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Design Blockchain Architecture for Population Data Management to Realize a Smart City in Cimahi, West Java, Indonesia

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ABSTRACT

Smart city as a concept of city development which integrates information and communication technology with the intention of optimizing city management becomes a major goal for Indonesia, especially through the movement towards 100 Smart Cities. However, population data management is crucial in achieving this for optimal planning and management. Personal data protection becomes a crucial challenge with the rapid population growth and mobility in cities. The need for a more reliable protection system is very necessary. This research proposes a blockchain architecture that not only manages digital identities but also population data. The focus is population administration in Cimahi City, West Java, with the hope of providing security, transparency, and a strong audit trail for all population data. The contribution of this research is to design a blockchain architecture specifically for population data management, meeting the needs of population administration in cities, especially the city of Cimahi. Through a blockchain architecture development approach, this research considers the diverse administrative needs of the population and applies a blockchain model that enables data security and integrity. This implementation of blockchain architecture provides promising results in maintaining the security and integrity of population data, enabling greater transparency and auditability. This implementation of blockchain architecture provides promising results in maintaining the security and integrity of population data, enabling greater transparency and auditability. This research also shows that the use of blockchain technology specifically for population data management can be a reliable and innovative solution in ensuring the security and reliability of data important for smart city development.However, this research has limited access to central data, so the data obtained is still very limited. Therefore, further research is needed to follow up on these limitations. Apart from that, this research is also expected to provide knowledge and solutions in securing data, especially population data in government environments.

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1. INTRODUCTION

Smart city is a city and regional development concept that is related to various concepts [1]. In general, the aim of this concept is to improve the quality of life of the population through integrating information and technology communication in all aspects of the city management [2]. In realizing development with this concept, there needs to be a strong and fast technological development response [3]. For example, economic

and health development cannot be separated from the maximum use of digital technology. The important thing needed in this development is a secure and accountable population identity system.

Resident identity is key to tracking, managing, and providing appropriate services to city residents efficiently and effectively [4]-[5]. By having accurate population identity and being integrated with the smart city system, city governments can use it to optimize public services such as health, education, transportation, security and infrastructure which means the concept of smart will be effectively achieved [6]. For example, the use of public transportation data can be optimized by analyzing transportation needs using data science technology or artificial intelligence technology so that government decisions can be made more efficiently and accurately. However, in collecting and using population identity data, it is also important to pay attention to aspects of data privacy and security [7]-[8]. The government must ensure that the personal data of city residents is safe and not misused by unauthorized parties. Along with the growth of population accompanied by increasingly rapid movement, the population management system, especially those related to population identity, is increasingly difficult to maintain security. Misuse of residents' identities is something that happens very often and has caused a lot of harm to various parties, both the government and the residents themselves. Therefore, a population data management system is needed that is designed to guarantee data security so that it can provide data that is accountable and well integrated [7]-[8].

Blockchain has great potential in managing population data because it is able to provide a secure, decentralized and transparent system to facilitate the exchange of information and data transactions efficiently and safely [9]-[11]. In the context of population data, blockchain can be used to build a decentralized database that can be accessed by various parties such as the government, private sector and city residents by regulating access rights according to their respective roles and responsibilities [12]. In the blockchain system, population data is stored in interconnected blocks and protected by cryptography, so that the data cannot be manipulated or changed by unauthorized parties. In addition, in the blockchain population data is stored in the form of a hash that is randomized with a strong cryptographic algorithm [13]-[20]. This makes data difficult to access and maintain security. Blockchain can also be used to facilitate the exchange of population data between various parties safely and efficiently [21]. In a blockchain system, data exchange can be carried out with smart contracts, which are automatic programs that regulate decentralized data agreements and transactions [21]-[22].

One of the great potentials in managing population data is the use of blockchain for digital identity. Blockchain research for digital identity has been carried out but is still limited to proposing a model. Fathiyana *et al.* [23] proposed blockchain implementation by adapting the electronic identity (SNI) scenario. The data used in the design still does not contain complete population data. Therefore, in research, the application of blockchain is not only for electronic identity but also for managing population data in accordance with the needs to support smart cities in Indonesia. In this research, architectural development was adapted to the conditions and needs of the city of Cimahi, West Java province.

Our contribution to this research focused on adapting architectural development to cater to the specific conditions and requirements of Cimahi, a city in the West Java province. Cimahi is a city near Bandung, the capital of West Java. The BPS (Central Statistics Agency) of Indonesia projects that 571 people will live in the city of Cimahi in 2021. This population is expected to grow as a result of the city's growing economy, which is bolstered by its advantageous location, and the city's rising rate of newcomer migration, therefore data management is an issue for Cimahi City, particularly when it comes to data population. Currently, all the business processes related to population in Cimahi were organized in a single online system Dilanda which does not have any tracking system and lack of security control to ensure the accountability of data. Therefore to conquer this issue, we aim to establish an accountable and integrated system by implementing blockchain. The system will not only enhance security measures but also improve public services, aligning with the vision of a smart city.

A key aspect of our research was prioritizing the management of population data following the unique needs of Cimahi. We identified this as a crucial area to address, given its significance in shaping the city's policies and services. To achieve this, we undertook a meticulous analysis of the current business processes and population systems existing in Cimahi. This comprehensive understanding served as the foundation for the development of our proposed blockchain model architecture. In our approach, we emphasized the integration of population data management into the architectural design. By incorporating the specific requirements of Cimahi's population systems, our designed architecture became more tailored and realistic for implementation. This meticulous consideration of local needs ensured that our proposed model was not only innovative but also practical and feasible for the city's context.

In general, the structure of the article is structured as follows. Section I is an introduction that explains the background and contributions of the research. Section II is previous research related to the development of

blockchain technology in various fields. Section III is the method used in the research carried out. Section IV is a discussion that discusses the results of the research, and the last section is the conclusion of this research.

2. RELATED WORK

Blockchain technology has now become a very important technology in various industries and continues to develop rapidly in recent years. Bitcoin transactions were the first use of blockchain technology applied to a cryptocurrency system [23]-[24]. Several other implementations of blockchain technology that have currently been carried out to support smart cities include the application of online identity in smart city applications [25], the application of blockchain for medical records for patient health which can only be accessed by certain people [26], election process (e-voting) with the implementation of blockchain which makes the election process fairer and more democratic [27], e-government with the blockchain implementation [28]-[32].

