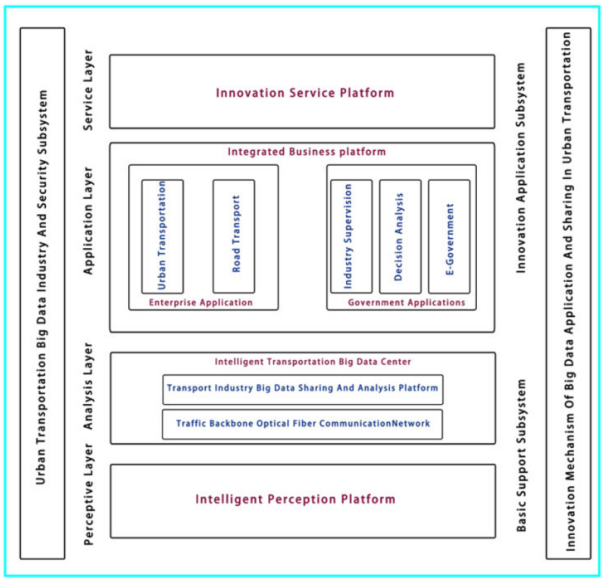

FIGURE 3. The architecture of the guangzhou intelligent transportation systems.

1) Guangzhou transportation industry data sharing and analysis service platform. As the core component of the transport big data center, the Guangzhou transport industry data sharing and analysis service platform integrates the data resources of the transport industry in Guangzhou. The data resources cover 17 sectors, more than 800 types of data, and are connected to more than 90 transportation industry information systems. The amount of new data is more than over 250 GB. At the same time, the platform has realized cross-department, cross-industry, cross-field information sharing and access to Guangzhou Public Security Bureau, Metro Group, Meteorological Bureau, Environmental Protection Bureau, and other data resources. It supports passenger flow monitoring and analysis, transportation guarantee, traffic management, expressway and expressway in key areas, road traffic security, and other applications. In addition, the platform has established data standards and specifications, a data resource directory, and data resources of Guangzhou transportation industry core systems such as sharing and basic application services have been sorted and completed by relevant data standards of the Ministry of Transport local data application needs.More than 5000 data standards have further strengthened and standardized the sharing and management of traffic information data and managed the number of transportation industries in the city. According to resources, it provides comprehensive data integration and analysis capabilities for various business systems.

2) Comprehensive monitoring and integrated management platform for traffic operation. The platform adopts the multi-dimensional integrated data fusion management mode to carry out the integrated management of the airport, port, railway, bus, taxi, subway, water bus, passenger, freight transportation, maintenance, driving training, transportation network, station yard, real-time road conditions,

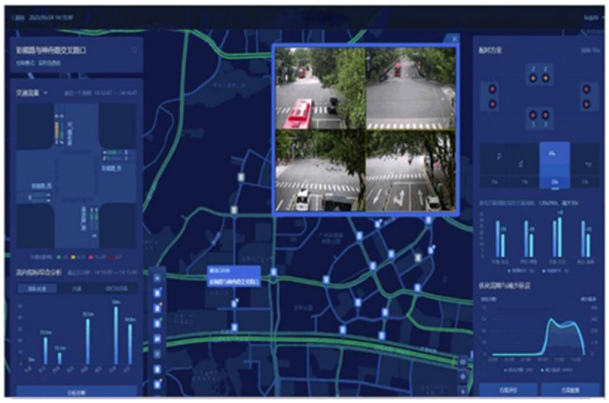

FIGURE 4. Intelligent optimization system for signal timing at road intersections in huangpu district, guangzhou.

crowd passenger flow, and other fields. It realizes the functions of comprehensive information monitoring, multi-dimensional thematic analysis, early warning, and warning [49], [50], [51]. Through business integration analysis, the platform targeted to carry out decision-making research on multiple business data such as comprehensive transport, public transport, road transport, urban traffic governance, established one-stop management and control of hierarchical, and hierarchical traffic situations to provide support for comprehensive control of traffic situation and scientific command and dispatching.

3) The urban traffic big data system strengthens the three-dimensional perception of traffic demand, supply, and the environment by collecting more fine-grained data, especially the quantitative perception of the space-time state of passenger flow and traffic flow. At present, the transportation industry in Guangzhou has formed a multi-source data acquisition mode. Through video, mobile signaling, machine vision, satellite positioning, all-in-one card, sensor, microwave, next-generation Bluetooth and other acquisition channels, it can sense the status information of vehicle flow, passenger flow, logistics, roads, traffic events, and other elements. Among them, the satellite positioning data is 1.25 billion pieces/day, which has fully covered more than 15000 buses, more than 20000 taxis, more than 130000 passenger and freight operating vehicles, and more than 20000 online rental vehicles in Guangzhou, realizing the functions of real-time vehicle positioning, operation safety supervision, travel information services, etc.; There are more than 10000 videos and 20 million business data per day; IC card data is about 9 million pieces/day, Figure 4 shows an intelligent optimization system for signal timing at road intersections in Huangpu District, Guangzhou.

4) Guangzhou Smart China Spring Festival Transport 3.0 system. To relieve the high pressure of passenger flow surge during holidays in China, Guangzhou Transportation Bureau organized the transportation and investment companies affiliated with the public transport group to integrate more than 230 types of data related to transportation, such as public transport, taxi, passenger transport, subway, aviation, railway, video, weather, etc., and upgraded the Smart Spring Festival Transport 3.0 system using big data, artificial intelligence, and other technologies. The system comprehensively and timely grasps the current situation, accurately and efficiently predicts the future trend, quantificationally and directionally dispatches the transport capacity, pre-assesses the impact of measures, and comprehensively evaluates and summarizes, forming a new mode of transportation guarantee for the science and technology spring festival transport.

