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Use of Internet of Things to Improve E-government Public Services

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Internet of Things (IoT) technology is accelerating societal and lifestyle changes, yet its application in E-government public services remains inadequate. E-government public services have a direct impact on public life and development, and they reflect the government's governance capabilities. Technological improvement is critical to the development of E-government public services. In this paper, the technical characteristics and advantages of IoT technology applied to E-government public services are systematically outlined and analyzed. The technical challenges faced by the current development of E-government public services are examined, and how IoT technology can be leveraged to improve these services is explored. By integrating emerging technology applications, creating a data-driven environment and a distributed multicenter, opening up government–civilian interaction channels, and developing intelligent scene-based services, IoT is utilized to significantly enhance public service experiences and effectively improve public services. The utilization of IoT technology in E-government public services presents enormous potential, as it facilitates the advancement of such services and supports the transformation of governmental organizations and social governance models. This report offers guidance for policy makers, implementers, and IoT technology engineers on comprehending the implications of IoT technology in E-government public services.

1. Introduction

In the digital network era, the rapidly developing Internet of Things (IoT) technology is increasingly changing all aspects of people's lives. From a technical standpoint, the IoT is an extension and expansion of the Internet, which connects people to people, people to things, and things to things. IoT technology also senses information, stores and transmits it in the form of data, and processes the data intelligently. Finally, a network system for extensive information interaction and intelligent processing between all things is realized. The core technology

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includes intelligent perception and interconnection aggregation, as well as system architecture integrating emerging technologies such as blockchain, artificial intelligence, cloud computing, and big data. It can realize the integrated and unified processing and digital intelligent application of scattered physical data information.[1] IoT changes the way humans interact with computers, solves the interconnection between the information world and the physical world, and strengthens the protection of security, privacy, and ethics. In this way, it brings intelligence and convenience to human life and production methods, and promotes the happiness of the public.[2] The characteristics of modern people's diverse and high-quality needs align perfectly with IoT technology, making it an important tool to promote coordinated and sustainable development across the economy, society, people, and nature. As a result, it is expected to bring about significant changes to E-government public services.

E-government public services are the services that reflect the government's governance ability, represent the government's image, perform government responsibilities, and provide the services to enterprises and the public. The actors of e-government include the government, enterprises, and the public. E-government is also regarded as a modern governance model in which the government integrates modern information technology for governance.[3] The core concept of a modern service-oriented government requires E-government public services to fully meet the needs of the public, to continuously innovate service forms and contents, to reflect the pursuits of public-centered service goals, and to achieve more satisfactory services for the public. As society continues to progress and develop, it is crucial to continually apply emerging technologies to innovate and improve E-government public services. This comprehensive approach is necessary to enhance the government's governance capabilities and build a service-oriented government. Meeting the needs of E-government public services in the digital technology environment is essential as it aligns with the modern ways of life and work. It enables the provision of intelligent, accurate, convenient, efficient, safe, and satisfactory services that cater to the demands of the people. When studying the development processes of E-government public services, it becomes apparent that their iterative advancements have been achieved through innovations and advancements in information and communication technology (ICT).[4,5] The roles of ICT in the development of online government network services, government one-stop online and offline combined services, and smart government public services have evolved rapidly.

In the digital economy era, the rapid development of emerging technologies such as blockchain, artificial intelligence, big data, cloud computing, and edge computing highlights the leading role of IoT in the new wave of information technology shaping the world. As information infrastructure continues to advance, it is evident that IoT technology will play a crucial role in various fields, including global economics and social development. However, the studies revealed that although the IoT and E-government public services have developed significantly in their respective fields, there is a lack of applied research to integrate the two to achieve common developments.[6] However, some research has contributed to the related cognitions of IoT and E-government.[7,8] However, there has been insufficient research on how to promote, improve, and benefit E-government public services using IoT technology to realize innovative government public service models through technological innovations and improve public satisfaction with government public services in digital environments. In other words, the application of IoT

technology in E-government public services is considered one of the most promising areas of research.

By systematically analyzing the advantages of IoT technology applied to E-government public services, at this stage, technical shortcomings were observed in E-government public services. The advantages of the IoT technology were mainly analyzed and studied to improve E-government public services, and the system architectures of the IoT technology for E-government public services were built. Also, in this study, implementation paths, such as integrating and deploying the emerging technologies, building a data-based environment, and constructing the distributed centers, were proposed. The aim of this study was to research and construct application models such as those of government–civil collaboration and intelligent scene services.

2. Design Background of System Technology

2.1 IoT architecture with integrated emerging technologies

The first topic mainly focuses on the system requirements of E-government public services. IoT is based on perception technology and integrates emerging technologies such as artificial intelligence, blockchain, big data, and cloud computing. In this study, we tried to integrate perception and identification, transmission communication, operation support, and business application technologies. The integrated technologies were fully deployed in the application, platform, network, and perception layers of the IoT technology. Finally, the IoT technology was applied to build a technical architecture system for E-government public services, as shown in Fig. 1.