In particular, the development of research related to the application of blockchain for digital identity still focuses on finding and identifying the challenges and limitations of blockchain for digital identity systems, which focuses more on the authentication process and is still very limited on its security aspects [33]-[36]. One of them is research conducted by Juan *et al.* [37] which implemented a blockchain model for electronic identity which was used for the document authentication process combined with biometric information to verify the ID owner. Research by Mudliar *et al*. [38] proposed a process of integrating national identity with blockchain technology so that it can be used in other applications such as banking and others. Jha *et al.* [39] proposed a framework that applies blockchain with each individual and government becoming an entity so that individual population registration can be carried out. Fathiyana *et al*. [40] proposed a design that adapts the electronic identity (SNI) scenario by implementing blockchain in Indonesia. However, what is proposed is still only a design that has not been implemented. While Fu, Y., & Zhu, J. have developed a comprehensive architecture designed to support comprehensive data security to be deployed in the smart city idea [41] and not focusing on population data management.

3. METHODS

The aim of this research is to develop a population system architecture by implementing blockchain technology to create an integrated population system to support the need for system accountability at the city level. The approach used to develop this architecture is to analyze the existing conditions of the population system in the city of Cimahi and alter the population system technology by applying the concept of blockchain technology. The city of Cimahi was chosen because this city is a small city that has implemented the smart city concept in its government.

The first thing to do is analyze and identify the current population system. The analysis process starts from analyzing the population system business processes that apply in the city of Cimahi in accordance with regulations and analyzing the population data architecture in the city of Cimahi as well as the system architecture.

The second thing is to conduct a literature study regarding the application of blockchain technology, namely regarding transaction models, data models and model architecture. The final process is to carry out technological alterations to the population system that applies in Cimahi City by applying Blockchain technology which produces transaction models, data models and population system model architecture that are adapted to the population process business needs and also system integration and accountability needs.

In general, the blockchain architecture development process was carried out through four steps which can be seen in Fig. 1.

The data used in this research was obtained from the results of Focus Group Discussion activities between the Cimahi city government and researchers. Apart from that, to strengthen the data, a literature study process was also carried out. However, it cannot be denied that this research also found several obstacles, especially in collecting population data. Because the city of Cimahi uses a centralized SIAK system, population data collection cannot be done freely. Centralized SIAK means that data collection must obtain permission from the central government.

Meanwhile, the tools and materials used in this research include VPS and non-relational databases. VPS is used to provide a remotely accessible platform that can be used for hosting websites, applications, or other online services. Meanwhile, non-relational databases (NoSQL databases) are used to handle large amounts of data, flexible data structures, and scale that can be scaled better than relational databases.

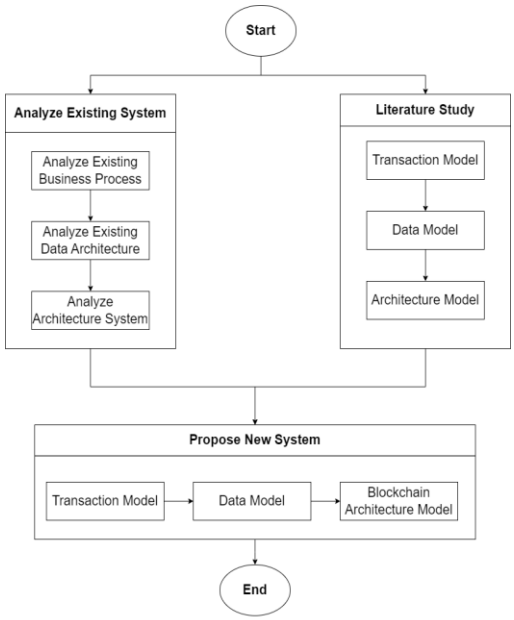

Fig. 1. The stages of the blockchain architecture development process

3.1. Analyze existing system

3.1.1. Analyze existing business processes

At this stage, an in-depth analysis of existing business processes in the environment that will be integrated into the blockchain system is carried out. This includes understanding the steps taken in current citizenship services.

3.1.2. Analyze existing data architecture

This step involves a review of the data structures and formats used in existing systems. This is necessary so that the data can be integrated into the new model that will be developed.

3.1.3. Analyze architecture system

This analysis focuses on the overall structure of the existing system, including the technological infrastructure used and how the system components interact with each other.

3.2. Literature study

3.2.1. Transaction model

This stage involves an in-depth study of relevant transaction models in blockchain technology. It covers how transactions are carried out, verified, and recorded in the blockchain network.

3.2.2. Data model

Conduct studies on data models suitable for use in blockchain environments. It includes optimal data structures to store and manage on the blockchain.

3.2.3. Architecture model

Study of various architectural models that suit the needs of developing new blockchain-based systems. This includes how to build the technical infrastructure that supports blockchain functionality.

3.3. Proposes New System

3.3.1. Transaction model

Formulate the transaction model that will be used in the new system. This includes a safer, faster and more efficient transaction process.

3.3.2. Data model

Design a data model that meets the needs of the new system, including the format and structure of the data that will be used and stored in the blockchain environment.

3.3.3. Blockchain architecture model

Making a technical architectural design that supports the implementation of a new blockchain-based system is carried out at this stage, including the blockchain infrastructure that will be used and integration with other system components.

4. RESULTS AND DISCUSSION

4.1. Existing business process

In general, the business process of the citizenship system in Cimahi City is shown in Fig. 2. Based on Fig. 2, the business process of the Cimahi city population and civil registration service is divided into 3 main blocks, namely management processes, main processes and supporting processes. In the business process diagram, there are 3 components involved, namely government, society, and stakeholders. The government will input infrastructure regulations, and this will produce accountability. The community will submit a service request, after submission the community will have or receive completeness and validity of the documents. Meanwhile, stakeholders can request data information and can submit requests. After the submission, stakeholders will receive the required data information through the application.