5) Guangzhou Public Transport Intelligent Management Service Platform. In combination with the establishment of ''China's Public Transport City,'' Guangzhou has promoted the construction of the public transport intelligent application demonstration project and built the Guangzhou public transport intelligent management service platform based on the intelligent public transport management system. The platform carries out macro management from the five sectors of the public transport network, transport capacity, passenger flow, service supervision, and operation monitoring. It carries out comprehensive real-time monitoring of the four major types of characteristic public transport in Guangzhou, including BRT, customized public transport, water bus, and sightseeing loop line, to meet the needs of people for comprehensive query and trend analysis of more than 100 items of information in the public transport industry, with mobile internet The national one-card interconnection and other technologies provide convenient travel services for citizens, integrates face recognition, and intelligent scheduling technology to provide one-click call and timely response services.

6) Guangzhou Urban Comprehensive Traffic Operation Situation Monitoring and Analysis System. Using mobile internet, big data, cloud computing, satellite positioning, and other information technologies based on the data sharing and analysis service platform of the transportation industry, Guangzhou has built a comprehensive urban traffic operation situation monitoring and analysis system that integrates public transport, taxi, passenger transport, road transport, station hub, highway, and other industry supervision services, to grasp the operation of various industries in real-time The rapid development of traffic command and decision-making provides strong technical support.

7) Urban public travel information service platform.To make general travel predictable, Guangzhou has built a comprehensive, multi-mode and all-coverage transportation service system by integrating data from multiple departments, launched a comprehensive transportation information service platform such as ''TravelSky,'' and provided more than 20 one-stop information queries such as travel planning, route navigation, arrival time prediction, waiting for the reminder, and bus arrival reminder, meeting the public's real-time understanding of the location and road conditions on the way Anticipated demands such as travel time, estimated arrival time, etc. In addition, to expand the coverage of information services, the Guangzhou Municipal Bureau of Communications and Transportation has carried out transportation through the mainstream Internet, such as Gaode Software

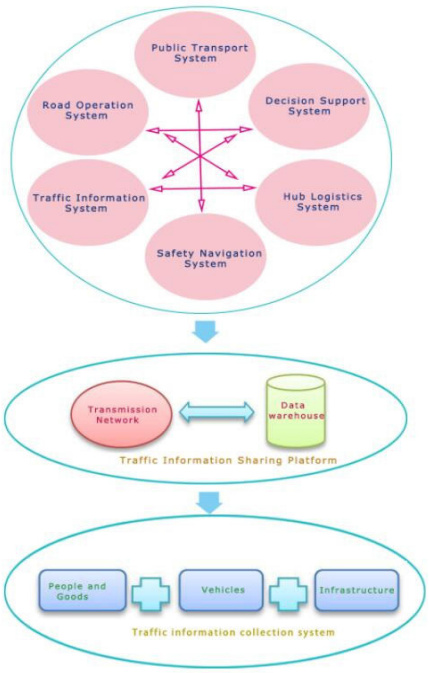

FIGURE 5. Shenzhen intelligent transportation systems.

Co., Ltd., and Alibaba Group Business cooperation provides more comprehensive and accurate information services for the public.

B. SHENZHEN INTELLIGENT TRANSPORTATION SYSTEMS

Shenzhen is the first special economic zone established by China reform and opening up, the window of China's reform and opening up, and has developed into an influential international city [52], [53]. Shenzhen's Intelligent Transportation Systems is divided into the following three steps, and Figure 5 shows the architecture of Shenzhen Intelligent Transportation Systems.

1) Shenzhen is the first city in China to establish an online transportation system [52]. It has built a public information platform for intelligent transportation, made a breakthrough in transforming the traditional transportation planning process, and formed a quantitative transportation operation forecast and auxiliary decision support system. Shenzhen has determined the three-layer framework of an Intelligent Transportation System (ITS) around information infrastructure, public information platform, and application services. According to the integrated service function of urban traffic planning construction management, 49 user services are provided to management organizations, transport practitioners, product (service) providers, and relevant departments in 9 service areas, including traffic information collection, public information platform, government decision support, traffic information service, public transport management, road operation management, hub logistics information, traffic safety, and vehicle safety, and ITS data management.

2) Taking the opportunity of holding the 26th Universiade, Shenzhen decided to build a "1+3" intelligent system framework for the near future implementation, that is, to build a traffic information sharing platform for the traffic bureau, planning bureau, and the competent departments of the public security traffic police bureau, to build an Intelligent Transportation Systems, traffic planning management, decision support system, and intelligent transportation management system respectively. With its own business, Shenzhen Transport Commission has built a platform (traffic information exchange platform) and five effective systems (traffic integrated monitoring system, traffic integrated control system, traffic operation command system, public travel information service system, and traffic management system). It has accumulated experience in big data collection and integration, application, and new technology storage. The municipal traffic police have basically completed the construction of eight management and control business systems (trunk traffic guidance, parking path guidance, traffic accidents, accident detection and release guidance, illegal management, illegal real-time notification, police service management, and 122 alarm reception and handling), and has initially carried out the collection of basic data, initially can control traffic signals, and has initially realized the basic application of data and multi-channel information release.