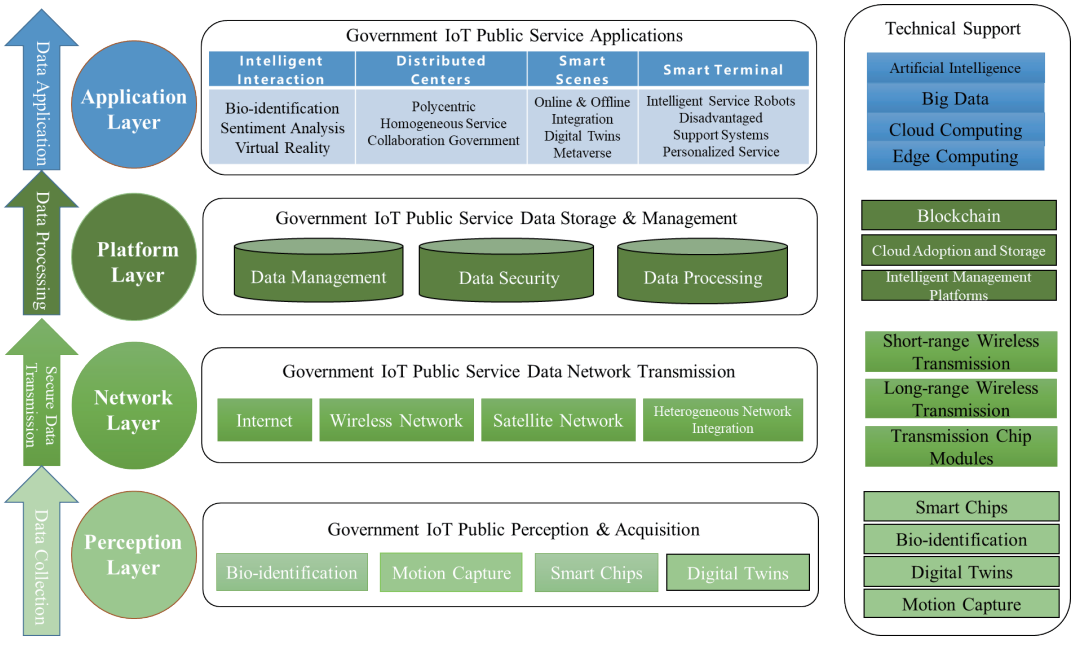


Fig. 1. (Color online) Architecture of IoT system for E-government public services.

(1) Perception layer. The perception layer in the IoT government public service system serves as the foundation of the overall architecture and information data source. Its primary function is to utilize perception sensing technology and carry out physical perception tasks. The technology employed in the perception layer includes smart chip, radio-frequency identification, sensor, GPS, multimedia information collection, and biometric identification technologies, among others. By intelligently analyzing the management information system's big data at the platform layer, we can harness the data values to enable intelligent E-government public services.

(2) Network layer. The network layer mainly uses the IoT technology to deploy transmission communication technology, including mobile communication networks, the Internet, wireless networks, WeChat communication, short-range wireless communication technology, and various mature network protocols. It mainly encrypts, converts, groups, and transmits all the perceived information data in real time in accordance with the settings. With the wide application of new-generation mobile communication technology such as 5G, it provides a guarantee for the data transmission of IoT of E-government public services.

(3) Platform layer. The platform layer brings together various emerging technologies, such as blockchain, big data, cloud computing, artificial intelligence, edge computing, and data mining, and aggregates, analyzes, processes, and applies the data from the perception layer to realize the integration of information and operational technologies.

(4) Application layer. The application layer is mainly aimed at the data of the E-government public service system, which is investigated in order to combine with the specific needs of the public and provide the targeted government public service solutions. The application layer is responsible for analyzing the data information of the service objects and feeding it back to the perception layer to realize specific government public service behaviors. At the same time, it is possible to build government public service applications such as smart government decision-making and smart assistance for the weak and the elderly.

2.2 Using IoT to integrate a system environment

(a) A blockchain is a type of distributed ledger technology consisting of a growing list of records, which are called blocks and are securely linked together using cryptography. Each block contains a cryptographic hash of the previous block, a timestamp, and transaction data. Blockchain technology has the functions of decentralization, tamper resistance, traceability, and programmability, and it plays a core role in security protection in the IoT E-government public service system. The blockchain can solve the key issue of lack of public trust among IoT users in insecure environments with a self-contained record of data that does not require third-party verification.[9] The blockchain has the following technical characteristics: The blockchain uses (1) a chain block structure with timestamps to store data, (2) a typically decentralized network for data transmission, and (3) encryption technologies such as digital signature, asymmetric encryption, and zero-knowledge proof to ensure data security. (4) Blockchain smart contracts enable all nodes in the system to automatically and securely fulfill contractual obligations on the basis of agreed-upon conditions. By leveraging blockchain technology, information transfer in IoT government public services becomes a trusted process that ensures high transparency and security.[10]

(b) Big data analyses are an application technology for analyzing and discovering the hidden laws, phenomena, and principles using massive data.[11] In the IoT E-government public service system, multidimensional and massive information data from huge and complex data sources can be aggregated. After all data are analyzed by big data analyses, new data, such as public usage habits, experiences, utility evaluations, and degrees of influences, can be formed. Comprehensive application in the fields of E-government public services will replace third-party research and become an important basis for scientific decision-making and model selection for E-government public services.