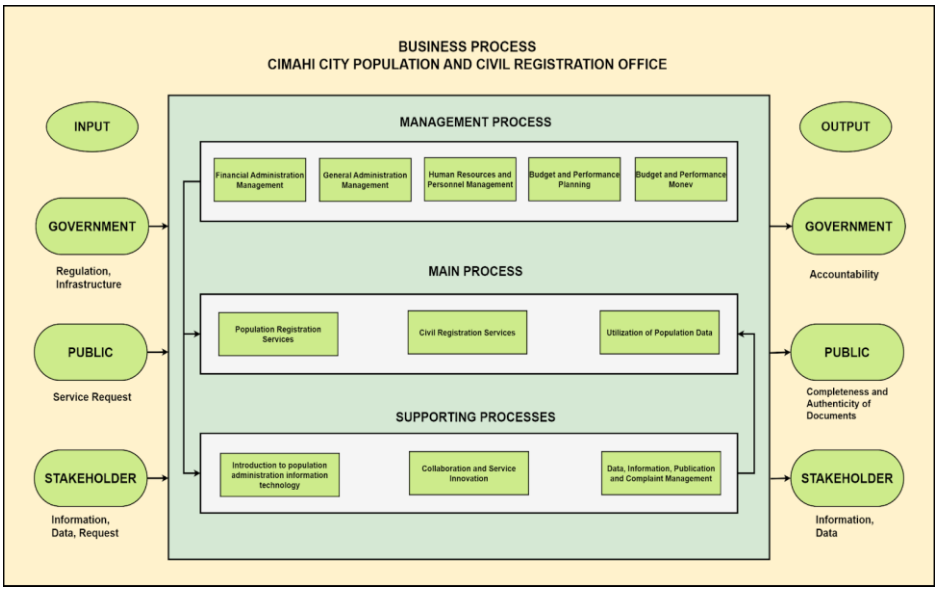

Fig. 2. Business processes for the population and civil registration services of the Cimahi city government (source: Cimahi city population and civil registration office)

Business progress shown in Fig. 2 are the current progress of recording and managing civil data, the main process generally interact directly with civilian as they input their data then go through the registration administration process and finally receive civil documents, management process mainly government involved process such as administration, verification and management process of the civil administration by city population and civil registration office, supporting process is involvement of other government branch to inquire or collaboration regarding civil data that has been collected, also technology that other parties created will be implemented in the supporting process. In general, the development of the main population system in Cimahi City only focuses on the main population processes, namely the population registration service process, civil registration services and population data utilization services. To support the main business processes shown in Fig. 2, the Cimahi city government uses two applications, namely centralized SIAK and the DILANDACITA population services application. A more detailed explanation for the citizenship data processing business is explained in Fig. 3.

In general, all population registration and registration services have relatively the same business processes (Fig. 3). What is different for each service is the data and document requirements that are required (see Fig. 4 and Table 1). Fig. 3 shows the complete activity that user can do and interact with the proposed system, activity diagram on the figures shows the flow of process in data that civilian submitted up until they receive newly signed documents, many actor and party are involved in the making of one document such as entry data officer, SIAK officer, head of sub division, head of division and head of citizenship service office. This step is necessary to ensure entries of data and the document to use in civilian administration is valid and verified.

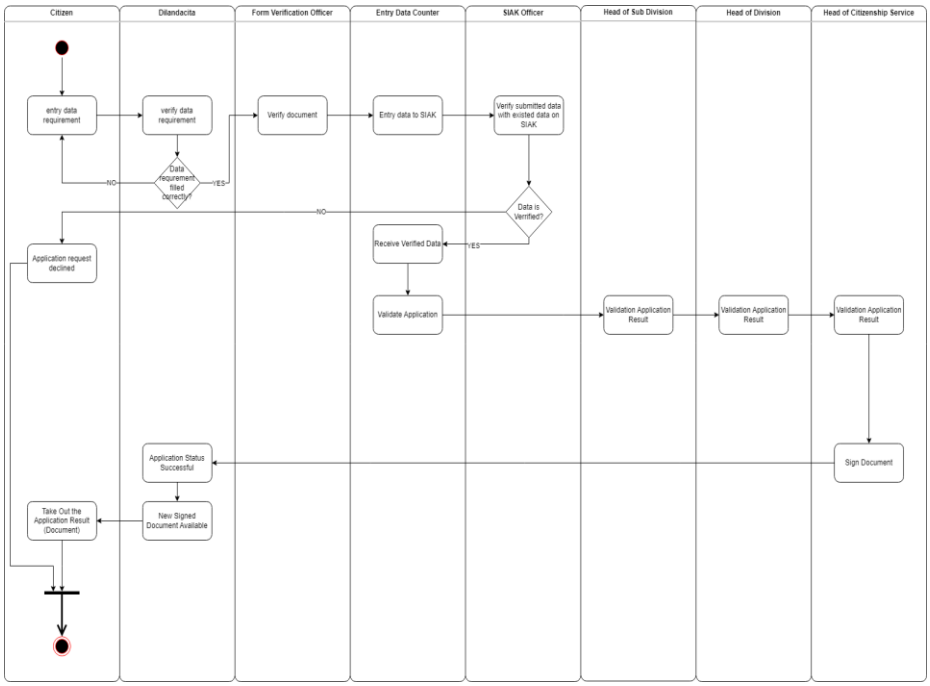

Fig. 3. Activity diagram existing business process

Table 1. Use Case for blockchain based citizenship system

Code	Use Case	Descriptions
UC01	Register Citizenship	Registration services consisting of: a. recording resident biodata. b. issuance of family identity ; c. issuance of identity card; d. issuance of child identity card . e. issuance of a residence certificate for registration of Population Events. f. data collection on vulnerable populations, population administration.
UC02	Record Citizenship Event	Civil registration services consisting of: a. Birth. b. stillbirth. c. Marriage. d. marriage annulment. e. Divorce. f. annulment of divorce. g. Death. h. adoption of a child. i. child recognition. j. child validation. k. change of name. l. change of citizenship status. m. Other Important Events. n. correction of Civil Registration deeds; And o. cancellation of Civil Registration deed.
UC03	Access Citizenship Data	Limited services for institution in local government (city)
UC04	Verify Application	Application document validation
UC05	Approve Application Result	Application document result approval
UC06	Hash Document Archive	Document archive hashing key calculation
UC07	Synchronize Data	Data synchronization from SIAK
UC08	Claim Document	Claimed document to citizen