3) The development of transportation and management in Shenzhen needs to strengthen the comprehensive connection with the big data platform at the national level. At the same time, the continuous emergence of new forms of transportation, such as online buses, online taxis, and shared bicycles, poses new challenges to the existing traffic management and service system. In 2016, to coordinate the strategic development plan of building a new smart city, Shenzhen successively launched the overall planning of Shenzhen's comprehensive transportation big data platform and the overall improvement project of intelligent transportation control. The former integrates cross-industry and cross-department transportation big-data resources. It promotes the comprehensive and in-depth application of big data in transportation planning, construction, and operation management by following the requirements of "multiple integrations, real-time simulation, and decision support." It also supports Shenzhen's urban transportation planning and construction decision-making with big data technology services to increase efficiency and improve comprehensive transportation services and the quality of the refined transportation environment. Build the platform as the decision-making support brain of the city's comprehensive transportation application, and boost the supply-side reform of Shenzhen's transportation infrastructure. The latter aims at active control focus on data fusion and vehicle-road coordination and takes data-driven policing as the direction to transform, expand and integrate the existing system and establish an operation control and policing control system for the whole network, the whole area, and the entire point.

C. FOSHAN INTELLIGENT TRANSPORTATION SYSTEMS

Since implementing the last round of intelligent transportation development planning, Foshan Intelligent Transportation

Systems construction has made specific achievements. In the past few years, Foshan initiated the preparation of the Foshan Intelligent Transport Development Plan (2015-2025) [54], which defined the goal of ''full system coordination, high data sharing, and comprehensive service delivery'' between the horizontal traffic and traffic police departments, and established the overall framework of ''1+2+2'', namely, a data exchange and sharing platform, two centers (the municipal public security traffic navigation and control information release center and the municipal comprehensive traffic coordination command center). Two comprehensive applications (comprehensive transportation information service platform and comprehensive transportation decision support system).Foshan intelligent transportation has been constructed in many applications. Figure 5 shows the architecture of Foshan Intelligent Transportation Systems.

1) Regarding industry governance, Foshan's competent department of transportation has successfully launched the construction of intelligent projects related to eight systems, including a taxi service and management information system and a comprehensive management system of vehicles.

2) Regarding traffic system management, it has realized urban traffic management functions such as traffic information collection, monitoring, and information release for the central metropolitan area, trunk roads, and the first ring expressway. It has realized networking and sharing with the city's security video checkpoint system.

3) In the aspect of intelligent public transport, it has built an online intelligent public transport platform across the network, completed the joint network control of the municipal and district governments, TC institutions, and business operations, and realized the automation and intelligence of operation scheduling, cost accounting, industry supervision, decision analysis, and comprehensive services.

4) Regarding travel services, the Municipal Transportation Bureau has successfully completed the construction of relevant projects of ''Foshan Transportation'' to serve citizens, providing real-time and accurate travel service information for citizens.

5) In terms of transportation decision-making, the construction of the Foshan Transportation Decision Support System was launched in 2012. At present, the basic framework of the system has been built, and the data-sharing access and processing of all departments need to be further deepened.

6) In terms of intelligent transportation data, the ''cloud'' platform for intelligent transportation virtualization has been built. The data center has gathered 38 application systems, 56 categories and 161 thematic data, forming about 900T of massive traffic data.

D. DEFECTS OF INTELLIGENT TRANSPORTATION SYSTEMS IN THREE CITIES

Intelligent transportation construction has achieved some positive results in China's three ultra-high-density large cities. However, there are still areas for improvement, such as tight constraints on transportation facilities and resources. At present, the proportion of transportation facilities has reached the upper limit of the national standard.

The contradiction between the supply and demand of traffic is increasingly intensifying, and traffic congestion is facing normalization. The development of transportation in the three places has entered a stage of ''equal emphasis on construction and management'' or even ''management-based.'' In this case, it is urgent to fully tap the service capacity of existing transportation facilities with the help of new intelligent transportation technology and bring about the improvement of traffic efficiency [55], [56], [57]. In addition, the traffic safety situation is still grim, which is far from advanced international cities. Compared with the death rate per 10000 vehicles, for example, Shenzhen (1.35 in 2015) is currently equivalent to Hong Kong (1.85 in 2014), which is generally equivalent to the level of developed countries in the 1990s. It is the best among the first-tier cities in China, but it is far from the wor- ld-class advanced cities of London (0.45 in 2013), Tokyo (0.38 in 2013), and Berlin (0.28 in 2013) [52]. The new Intelligent Transportation Systems (ITS) will improve traffic safety and the environment and produce substantial social benefits [58]. For example, the new Internet of Vehicles System will reduce the accident rate by 44%, and the New Driverless System will reduce the accidents caused by human factors by 80%. The reliability of traffic information service is insufficient, and the travel experience needs to be improved. Under the new generation of information technology environment, high-precision maps, 5G communications, Internet big data, etc., have laid a strong foundation for improving the travel experience in the whole process, and the means of transportation information services are becoming more and more abundant. However, because the traditional existing information release still relies on the traditional three screens (mobile phone screen, TV screen, and induction screen), there are deficiencies in the diversification, real-time, personalization, and reliability of information services, which need to be improved urgently [59].

More importantly, in the current hierarchical distribution of the three urban intelligent transportation data networks, each organization independently manages and uploads data, which makes it challenging to realize data sharing. Enterprises, government departments, industrial organizations, and relevant scientific research institutions collect static data and build basic databases for business needs [60]. These organizations have limited data collection channels and are limited by their data management capabilities, resulting in imperfect basic database construction and low data collection rate, In contrast, dynamic data is collected by various devices arranged in the Urban Intelligent Transportation Systems(UTIS) [61], [62], [63]. The collected dynamic data directly belongs to the collection equipment management or user organization. In the traditional mode, data belong to various organizations, making verifying and sharing data difficult. Due to the actual demand of the industry for big data sharing, big data com- panies, relevant scientific research

institutions, government statistical departments, and other organizations collect basic data for big data analysis or trading. These comprehensive data management organizations are also organizationally independent, and there are few big data sharing at the same level. Instead, they actively expand the basic data source and collect data from the lower basic data layer [64].