(c) Research in the field of artificial intelligence (AI) includes robotics, language recognition, image recognition, natural language processing, and expert systems.[12] Through continuous learning and iteration, AI drives the intelligent matching of E-government public services and identifies logical and process conflicts in system services. In this way, the supply mechanisms for E-government public services can be improved and the optimal affairs allocation can be achieved. In the E-government public service scenario, AI can be used to analyze the internal logic and correlation of object behavior characteristic data through machine self-learning and self-judgment abilities. In this manner, it provides specialized, standardized, and institutionalized E-government public services with intelligent features. That is, AI creates new scenarios in the E-government public services and has unlimited potential to enhance service values.

(d) Cloud computing is centered on IoT and uses IoT's convenient services; therefore, it can easily realize data and application sharing between different devices, reduce the burden on system terminals, simplify I/O devices, reduce operating costs, and improve data utilization efficiency. The blockchain enables identity identification for IoT data, realizes a credible guarantee of the data source, and solves the problem of trust in the government and security consensus. The terminal sides of both edge computing and cloud computing jointly provide computing power support. AI algorithms are optimized with the support of cloud computing and the data and computing power of big data technology; this can realize intelligent human–computer interaction and ultimately serve the scenario application of IoT, as shown in Fig. 2. As

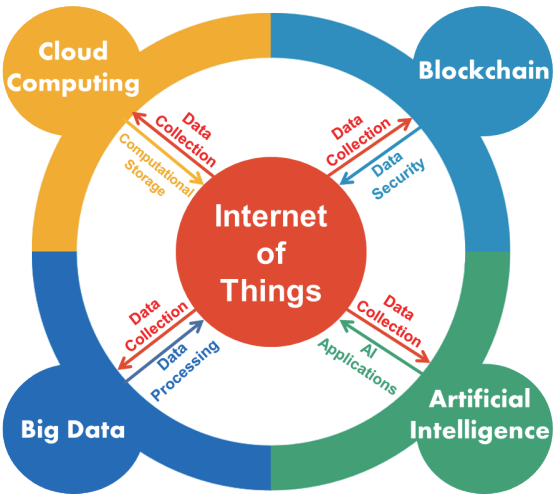


Fig. 2. (Color online) Relationships between IoT and E-government public services for the investigated technology.

stated above, the IoT system presents an environment in which the clearly hierarchical and technical structures and the emerging technologies are fused and integrated, providing a guarantee for enabling E-government public services, as shown in Fig. 3.

3. Key Issues at the Current Stage and IoT Technology Improvement Goals

(a) Public trust risk of the government's centralization

E-government public services are the reflection of trust in the government and governance capability. The centralization of government typically results in government functions being limited to sharing the content of public services that are overseen by different departments. Moreover, the hierarchical organizational structure of the government establishes well-defined relationships between powers and responsibilities. Therefore, the cross-level and cross-departmental information and data connections generally have problems such as slow response and information distortion, and it is impossible to achieve ideal data sharing and trust transfer. The presence of uncertainties can result in a lack of trust in the government and may impact the public's trust as well.[13] Therefore, there is an urgent need for technical tools that can ensure the transmission of trust in the government.

(b) Expectations of the government's public service

In the traditional centralized government public service system, the government is the provider of services and the public is the receiver of services. The E-government public services should cover the entire public, that is, a large audience and diverse groups, by providing high service frequency and a variety of service contents.[14] At the same time, government public services directly affect the public's personal rights such as daily life, work, education, medical care, and development.

(c) Demand for participation rights by the public

As public awareness of their rights continues to increase, so does their willingness and demand to actively participate in government public services and facilitate government–civilian coordination.[15] In the traditional E-government public service system, the communication and coordination between government agencies and the public are mainly carried out through mutual

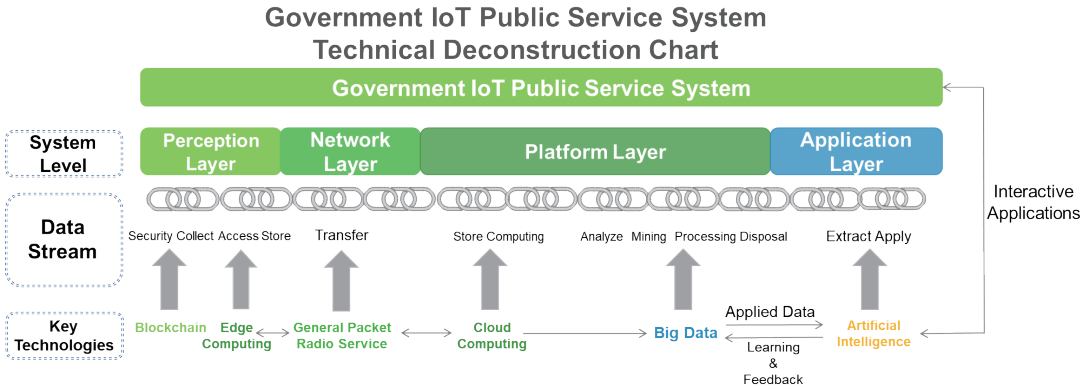


Fig. 3. (Color online) Deconstruction of the investigated IoT E-government system.