Table 1 shows a description of each use case in the use case diagram. Based on Table 1, there are 8 use cases which are described in detail. Table 1 shows each use case that becomes the foundation of designing architecture, each use case represents a series of activities users can interact with the system. In the use case number 1 (UC01) is mainly citizenship document registration process of newborn or previously unrecorded citizen and will focused on feature to interact with civilian, use case number 2 (UC02) while similar to UC01, UC02 is for registered citizen to issue ID card, marriage and divorce documents and correction on their civil data, use case number 3 (UC03) is the process to access civil data for other government branch, UC04 is verifying submitted civil data to then administrator can issue new documents, UC05 is the process where head office of civil registration office will approve new civil documents, UC06 is the process of storing recorded civil data into a blockchain based architecture, UC07 is a process of synchronizing received data in branch office to the central office using a system called SIAK, use case 8 (UC08) is the final process where citizen can claim their newly signed civil document. Based on the use case diagram that has been designed, the system to be built is also depicted through the activity diagram shown in Fig. 5 – Fig. 8. Activity diagrams are created to describe the work flow or activities of a system, business process or menu in the software. The depiction of activity diagrams is similar to flowchart diagrams. There are four use cases depicted with activity diagrams, namely use case register (Fig. 5), use case record (Fig. 6), use case verify (Fig. 7), and use case validate and sign (Fig. 8).