Traffic is chain management, where data is constantly exchanged to improve management [65], [66]. Intelligent traffic is information management based on traffic network infrastructure and traffic flow, which is naturally consistent with the chain mode of blockchain. Introducing blockchain technology into the field of intelligent transportation, carrying out the construction of the underlying platform of transportation blockchain, and breaking through the thinking of internal research in the field of transport are of great significance to mining the potential value of various types of data across areas, industries, and regions [67], [68], [69].

IV. URBAN INTELLIGENT TRANSPORTATION BIG DATA PLATFORM BASED ON BLOCKCHAIN TECHNOLOGY

A. APPLICABILITY AND FEASIBILITY OF BLOCKCHAIN TECHNOLOGY IN URBAN INTELLIGENT TRANSPORTATION SYSTEMS IN DEVELOPING COUNTRIES

Seven significant areas of focus for constructing new infrastructure in developing countries: 5G base stations, ultra-high voltage, intercity high-speed railways, intercity rail transit, new energy vehicle charging piles, big data centers, artificial intelligence, and industrial internet. The essence of new infrastructure is to promote the construction of smart city infrastructure with information digitization infrastructure, improve the importance and security of data, and complement the development of blockchain technology. Artificial intelligence promotes single-point intelligence, industrial internet promotes single-point intelligence integration, and blockchain forms a group contract to establish a trusted mechanism for edge blocks. With edge computing as the core, combined with artificial intelligence and 5G technology [81], the smart road, by deploying smart street lights, establishes a holographic road network system, dynamically tracks and counts block traffic, links traffic trends, and controls intersection information control units in real-time. New infrastructure policies in developing countries provide reliable support for blockchain technology linkage.

Advanced chips at home and abroad continue to be upgraded and supported. High computing power, outdoor process power chips, including industrial grade TX2 and Shengteng 310, support high requirements such as edge artificial intelligence. Disk storage specifications have also made some notable progress in recent years. Industrial-grade storage chips with high capacity and high-speed read and write performance are improving. The needs of various scenarios are gradually sorted out, and business agreements are increasingly improving, coinciding with the digitization of transportation. With the policy support of networking, the feasibility of blockchain landing in the transportation industry is growing. Under the pressure load of the new cloud center, the development characteristics of blockchain technology with edge computing as the core meet the requirements of the era of intelligent transportation.

Relying on the decentralized, tamper-proof, and traceable characteristics of blockchain technology, taking block data as the core, removing the centralized data management of various organizations, changing the data collection, data processing and analysis, data storage mode, methods, and fully realizing the platform-based big data sharing, decentralized and distributed computing of the multi-source system of urban intelligent transportation. Using blockchain technology in big data can prevent data from being arbitrarily added, modified, and deleted, greatly enhancing the elasticity and storage capacity of big data. While enhancing security, various technologies in big data can be interacted with without barriers, forming a higher level of interaction and generating new data support.

Applying blockchain technology to intelligent transportation big data platforms can solve various problems of existing big data centers. Firstly, blockchain technology's distributed and decentralized nature distributes hundreds of servers and massive storage across the nodes of each participant, which can significantly reduce the system's deployment, operation, and maintenance costs. Secondly, blockchain technology adopts the concept of peer-to-peer nodes. In addition to a unified basic service node, each participant node also focuses on its business. On the one hand, it has dramatically reduced the difficulty of technological research and development of the unified transportation big data platform. On the other hand, it has improved the processing capacity of dedicated data. Finally, the introduction of smart contracts allows the system to complete the introduction of new business models and data models only through software deployment in the form of smart contracts, without the need to reconstruct the storage structure of the back-end database and the data structure of the access interface, significantly improving the flexibility and scalability of the system.

B. BIG DATA PLATFORM ARCHITECTURE OF URBAN INTELLIGENT TRANSPORTATION BASED ON BLOCKCHAIN TECHNOLOGY

The urban intelligent transportation data block in the data layer includes static and dynamic data blocks. Both types of data have timestamp characteristics [70]. The static data is relatively poor in liquidity, and the dynamic data is more time-varying. Therefore, these two data types are constructed separately in the blockchain data layer to form an interconnected blockchain network [71]. Moreover, in some cases, urban transportation big data is a combination of dynamic data and static data. Therefore, a consensus algorithm combining dynamic and static traffic data should be established at this layer in the future. Accordingly, the dynamic and static data consensus algorithms are established in the consensus layers,

respectively. At the incentive level, the resource provision mechanism and resource adjustment mechanism are used to encourage the data sharing of all nodes and realize the network's decentralization, as shown in Table 2.

The basic architecture of the big data platform of urban intelligent transportation based on blockchain technology reconstructs the basic data layer of the traditional urban intelligent transportation data network architecture, excluding the basic data source layer. The relationship between urban intelligent transportation data blocks and data sources, and adds regulatory access servers for each blockchain node to ensure the security of information. It can be seen that the urban intelligent transportation big data platform of blockchain technology takes block data as the core, removes the centralized data management of various organizations, and fully realizes the platform-based big data sharing. Especially through the role of the consensus layer, incentive layer, and contract layer, data can be verified, trusted, interactive, and easy to analyze; Through the network layer and data layer, the data can be easily traced, stored, standardized, unified and standardized, and the data of the urban intelligent transportation data network can be more complete and authentic. The data platform can be more optimized, intelligent, and global.

TABLE 2. The architecture of big data platform for urban intelligent transportation based on blockchain technology.