communication between government employees and the public. However, there are few relevant communication channels, and communication methods are disconnected from emerging technology application modes such as social media in the digital environment. If things continue likewise, the willingness of the public to participate will be further reduced, the public's satisfaction will be reduced, and the ability of the government to govern will be deeply affected and the image of the government will also be affected.

(d) Data security risk challenge of the government's centralization

Government centralization enables the government to centrally control the most important government public service data of the entire society in government public services; this makes the government a data center where massive amounts of data are stored. A centralized data system, on the one hand, has risks such as data tampering and deliberate forgery; on the other hand, centralized data causes isolated data islands to easily form. In the event of a cyberattack, huge losses of data may be incurred.[16] At the same time, the integration and storage of data cannot flow smoothly, and it is difficult to raise the value of data; this restricts innovation and the development of data-based models for E-government public services.

(e) Appealing a better service experience for the government's public services

The rapid development of the digital social environment has made the public's expectations that government affair services match the developments of the times stronger,[17] prompting the government public services to change from meeting the basic needs of the public to meeting the demands for personalized and precise services and for intelligent and elegant developments. The intelligentization of government public services and the precision of service effectiveness have become the general pursuit of the public and have also become an important motivation for the technological revitalization of government public services.

4. Implementation and Improvement of E-government Public Services

4.1 Using IoT to build a data environment for E-government public services

The core functions of IoT are to build a data-aware society and to realize mutual perception and data connection between humans and physical facilities. Metcalfe's law states that the value of a network is proportional to the square of the number of connected users.[18] IoT can be adopted to build a public system for E-government public services, which integrates all things and enables them to be perceived intelligently. Such a system would surpass the human-to-human interaction models of the traditional government public services. Therefore, the way to realize the system is to forge comprehensive network interconnections of all government agencies, organizations, the general public, and related physical objects related to E-government public services. The advent of the emerging technology IoT enables the sensing and transmission of information and data between devices, thus creating a dynamic and interactive community of supply and demand convergence for IoT E-government public services.

In the digital social environment, the E-government public services start from the concept of public services. In particular, with the comprehensive application of blockchain, artificial intelligence, big data, and cloud computing technologies, the IoT system surpasses the

comprehensive data perception of the Internet. The largest network system covering the entire populace in this way has resulted in a data-based E-government public service system. As a consequence, the value of the IoT government public service system may even surpass that of the service itself. The architecture of the service system and the enhancement of data value are shown in Fig. 4.

4.2 Use of emerging technology IoT to create a safe environment for public services

The IoT government public service system covers all government organizations, the general public, and related entities. Each system device records and saves massive amounts of data related to government services and personal information. It is often faced with systematic data infringement that abuses the loopholes in data security, which may endanger the entire government public service infrastructure and service system. Therefore, in previous studies, a technology that can protect secure data was investigated, because only secure data is of true value. In the report "Security Guidance for Early Adopters of the Internet of Things (IoT)" released by Cloud Security Alliance (CSA), the protection of private personal data is listed as the first challenge of new security issues facing IoT.[19] On September 19, 2019, the Internet Society released the IoT privacy report "Policy Brief: IoT Privacy for Policymakers", which elaborated the risks and challenges brought to the issue of personal privacy protection by IoT.[20] They also put forward action recommendations for the collaborative governance of policy makers, IoT service providers, and stakeholders.

In our analysis of the entire government public service system, we found that IoT technology is utilized to its fullest potential by deploying blockchain technology. This enables seamless data sharing across regions, subjects, and systems, while facilitating the flow and exchange of valuable data. The blockchain can encrypt key data after the trusted IoT data is on the chain, and it can distribute and store data in all terminal devices, such as computers connected to the blockchain, instead of in a traditional centralized storage on a central server, as shown in Fig. 5(a). The developed technology enables the implementation of decentralization, the