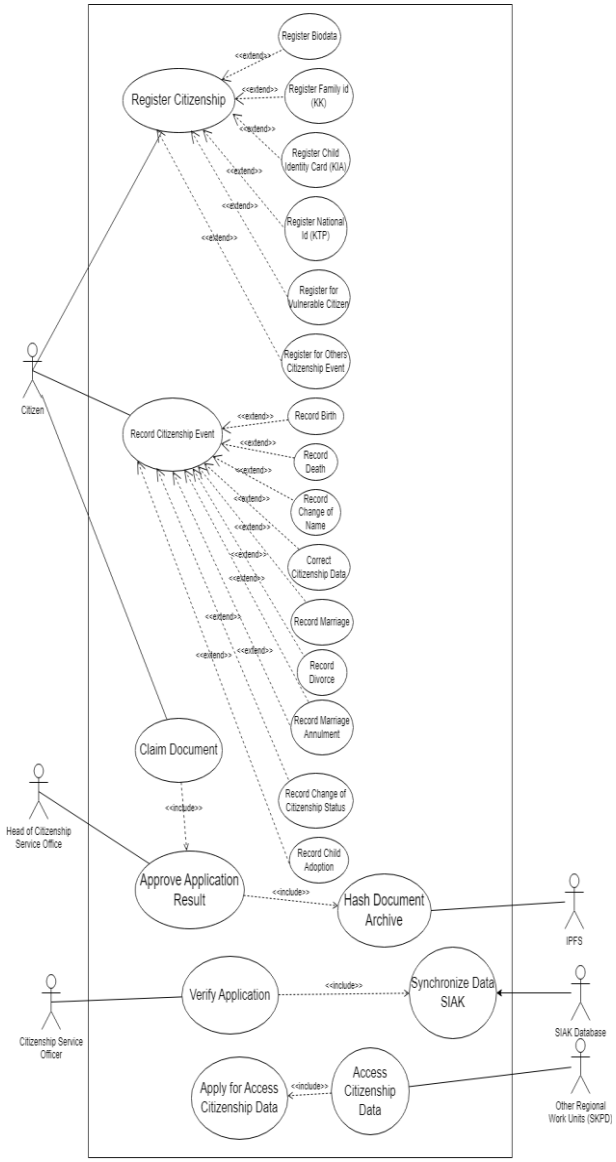

Fig. 4. Use case diagram for blockchain based citizenship system

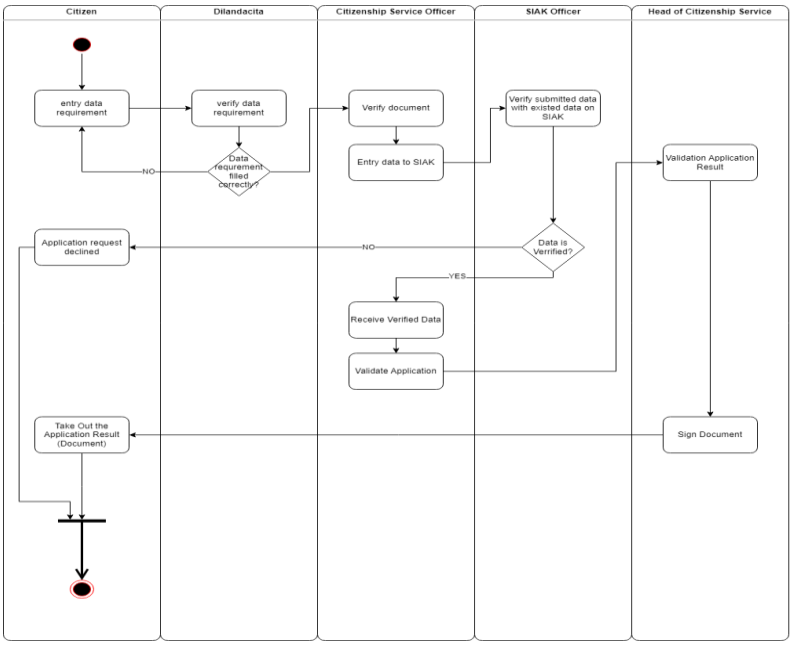

Fig. 5. Activity diagram for registering citizenship

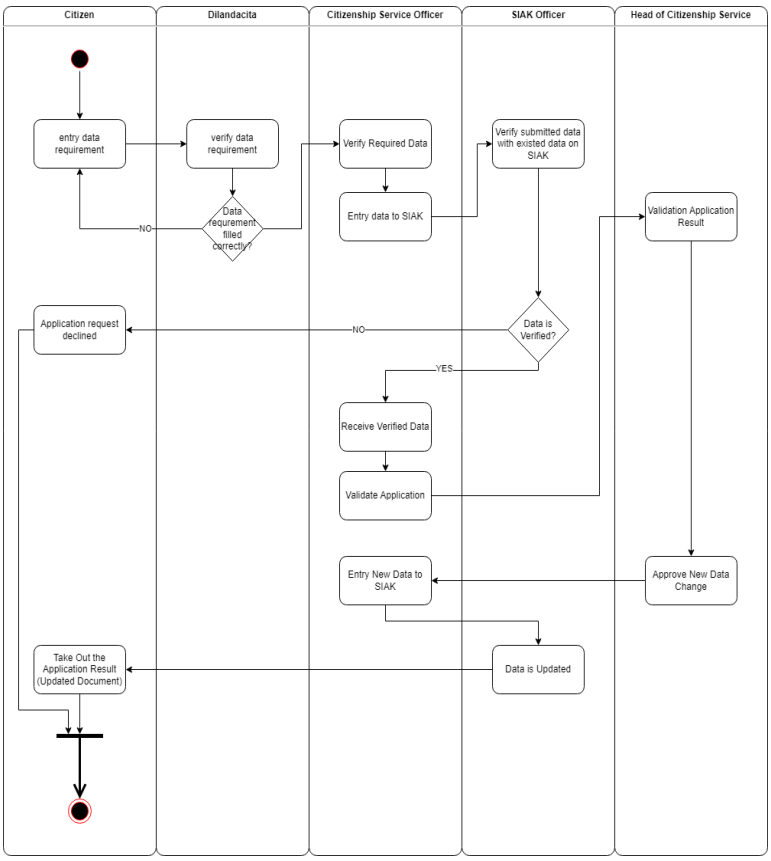

Fig. 6. Activity diagram for recording citizenship event

Fig. 5 shows activity diagram or flow of citizen application of citizenship document registration process of newborn or previously unrecorded citizen and will focus on features to interact with civilians. Citizen will insert their data and the system and 2 elements of officer will verify and validate submitted data to then the result will be a signed new document such as birth certificate by the head of citizenship service.

Fig. 6 shows activity for registered citizen to issue ID card, marriage and divorce documents and correction on their civil data, the entire activity is very similar to registering citizenship where citizen will have to submit their data and then get validated by officer with the output product are the requested document signed by head of citizenship office.

Fig. 7 shows how citizenship service officer and head of office verify and validate the submitted data by citizen as well as inserting those data to the blockchain based database, if all the required step is validated and accepted citizen then will receive their requested document.

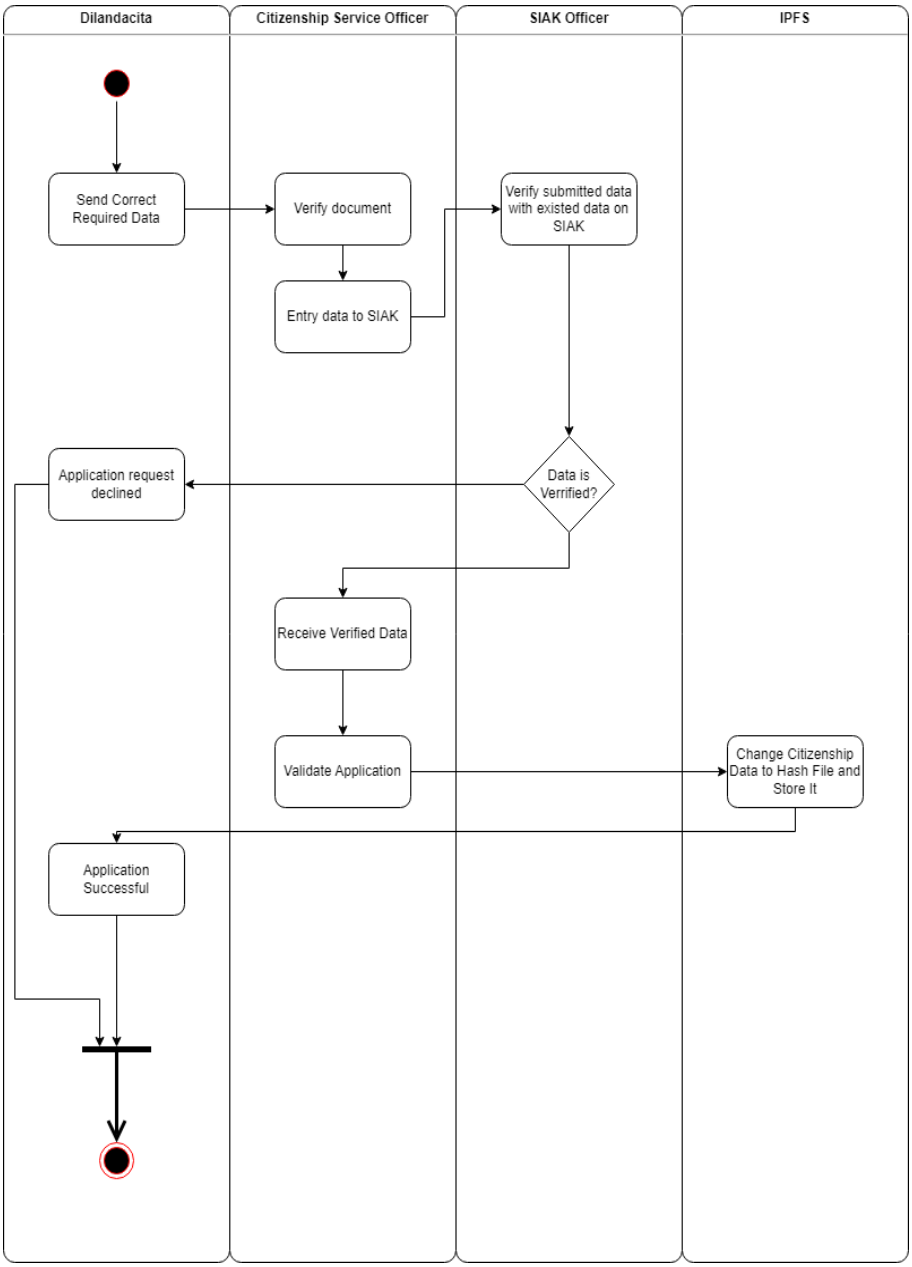

Fig. 7. Activity diagram for verify application

Fig. 8 shows the process of approval of new citizenship document application, after verifying document to the central government database, citizenship service officer then will send the data and the proposed document to the head of office where then it will be signed and printed.