Before Optimization	Blockchain Architecture	After Optimization
Programmable Currency	Application Layer	Industry Users
Programmable Finance		Government Users
Programmable Social Industry		Resident users
Script Code	Contract Layer	Script Code
Algorithm Mechanism		Algorithm Mechanism
Smart Contract		Smart Contract
Issuance Mechanism	Incentive Layer	Resource Provision Mechanism
Allocation Mechanism		Resource Regulation Mechanism
PoW	Consensus Layer	Dynamic Data Consensus Algorithm
PoS、DPoS		Static Data Consensus Algorithm
		Dynamic And Static Combination Algorithm
P2P Network	Network Layer	P2P Network
Communication Mechanism		Communication Mechanism
Verification Mechanism		UIT Data Validation Mechanism
Data Block	Data Layer	Urban Intelligent Transportation system Data Block
Chain Structure		Chain Structure
Time Stamp		Trusted Timestamp
Hash Function		Cryptographic algorithm（Hash algorithm）
Merkle Tree		Merkle Tree
Asymmetric Encryption		Asymmetric Encryption

C. ADVANTAGES OF BLOCKCHAIN TECHNOLOGY IN URBAN INTELLIGENT TRANSPORTATION BIG DATA PLATFORM

Under the traditional intelligent transportation data network architecture, take urban road traffic dynamic information as an example: road congestion information is collected by the data source terminal equipment of the transportation department or uploaded by the user of the navigation software; Relevant government units upload the control information; Road environmental information is mainly collected by monitoring equipment of meteorological department; Vehicle distribution information is provided or collected by navigation platform, operation company, and traffic monitoring equipment [72], [73], [74]. The data sources of this information are different. After each provider of the basic data management layer processes the collected data, the comprehensive data management layer processes the data again. In the whole process, the data is collected in a decentralized way and then processed by the organizations of the basic data management layer, and then collected and processed by the comprehensive data management layer for the second time. Due to the independence of the organizations of the basic data management layer and the comprehensive data management layer, data cannot be shared at the same level but can be transferred between different levels according to the business and functions of each organization.

Under the big data platform architecture of urban intelligent transportation based on blockchain technology, all data sources are directly connected to the network through blockchain nodes, and data processing and analysis are completed by the network itself rather than by various organizations so that data is ''shared'' from beginning to end. Moreover, the distributed computing and decentralization of blockchain ensure the ''levelization'' of all data and avoid the loss, distortion, and verification difficulties of inter-level data transmission.

In comparison, the urban intelligent transportation big data platform architecture of blockchain technology has fundamentally changed the traditional intelligent transportation data network architecture, completely changed the data collection, data processing, analysis, data storage mode, and methods, and truly realized big data sharing, decentralization, and distributed computing. It can be predicted that the big data platform of urban intelligent transportation based on blockchain technology can bring advantages such as significantly reducing system costs, significantly increasing system data volume and encouraging data sharing, removing the limitation of administrative management level, improving computing efficiency and related resource utilization, expanding application fields and service objects, improving data professional analysis ability, and improving system data reliability.

D. KEY TECHNOLOGIES OF BLOCKCHAIN IN BIG DATA PLATFORM FOR URBAN INTELLIGENT TRANSPORTATION

The main problems to be solved and faced by the big data platform of urban intelligent transportation based on blockchain technology are the unification of different data sources, the unified supervision and operation of data, and the technical compatibility with other advanced technologies. To solve these problems, the key technologies of blockchain technology on the big data platform of urban intelligent transportation are discussed from the perspective of technology.

1) Unified technology of each node. The unification of data from different sources includes the unification of data format, data acquisition frequency, data storage structure, data update, modification, etc. The unification of data from other data sources is realized between blocks and data sources, data layer, and network layer [75]. The data sources of urban intelligent transportation data blocks are different. To achieve the unification of data, first of all, through the supervision and access server, the network access technical certification and technical supervision of the data source are carried out to ensure that the data source can technically meet the basic standards of network access, and ensure that the data source can upload data without fault, redundancy, and error during the operation process [76], [77], [78]. After that, in-depth analysis is needed to analyze the relationship between data provided by different data sources, including source relationship, logical relationship, value relationship, relevance relationship, accuracy comparison, etc. Based on this, the urban intelligent transportation data block model with unified data is determined, and the data block is constructed. Finally, the blockchain's data layer and network layer technology are used to realize the unified storage and transmission of data based on the urban intelligent transportation data block.

2) Supervision and operation realization of multiple technology sharing. The big data platform of urban intelligent transportation based on blockchain technology differs from the traditional big data platform of urban intelligent transportation. Different organizations supervise the data of the conventional urban intelligent transportation big data platform and then share it on the platform, which makes it challenging to achieve unified supervision and operation of data.

The decentralization of the big data platform of urban intelligent transportation based on blockchain technology is the ''ownership'' of data, which enables the unified intelligent management of data after access to the network to achieve suitable data supervision and automatic operation. Specifically, the unified supervision and operation of data is realized at the consensus, incentive, contract, and application layers of the urban intelligent transportation big data platform of blockchain technology and is the result of the sharing of multiple technologies. In terms of data supervision and operation, the consensus layer, the incentive layer, the contract layer, and the application layer have respectively constructed the technical processing mechanism, the resource allocation mechanism, the management rule mechanism, and the application mechanism of data supervision and operation. All data blocks are automatically processed, transmitted, and provided services according to these mechanisms.

3) Blockchain technology is compatible with the Internet of Vehicles and vehicle-road collaboration technology. The Internet of Vehicles is a dynamic mobile communication system that realizes the network communication between vehicles and the public through the interaction between vehicles & vehicles, vehicles & roads, vehicles &people, and vehicles & sensor equipment. In essence, the Internet of Vehicles can also be seen as a networked realization of multi-source data around vehicles, roads, and people [79], [80]. The key issues of the Internet of Vehicles are what data to collect, what network communication technology to use, and what data applications to provide.