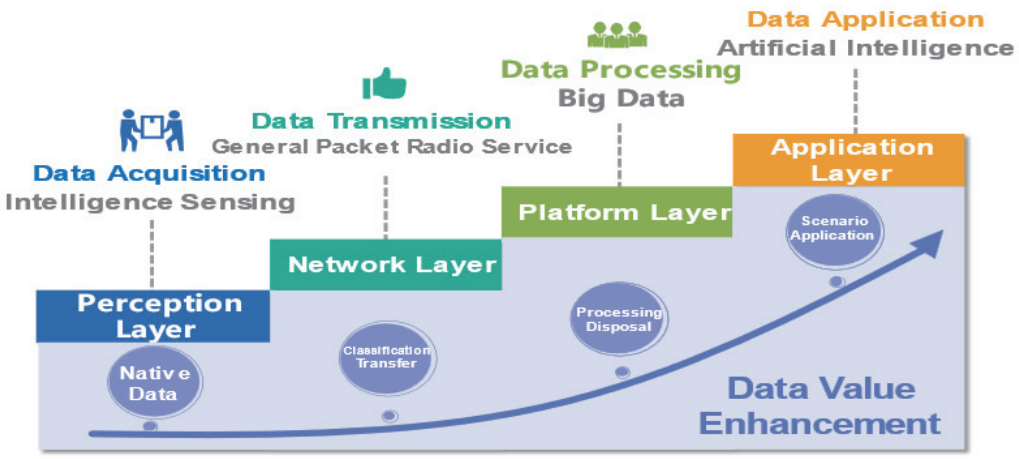
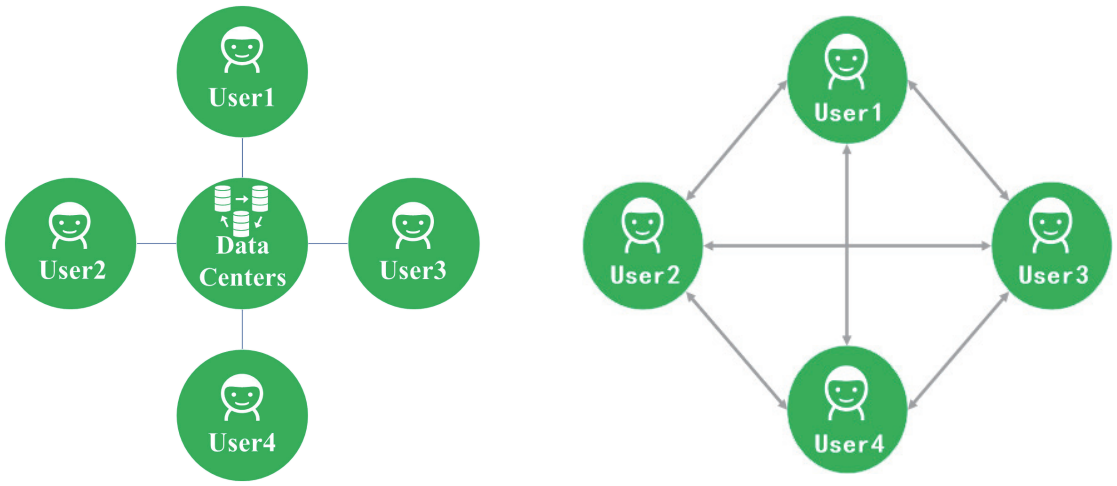


Fig. 4. (Color online) Architecture of the service system and enhancement of data value.



(a) (b)

Fig. 5. (Color online) (a) Traditional data storage model and (b) blockchain data storage model.

distribution of accounting, permanent storage, and the guaranteed equal access and verification rights of the entire public, as shown in Fig. 5(b). With the advent of the digital age, the elimination of isolated information has become the consensus of the public, but there is always a contradiction between data sharing and privacy protection. Data owners require strong privacy protection, data users require high ease of use, and data flow requires strong liquidity. To m*eet all* the requirements of data parties, the combination of blockchain and privacy computing provides a solution.

In this study, we combine blockchain and privacy computing technologies to ensure the credibility of the computing process and data without the need for the collection and sharing of original data. This is achieved by allowing data to be freely circulated or shared while ensuring data security, thus conferring a greater data value. Privacy computing with different strengths is designed, that is, data flow can be guaranteed by a joint blockchain + basic identity system through the privacy computing of zero-knowledge proof, homomorphic encryption, and secure multiparty computing. This can solve the problem of unwillingness to share data and daring not to share, thus realizing the establishment of the data value.[21] By exploiting and utilizing the data value to the fullest while ensuring data security, the transfer of trust from the government and the protection of personal privacy can be achieved. This can enhance the public's confidence in government public services.

4.3 Using distributed multicenters to relieve the pressure of centralized government public services

E-government public services carry the huge public service pressure of the centralized government, as shown in Fig. 6. To effectively resolve the pressure of centralized services, a key strategy, that is, building a distributed multicenter, establishing consistent government trust, and realizing decentralized, diversified, and equivalent services, as shown in Fig. 7, was investigated.