Meanwhile, to describe a structure and relationships between objects in the system. This structure includes the attributes and methods in each class, so a class diagram is designed. The relationship between each class can be seen in Fig. 9.

Fig. 8. Activity diagram for approve application result

4.2. Proposed Design Model

4.2.1. Data Model

A block represents a family consisting of 1 or many people. a family has a family id and a publication date (see Fig. 9). so that the data that will be stored in the on chain is family data which is added with transaction data. Transactions in this case are population services in accordance with the use case in the population system. In a transaction it has an ID and other data adapted to the transaction, such as data on the date of change, verifier, validator and witness to the event that occurred. Key component on class diagram is the blockchain based class that is civil data, civil data will be stored in a separate database from the main system. Another key component is submission_data, this is a class that accommodate citizen when they are inputting their data, the output of the entire process is document class where signed document will be received by citizen. Other component are the identification of citizenship service officer, head of citizenship service, office data, user and other involved parties that support the entire system.

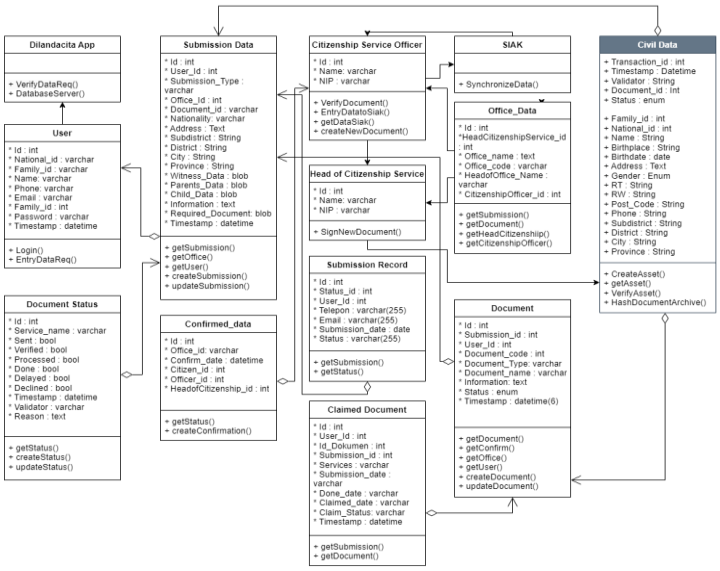

Fig. 9. Class diagram for blockchain based citizenship system

4.2.2. Transaction Model

Table 2 show Blockchain Assets, Transaction, Access Rights, and Stakeholders in the system population data management to realize a smart city in Cimahi based on blockchain.

Table 2. Blockchain Assets, Transaction, Access Rights, and Stakeholders

Assets	Transaction	Access Rights	Stakeholders
Register Citizenship Status	Register Biodata	Create	Citizen
	Register Family Id	Create	Citizen
	Register Nasional Id	Create	Citizen
	Register Child Id	Create	Citizen
	Register for Other Citizen Event	Create	Citizen
	Register for vulnerable citizen	Create	Citizen
Record Citizenship Event	Record Birth	Update	Citizen
	Record Death	Update	Citizen
	Record Marriage	Update	Citizen
	Record Divorce	Update	Citizen
	Record Marriage Annulment	Update	Citizen
	Record Adoption Child	Update	Citizen
	Legitimizing Child	Update	Citizen
	Record change of name	Update	Citizen
	Record change of citizenship status	Update	Citizen
	Correct Civil Registration Deed	Update	Citizen
Approve Application Result	Approve Document Result	Create	Head of Citizenship Service Officer
	Verify Document Validation	Create	Citizenship Service Officer
Verify Application	Calculate Hash Key for Document	Create	IPFS
Hash Document			
Access Citizenship Data	Access citizenship data	Read/View	Other Regional Work Units (SKPD)

Table 2 shows the transaction happening within the system, actor like user or citizen will involved in register and record citizenship status and event, citizen service officer will be involved in verifying application and hash document as well as granting access to other regional work unit, head of citizenship office will be involved in approving application result as well as approving access to citizenship data. Blockchain asset is the civil data as shown in Fig. 9 with people who have access right are the citizenship service officer and head of citizenship office, stakeholder that can use data with permission are other regional work units such as healthcare department, police and other government branchTransactions that occur in the system model developed start from transactions carried out in the front-end environment to data stored in backend applications that use the blockchain network**.** Fig. 10 shows population data processing transaction activities in a blockchain-based population system.

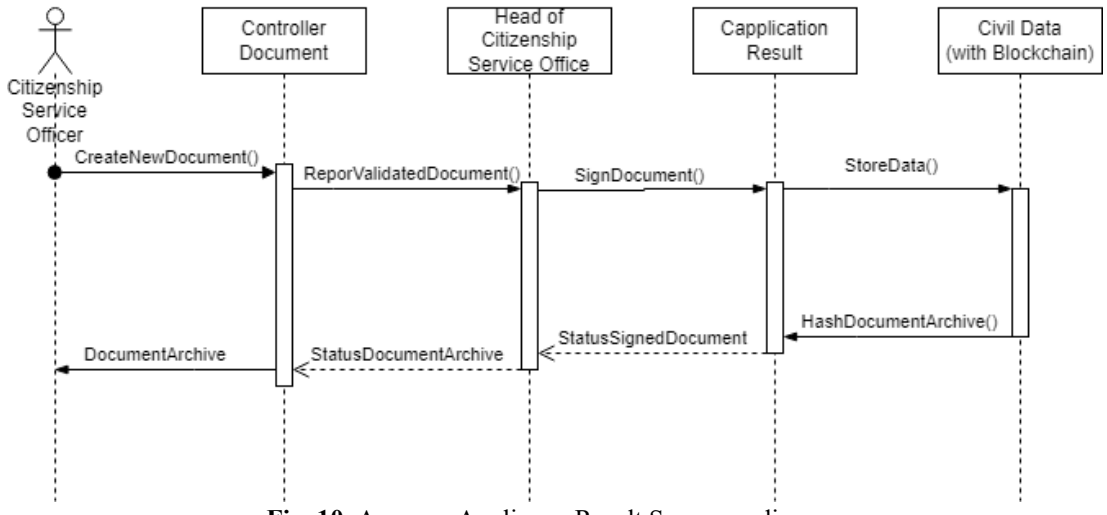

Fig. 10. Approve Applicaon Result Sequence diagram

4.2.3. Blockchain Architecture model

Based on an analysis of the conditions of population data management in the city, in accordance with existing regulations, the population data management process carried out by the city government, in this case the Cimahi City government, is limited to management for recording or registering population data. Meanwhile, the process of using population data is carried out centrally on a national scale. Therefore, the development of city management architecture carried out for cities in Indonesia is limited to management for recording or registration.