Blockchain technology can be directly used for the data network communication of the Internet of Vehicles as the technical basis of the Internet of Vehicles data network. It can also be used as the external network link of the data network communication of the Internet of Vehicles when meeting the technical compatibility requirements to assist or supplement the various functions of the Internet of Vehicles [81], [82], [83], [84]. In addition to realizing the intelligent perception of people, vehicles, and roads, vehicle-road coordination is more important to learn system coordination, optimizing system resource use, and achieving traffic supervision and operation objectives such as improving road traffic safety and easing traffic congestion. In addition to the basic data network functions, blockchain technology's consensus layer and contract layer can be used as the basis to ensure system collaboration. In contrast, the incentive layer can achieve the goal of optimizing the use of system resources.

The sharing of multiple technologies in blockchain technology can realize automatic supervision and operation. Therefore, applying blockchain technology to vehicle-road collaboration can achieve various objectives of the vehicle-road association. The blockchain nodes of the big data platform of urban intelligent transportation based on blockchain technology can theoretically connect different data sources and have technical compatibility [85], [86], [87]. As long as the data source meets each node's unified technical standards and requirements, the data source can be connected to the network by generating a new blockchain node. Therefore, the big data platform of urban intelligent transportation based on blockchain technology is open.

4) Trusted timestamp technology [88]. A trusted timestamp is an electronic certificate issued by the Joint Trust Timestamp Service Center that can prove that a data message (electronic file) exists, is complete, verifiable, and has a legal effect at a certain point in time. Trusted timestamps are mainly used to prevent tampering and subsequent repudiation of electronic files and to determine the exact time when electronic files are generated. According to the International Electronic Timestamp Standard Specification ''RFC 3161'', the essence of a trusted timestamp service is to bind the

hash value of a user's electronic data to an authoritative time source, and on this basis, generate an unforgeable timestamp file through a joint trusted timestamp service center digital signature.

5) Ledger Database [89]. In actual blockchain applications, many scenarios do not have a strong demand for decentralization, but they only want their tamper-proof, traceable, transparent, and auditable features. Based on this, Alibaba Cloud has designed LedgerDB, a centralized ledger database that cannot be tampered with. Ledger DB is more lightweight than the heavy licensing chain and has a high throughput (up to 80 times that of Hyperledger Fabric). It also supports strong auditing, which can simultaneously prevent DB users and service providers from committing crimes to meet the demand for ledger expansion, Ledger DB can delete historical data but still ensure the verifiability of the data. Moreover, it can ''modify historical data'' (which seems to violate the essence of blockchain but is indeed the requirement of real scenarios). Some already linked data has problems (such as non-compliance), and it needs to be hidden later.

V. CONSTRUCTION CONCEPT OF NEW GENERATION INTELLIGENT TRANSPORTATION SYSTEMS

The new generation of Intelligent Transportation Systems (ITS) is a new type of intelligent transportation ecosystem that is guided by the balance of urban traffic supply and demand, based on the in-depth perception and research, and analysis of urban traffic travel characteristics, realizes the cross-department collaborative decision-making of urban traffic management through advanced technologies such as blockchain and artificial intelligence, and can dynamically optimize the matching of urban traffic supply and traffic demand space-time resources through self-learning and optimization. As a new generation of Intelligent Transportation Systems (ITS), the construction of the traffic brain serves the needs of fully automatic and accurate traffic management is applied to solve the persistent problems of urban traffic, which helps greatly improve the efficiency of traffic operation, and injects new vitality and intelligence into the development of urban traffic industry [90].

Traditional Intelligent Transportation Systems emphasize hardware construction in the development process. At the same time, the system control strategy needs a lot of human resources invested in the implementation process, which can not realize the auxiliary implementation of automation. The lag effect is evident in the long-term urban traffic management process [91]. In the face of the unprecedented travel pressure of the current city and the new opportunities brought by the rise of the new generation of information technology such as blockchain, big data, cloud computing for the development of intelligent transportation, and construction of the new generation of the intelligent transportation system has become an inevitable choice for the development of the times and the construction of smart new forms of urban transportation. It also frees urban planners and managers from heavy business processing and creates immediate control benefits.

The development of blockchain technology is driving ITS towards a new mode of transportation operation, management, and service. In the future, traffic management will be reshaped into AI global decision-making, automatic adjustment of traffic systems based on travelers' needs and preferences, and highly developed mobile internet and intelligence. It can be predicted that the intelligent traffic management system will gradually rely on blockchain technology, big data perception, and artificial intelligence decision-making to provide customized and highly intelligent services for traffic managers and travelers, as follows and shown in Figure 7.

A. KEY FEATURES OF THE NEW GENERATION INTELLIGENT TRANSPORTATION

Intelligent transportation will be based on big data, blockchain, artificial intelligence, and the Internet of Things to build an urban traffic management ecosystem with mobile connectivity, collaborative control & intelligent services and comprehensively improve the traditional Intelligent Transportation Systems [92], [93], [94]. In the future, cities will present the key features of mobile awareness of global information, smart governance of traffic decision-making, and accurate customization of travel services, including training application blockchain AI is the driving force for entering the era of intelligent transportation and industry 4.0 [95].

1) As a complex and multi-dimensional physical network, urban transportation in the future should have the ability to global information perception and gather massive, heterogeneous, and complex big data such as automatic data collection by front-end equipment, manual data collection, administrative data collection, shared data collection, and data provided by the public voluntarily. Utilize advanced block, mobile internet, Internet of Things, and other information technologies to sense the real-time status information of road, vehicle, traveler, facility, and other elements in the massive multiple data, realize cross-level, cross-domain, cross-system, cross-business information exchange, and break the current situation of information management and split operation, realize the interactivity of intelligent transportation information exchange and the universality of information application, for the sake of accuracy Customized traffic management and travel services provide a data awareness platform.