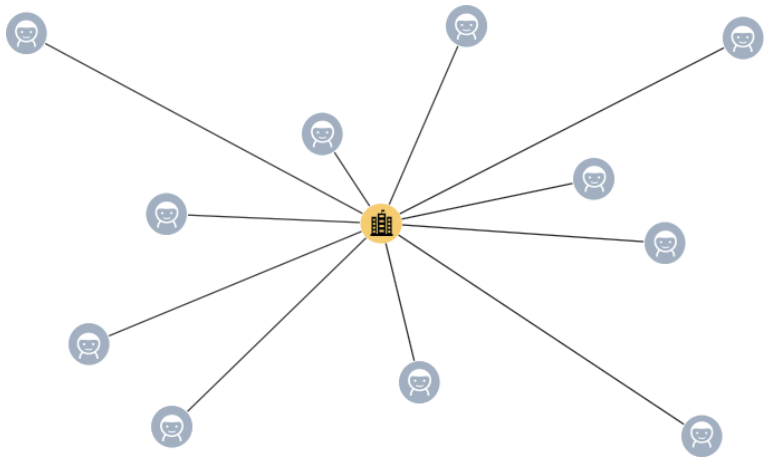


Fig. 6. (Color online) Architecture of the traditionally centralized E-government public service model.

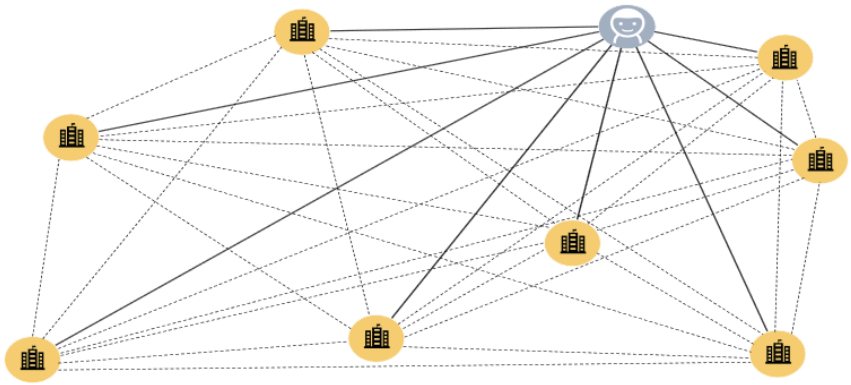


Fig. 7. (Color online) Architecture of the multicenter IoT E-government public service model.

IoT deploys the blockchain in the government public service system and uses its decentralized underlying logic technology to create government public services in a distributed and multicenter pattern. Therefore, we develop technologies that realize trust transfer and multicenters to improve the improvement model of government services. The multicenter government public services developed using the above technologies have been used in practical cases. For example, on August 24, 2022, the real estate registration center of Dongguan City, Guangdong Province, China, issued an "Announcement on implementing some high-frequency real estate registration businesses in the city". The municipal government tries to implement a cross-regional real estate registration business for the incremental commercial housing transfer registration business in the city. For commercial houses that meet general requirements, the public can enquire at any town street (park) government affairs hall counter and is no longer restricted by the town street (park) administrative division.

4.4 Using IoT to build a government–civilian coordination public service community

Given that the IoT can perceive all things, in this research, we established an E-government public affairs service innovation ecosystem that facilitates smooth interaction and collaborative services between the government and citizens. This ecosystem includes government agencies and the public, as shown in Fig. 8. In the government public service ecosystem, the data on the perception of each subject has become the basis for decision-making on the type of E-government public service. The investigated technology can realize that the data on the state of each subject can be sensed, acquired, and transmitted in an all-round manner. The proposed system, which is applied in the government public service ecosystem, can achieve the goal of intelligent prediction, active matching, and suitable policy implementation of public services, for example, the decision-making scenarios of government public services in which the government and citizens are coordinated, and the two groups together vote on the decision-making results of government public affairs service projects. During the voting process, the improved IoT technology can play a major role in the communication and security functions.

5. An Application Case: Intelligent Scenario of Using IoT for E-government Public Services

A number of related survey results on E-government public services show that the key factors affecting the public service experience are concentrated in the modernization of service technology, the degree of matching service supply, the sense of public participation, and the intelligence and personalization of the service experience.[22] As a result of the analyses of the technical path and application modes of the IoT technology in E-government public services discussed in this study, the IoT system architecture characteristics and technology integrations can be exploited to build the IoT scenarios of the E-government public services. In this way, the

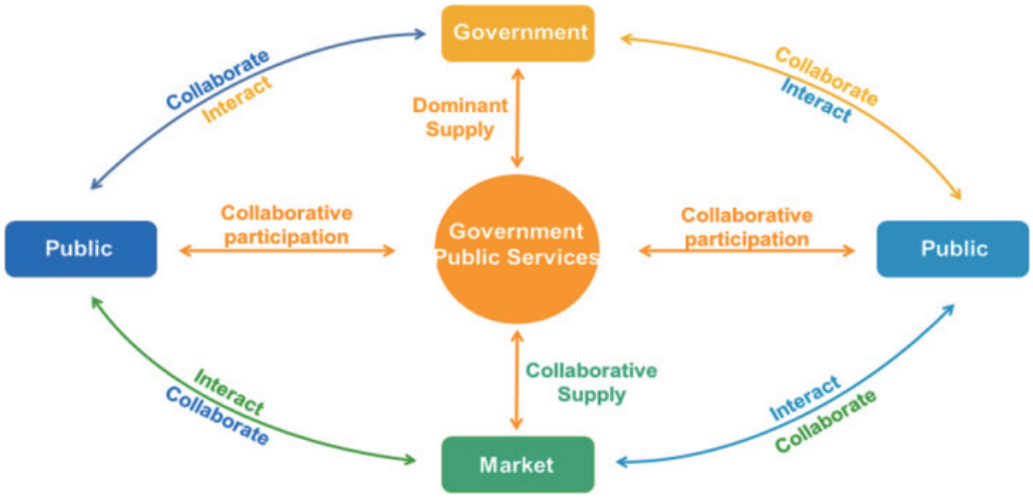


Fig. 8. (Color online) Proposed architecture of a community model to facilitate government–civilian coordination in public services.

promotion and enhancement of the E-government public services have indeed been realized, as shown in Fig. 9.