Based on Fig. 11, the main users of this population system are the community or residents who need public population services in Cimahi City, as well as the disdukcapil office and the SIAK system. Centrally owned by the Ministry of Home Affairs. The public can use this service by utilizing the DILANDACITA application belonging to the Cimahi City Dukcapil Office. The development of the DILANDACITA application is by integrating it with blockchain technology so that transparency and traceability of population public service data can be more trusted and secure. The system being developed will integrate previously existing services using an Application Programming Interface (API) which is the link between transactions in the application and the Blockchain environment being developed. Users will later get a digital identity that is generated in the blockchain environment and interact with smart contracts to obtain the required population services. The use of smart contracts is a fundamental requirement in Blockchain technology to ensure validation and verification of transactions before being stored in the Blockchain environment. The data model used will be based on the use of distributed data (on-chain transactions) where data is stored and replicated on each node in the Blockchain network, as well as on conventional databases. This is done so as not to burden the work of the Blockchain network.

The proposed design, integrating blockchain and IPFS into the population data collection system for Cimahi, directly addresses several challenges identified in the existing business processes. By leveraging blockchain, the system ensures immutability, transparency, and decentralization, enhancing the integrity and security of population data. This aligns with the research objective of establishing a tamper-proof and trustworthy record-keeping system for citizenship registration. Moreover, the integration of IPFS seamlessly improves data accessibility and storage efficiency, addressing the challenges of centralized data storage and potential bottlenecks in the current system. The proposed model builds upon the existing system by providing a more robust and resilient infrastructure that mitigates the risks associated with data manipulation or unauthorized access.

The transition from the existing business process to the proposed design model is streamlined by integrating blockchain and IPFS into the data storage and management layers. This ensures a smoother and more secure registration process, reducing the chances of data discrepancies or unauthorized alterations. The decentralized nature of the proposed model decentralizes the authority over data, mitigating the limitations of a centralized system and enhancing overall system reliability. Additionally, the improved transparency and accessibility contribute to a more efficient citizenship registration process, addressing the limitations identified in the analysis and providing a foundation for a modernized, secure, and decentralized population system in Cimahi.

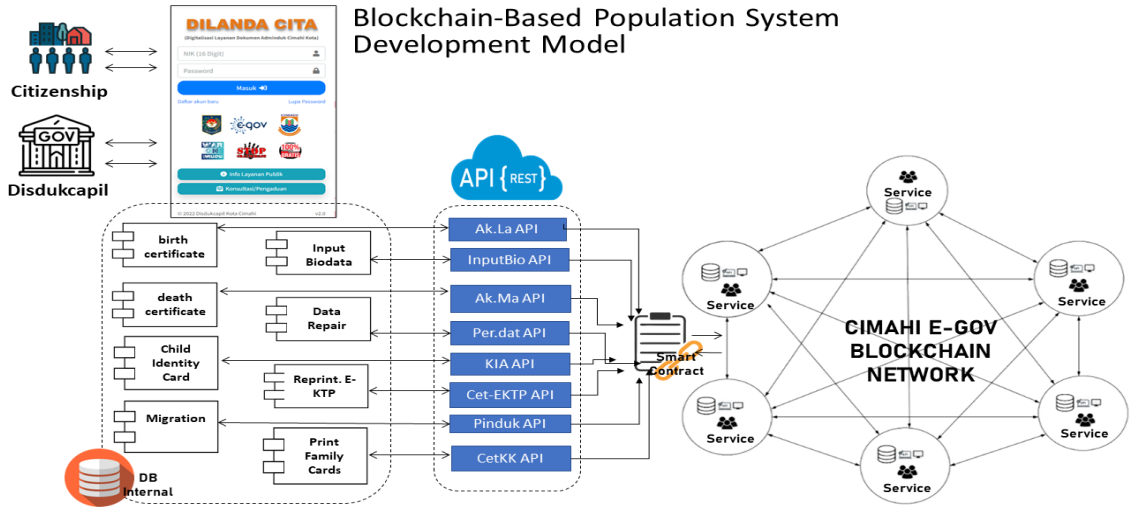

Fig. 11. Blockchain Architecture for Citizenship Data in Cimahi

The choice of blockchain technology in the system being developed requires compatibility with current business processes. Choosing a platform is important, so that the system can run well and provide optimal performance. Table 3 shows blockchain platforms that can be a solution for developing a blockchain-based population system [25].

Table 3. Type of blockchain system [42]

Property	Public	Private	Consortium
Consensus	All nodes	All nodes in organization	Selected set of nodes
Permission	Public	Could be public or restricted	Could be public or restricted
Efficiency	Low	High	High
Process	Permissionless	Permissioned	Permissioned
Access	Anyone	Single organizations	Multiple organization
Participants	Anonymous	Known identities	Known identities
Security	Consensus mechanism, and proof of work/proof of stake	Pre-approved by organization, and voting/multi-party consensus	Pre-approved by consortium, and voting/multi-party consensus
Speed	Slow	Lighter and faster	Lighter and faster
User capacity	millions	Dozens to few hundreds	Hundreds of thousands;

The integration of IPFS with the blockchain system for Cimahi's population data collection ensures data immutability, transparency, and decentralization, Utilizing IPFS aligns with the current flow of citizenship registration by decentralizing data storage, ensuring accessibility, and enhancing data integrity, which facilitates a transparent and secure registration process for citizens in Cimahi. Details about this system can be seen in Fig. 12 and Fig. 13.

In Fig. 12 we are shown by how on-chain and of-chain storage of document works, first the archived data through website sill be process and then stored in IPFS protocol to be mapped and ready to be hashed and stored in blockchain database, data then will be identified by smart contract before stored in a block.