2) In the future, smart transportation will deeply integrate blockchain, artificial intelligence, deep learning, and other technologies with traffic management, with strong cognitive and learning abilities, and be able to continuously self-learning and self-evolution in the process of business processing to adapt to the changing and complex traffic development situation. It has changed the previous empirical decision-making mode of solving traffic problems and formed a highly automated command & decision-making system that integrates perception and prediction, decision-making and management, and evaluation services. It can complete the refined perception of the traffic situation and laws, intelligent decision-making of traffic control schemes, accurate analysis

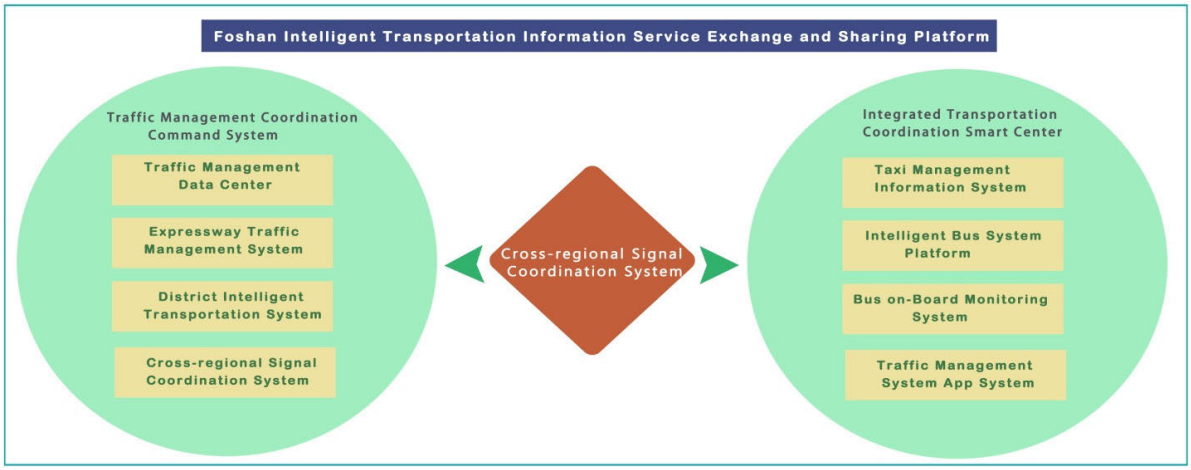

FIGURE 6. Foshan intelligent transportation systems.

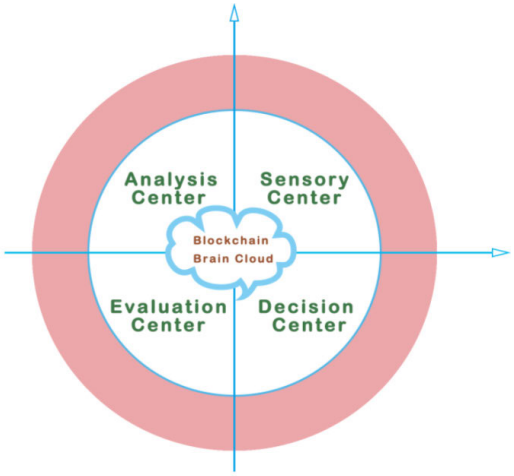

FIGURE 7. Top-level architecture of intelligent transportation brain in yun city based on blockchain.

and optimization of traffic services, and liberate the limited police resources investment based on the global shared big data. It will enable the intelligent mode to cover the whole business field of traffic control.

3) Using the intelligent information interconnection and sharing mechanism, intelligent transportation can trace the travelers' personal preferences in the future and provide more personalized directional service information for travelers in combination with real-time perception and prediction of the traffic operation status of the road network. At the same time, we will improve the ability of comprehensive travel information service to cover the whole chain, mode & region, achieve real-time, diversified & accurate information queries, and release and intelligent feedback throughout the process. Make full use of the holographic information perception tentacles of intelligent transportation, integrate travel guidance and traffic police control business, and promote the optimization and improvement of urban, comprehensive decision-making, facility construction, demand regulation, and other aspects based on individual travel behavior.

B. BRAIN STRUCTURE OF FUTURE URBAN INTELLIGENT TRANSPORTATION

With the enrichment and improvement of the vast and complex urban intelligent transportation management system, building the urban intelligent transportation brain will be the trend of intelligent transportation development in a city, especially in a developing country.

Under the background of the rapid development of a new generation of information and intelligence technologies such as big data, blockchain, and artificial intelligence, the urban intelligent transportation brain is to comprehensively acquire, deeply analyze, comprehensively study and judge, intelligently generate countermeasures, precise decision-making, and system application of urban and urban transportation-related information through comprehensive intelligence such as human-like brain's perception, cognition, coordination, learning, control, decision-making, feedback, and innovation Cyclic optimization is the core hub of Urban Intelligent Transportation Systems(UITS) better to realize the governance and service of urban traffic, solve the problems of urban traffic and provide systematic and comprehensive services. Therefore, its construction needs to follow the top-level scientific, establish hierarchical construction objectives, and achieve various functional requirements with the goal as the guide. Based on the latest technology's application status and development trend, the pilot overall planning of the future traffic management function is carried out.

The urban intelligent transportation brain will form a top-level structure of "one cloud and four centers," integrating the transportation cloud, perception center, analysis center, decision-making center, and evaluation center. Based on blockchain technology, the Brain Traffic Cloud is responsible for interconnecting and sharing all reliable and safe blockchain distribution data provided by the existing business systems of traffic police and other parts and managing and dispatching all business centers. The perception, analysis, decision-making, and evaluation centers are the basic engines for realizing various functions of the intelligent transportation

brain. They respectively undertake the important functions of global perception, real-time analysis, intelligent decision-making, and scientific evaluation.