The E-government public services are used to construct a community intelligence scene mainly to establish an environment for helping the weak and the elderly, as shown in Fig. 10. Smart scenarios for public services that cater to information-disadvantaged communities are crucial aspects of implementing intelligent and scenario-based services within the Smart Public Service system. The construction of such scenarios involves utilizing an IoT technical architecture system for E-government public services, as illustrated in Fig. 10. This approach aims to safeguard government public services for the underprivileged with limited access to information.

(a) Customized channels for friendly interaction

Intelligent human–computer interaction channels are tailored to the specific needs of information-disadvantaged groups. To create a more user-friendly and accessible interface for information-disadvantaged groups to interact with government public services, the perception layer can be optimized with the use of relevant technologies. This can involve implementing smart wearables, biometrics, dynamic capture, virtual reality, intelligent terminals, and intelligent perception devices that integrate multiple sensory inputs such as vision, hearing, touch, and movement.

(b) Individuals are authorized and the government is trusted.

The government establishes a secure public information database, backed by its credit, to ensure data privacy and integrity with the consent and trust of citizens. In addition, the data transmission hub at the network layer ensures a reliable and efficient transmission of IoT government public service data. By including personal data from authorized individuals who may face information disadvantages, the intelligent service system of IoT government public

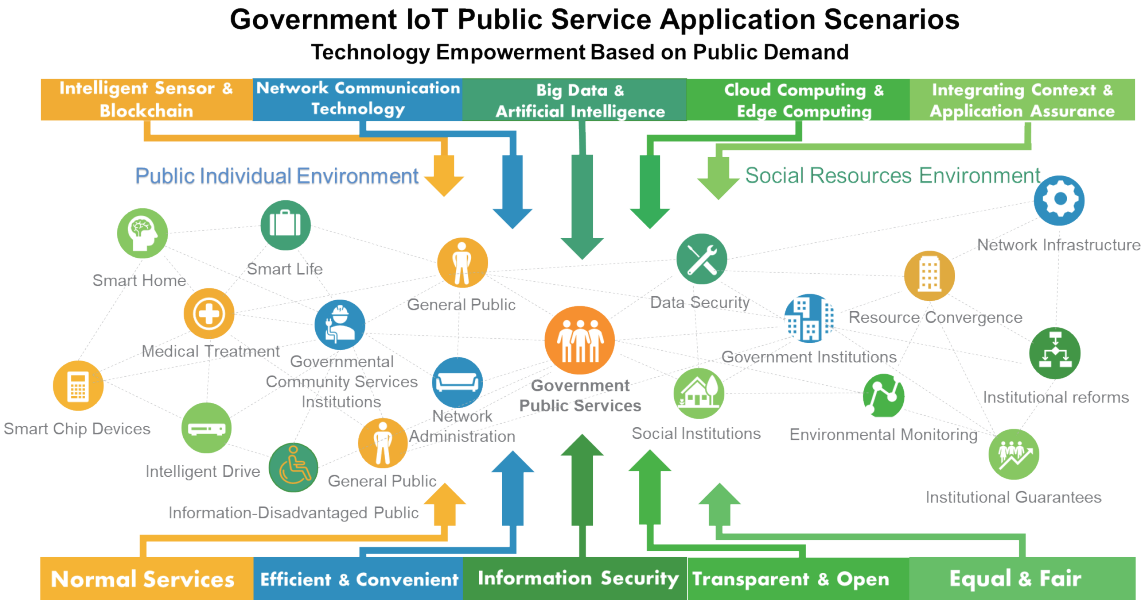


Fig. 9. (Color online) Public service application scenarios of the IoT E-government.