Fig. 13 shows how system approval flow. After citizen input their data citizenship service officer will validate and verify the data, SIAK officer then will do the same thing but with existing data in central government database, after the data is validated head of citizenship service then will sign the document and citizen can receive the requested document.

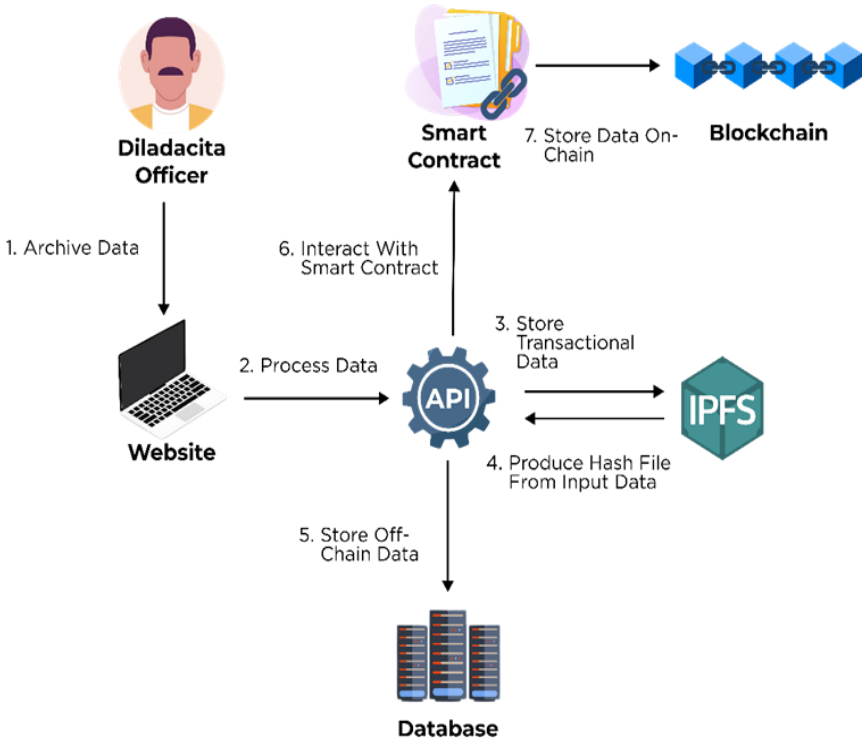

Fig. 12. On-chain and off-chain storage

The following is an explanation of the flow shown by Fig. 12.

1. DILADACITA Officer archive document data.
2. API process the data.
3. IPFS uses to store transactional data.
4. IPFS produce hash file from input data.
5. Store off-chain data on database.
6. API interacts with smart contract.
7. Smart contract store data on-chain on blockchain through consensus mechanism.

The following is an explanation of the flow shown by Fig. 13.

1. Citizen register citizenship and citizenship event data
2. Website show submitted citizenship and citizenship event data to DILADACITA Officer.
3. Dilandacita officer confirm the congruity of submitted data with format.
4. Website show submitted citizenship and citizenship event data to SIAK Officer.
5. SIAK officer search for related existed data.
6. SIAK officer compare the submitted data with existed data.
7. SIAK officer confirm the congruity of submitted data with existed data in SIAK Database.
8. Website show document to Head of Citizenship Service.
9. Head of Citizenship Service sign and upload the signed document.
10. Website show confirmation about completed registration process and receive.

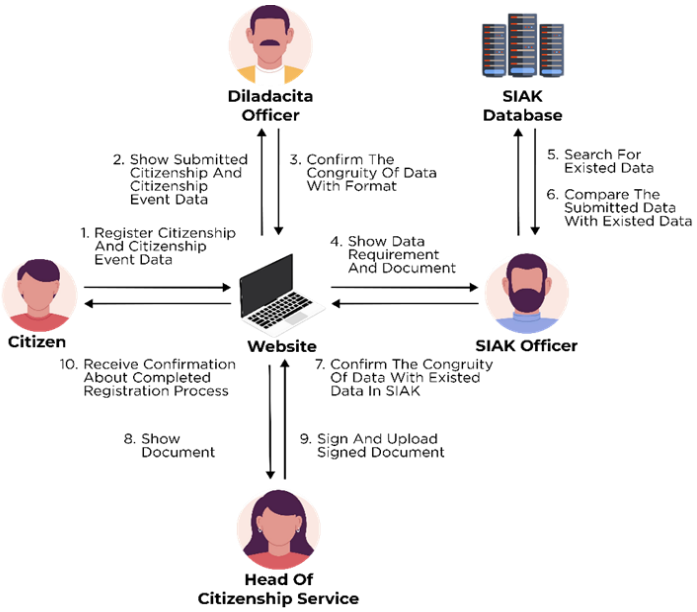

Fig. 13. System approval flow

5. CONCLUSION

The development of a citizenship blockchain architecture in Cimahi through the integration of DILANDACITA as a citizenship in the city of Cimahi offers a solid foundation for subsequent research. The use of APIs as a link between transactions in applications and the Blockchain environment is a step forward that allows integration of previously existing services. This integration not only allows unification of legacy services, but also improves overall system functionality and efficiency. Users will later obtain a digital identity generated in the blockchain environment and interact with smart contracts to obtain the necessary population services. Please note, users in this research are categorized into 3 categories, namely citizens, officers, and the National Population Services System (SIAK), these three users have specific roles in this system. Citizens use digital identities to access services, officers are responsible for carrying out administrative processes, while SIAK plays a role in broader system integration.

These conclusions pave the way for new theoretical developments that contribute to this domain. However, it is important to note that this research has limitations, especially in terms of practical implementation and scalability in broader environments. Future research prospects may include further monitoring and evaluation of the security and efficiency of the system, as well as detailed research on the interactions between users, smart contracts and blockchain systems in the context of population services.

This research shows the successful integration of DILANDACITA into the blockchain environment for citizenship services, building digital identities for users and efficient interaction with smart contracts, contributing to the concept development and practical implementation of blockchain-based citizenship systems. Smart contracts play a role in facilitating and automating the services required by users, creating more efficient and trusted processes.

Overall, this article provides an important foundation for the development of blockchain-based citizenship systems. Its contribution lies in combining advanced technologies with public services to create secure and efficient digital identities for citizens as well as contributing to the theoretical understanding of blockchain applications in the context of public administration.

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