The perception center relies on blockchain, big data technology and other holographic perception of urban traffic conditions to realize multi-level, all-time and even node-level comprehensive perception of traffic facilities, traffic demand and traffic operation situation; Through blockchain technology, artificial intelligence and machine learning, the analysis center supports the analysis of abnormal condition such as traffic congestion mechanism analysis and judgment, traffic incident research and review, and early warning, and real-time deduces and predicts the space-time passenger flow characteristics and traffic operation status; The decision center builds a closed-loop control mechanism for the coordinated operation of ''perception - analysis - decision - evaluation'' of traffic big data, and provides the formulation, distribution and resource allocation of comprehensive traffic management solutions, as well as visual scheme and whole-process tracking and supervision; The evaluation center uses the traffic simulation technology and mathematical model to track the characteristics and evolution trend of traffic operation under the multi-class status quo and optimized traffic control measures, carefully evaluate the implementation plan and identify the existing problems, and support the travel planning and guidance services based on real-time traffic conditions and behavior analysis, intelligent parking guidance services, and the sharing and real-time release of various types of traffic information.

In the future, the urban intelligent traffic brain will realize brain-like reasoning and decision-making to assist urban management, traffic control [96], and public travel services based on blockchain, big data, artificial intelligence, and other new generation information technologies, cultivate the self-learning, self-evolution ability of the traffic brain and continuously improve its intelligence so that it can realize closed-loop intelligent management of autonomous perception, intelligent analysis, intelligent decision-making [97], and scientific evaluation in some application businesses in the long-term stage, It provides comprehensive and intelligent services for the future development of the city, traffic business management and public travel.

VI. FUTURE PROSPECTS

This survey paper has covered blockchain technology and Urban Intelligent Transportation Systems (UITS) integration architecture model in developing countries. Intelligent Transportation Systems (ITS) are the key to improving the efficiency, service quality, safety level, environmental protection, and energy conservation of the transportation system. Relying on the new generation of information technology, such as blockchain and big data, Intelligent Transportation Systems in developing countries will achieve rapid development, and the level of intelligence will be significantly improved. The future development of intelligent transportation will focus on building a sharing platform for urban transportation systems [98], creating an advanced and practical urban ''intelligent transportation brain,'' making a world-leading Urban Intelligent Transportation Systems (UITS), achieving high-level vehicle and road coordination, improving the intelligent level of passenger and freight transportation services [99], achieving intelligent, comprehensive transportation, solving traffic congestion with the help of a high degree of intelligence, improving the safety level, and achieving green traffic dominance.

Prospects of future Urban Intelligent Transportation Systems (UITS) is an urban transportation strategy and countermeasure system composed of urban land use form adjustment, urban transportation structure adjustment, urban road network structure optimization, and urban road system right-of-way adjustment. It should serve urban development planning and comprehensive transportation development planning. To do a good job in the construction of the Urban Intelligent Transportation Systems (UITS), we should attach great importance to the top-level design of the Intelligent Transportation Systems (ITS), adhere to the principle of traffic infrastructure and traffic engineering facilities construction first, not only pay attention to the hardware construction of the Intelligent Transportation Systems (ITS) but also pay attention to the software development and function improvement of the Intelligent Transportation Systems (ITS).

The construction of Urban Intelligent Transportation Systems (UITS) in the future should focus on realizing functions and be problem-oriented [100]. It should be both progressive and practical. The first key to developing an Intelligent Transportation System is to achieve the expected function and actual application effect rather than the system construction itself. The structure of Intelligent Transportation Systems should be fully demonstrated by experts, interviewed by citizens, and analyzed by construction effect. Clear system objectives, clear acceptance criteria, sufficient expert argumentation, and a perfect post-evaluation system are the basic requirements to ensure the healthy development of ITS. We should speed up the introduction of relevant standards and specifications, form a perfect system, guide the construction of an Intelligent Transportation System (ITS), and avoid decision-making mistakes and investment waste.

Although the Urban Intelligent Transportation Systems (UITS) integrated with blockchain technology has a good development prospect, blockchain technology still has some potential security risks. For example: 1) 51% of attacks [101]. When the malicious attack node of the entire network holds 51% of the total computing power, it can attack the whole network and maliciously alter or delete the general ledger. 2) Anonymity issues [102]. Although the cryptography principles used in the current blockchain seem impregnable, if the key is acquired or stolen, no third party can help retrieve it. And with the emergence of quantum computing, the encryption key may be quickly cracked, thus destroying the foundation of the blockchain. 3) Illegal attack [103]. In the blockchain mesh structure, malicious nodes will intercept new blocks' work and transaction processing and even

disconnect the entry registration channel with the network. Malicious nodes may also block the new blocks created by other nodes so that the main chain can only link the blocks created by itself. Therefore, there is still a long way to go to build Urban Intelligent Transportation Systems (UITS) in developing countries in the future.

VII. CONCLUSION

The development of blockchain, big data, artificial intelligence technology, and other technologies has led to the innovation of urban government management, traffic police traffic management, and resident travel service, which can improve more refined and three-dimensional urban services. Developing countries still have a long way to go in constructing Urban Intelligent Transportation Systems (UITS) for Various factors. The paper describes in detail the current situation of the construction of Intelligent Transportation Systems (ITS) in three cities in China, including the research system architecture, functions, functions, advantages, and disadvantages. It proposes a structural model for building a big data platform for Urban Intelligent Transportation Systems (UITS) based on blockchain technology. This paper also constructs a top-level design structure model of an Urban Intelligent Transportation System (UITS) based on blockchain traffic cloud, which can also be used for reference by developing countries. A detailed discussion concerning future and open research avenues is also performed, which could help pave the way for researchers and urban transport system designers to explore the key challenging areas in integrating blockchain technology and Urban Intelligent Transportation Systems (UITS), especially in developing countries.

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