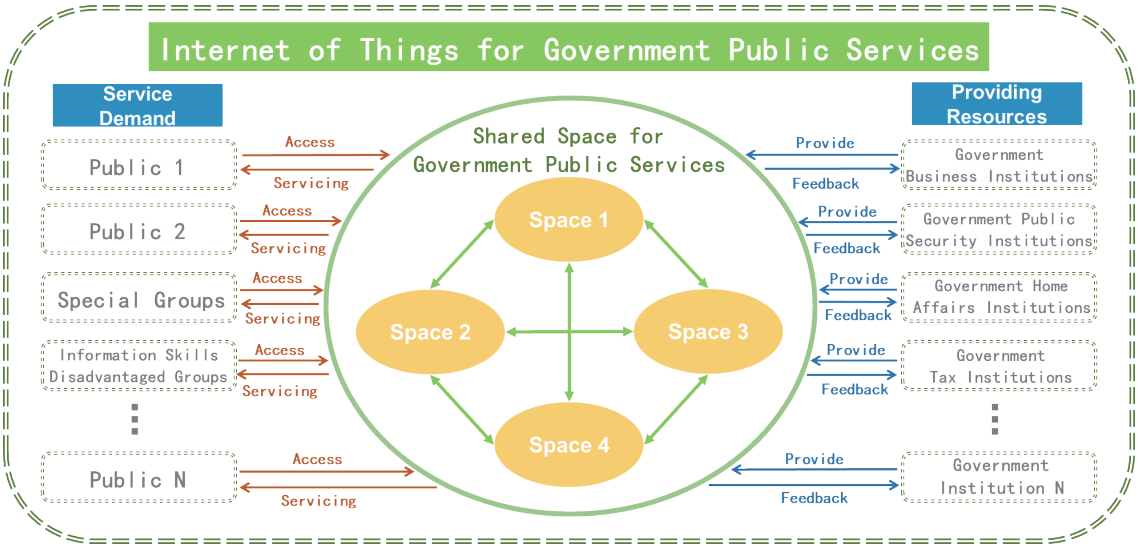


Fig. 10. (Color online) Public service scenarios of E-government for disadvantaged groups.

service is enhanced with essential data support, facilitating the provision of effective public services.

(c) Intelligent services and all-around management

To move away from the passive service mode of traditional government public services, artificial intelligence and big data technologies can be leveraged to dynamically detect and intelligently analyze the needs and effectiveness of information-disadvantaged groups. This includes the comprehensive management of the service cycle, such as determining the content, intensity, and frequency of services required, as well as considering individuals' life status, demand characteristics, and ability traits. Through such measures, a more proactive and personalized approach to public service can be achieved. Data are obtained and integrated at the platform layer to enable the secure storage, analysis, and processing of data, as well as to facilitate system application operation, edge computing configuration, and data privacy protection. This allows for dynamic adjustments to service delivery methods, quantity, and content, leading to continuous service improvements.

(d) Integration of online and offline resources

Using data from the platform layer, the application layer analyzes information from information-disadvantaged groups through the Internet of Everything environment and provides feedback to the perception layer to perform specific public service actions. In delivering services, the online space is integrated with the offline physical environment, including community libraries, cultural centers, and public services, to enable the mutual integration of online resources and physical entities. Furthermore, a service system that connects families and communities can be established by integrating online and offline services. Public service resources can be integrated to create a comprehensive service space that addresses individual needs holistically. This includes the integration of online and offline services such as hospital registration, license processing, transportation, taxation, online ordering, shopping, logistics and

delivery, as well as the payment of utility bills (e.g., water, electricity, and gas), TV and telephone bills, and house maintenance services (e.g., water and electricity repairs and heating).

(e) Connecting families and communities to help everyone

Community public officials and volunteers can be connected with information-disadvantaged individuals, especially those with physical and mental impairments. With proper authorization, services such as representative processing, home processing, and community-integrated self-help assistance can be provided in an IoT security monitoring environment, creating a humanized, multi-channel, all-encompassing, interactive, intelligent, and self-help service environment. This approach also promotes the participation of disadvantaged groups and the monitoring of government services, which can significantly enhance the public service experience.

This investigated system mainly builds the service scenarios that serve the populations with disadvantaged information skills. The system can analyze the digital divide of information-disadvantaged groups and build smart government public services that provide meaningful experiences. According to the information released by the National Bureau of Statistics of China in June 2021, China's illiterate population (those aged 15 and above) is 37750200 and the illiteracy rate is 2.67%.[23] Statistics show that the elderly over the age of 65 in China account for 13.5% (180 million) of the total population. The living and development spaces of the information-disadvantaged group tend to be passively compressed in the digital environment. Living communities often become their primary service-receiving space. In the face of such a large number of information-disadvantaged public groups, if there is a lack of dedicated government public services, it will inevitably seriously affect the efficiency of the government to govern and even cause social instability. Therefore, it is a very urgent and important task for the government to construct government public services for information-disadvantaged groups.

6. Conclusions

In this study, the IoT system was combined with blockchain, artificial intelligence, big data, and cloud computing technologies to improve E-government public services. The blockchain technology is fully deployed in IoT to realize data sharing across regions, subjects, and systems, and to realize the flow and exchange of the data value. To meet all the requirements of data parties, the combination of blockchain and privacy computing has provided a solution. With this combination, blockchain can ensure the credibility of the computing process and data without the need for the collection and sharing of original data. To effectively alleviate the pressure of centralized services, a key strategy of building a distributed multicenter, transmitting homogeneous government trust, and realizing decentralized, diversified, and equivalent services was also investigated. Therefore, in this research, we developed technologies that can realize trust transfer and multicenters to improve the improvement model of E-government public services.

Acknowledgments

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