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Blockchain-Based Digital Identity Framework for Trusted e-Governance

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ABSTRACT

The digitalization of government services has increased the efficiency, accessibility and transparency of public administration, with an impact on the speed of change. Government service digitalization has increased the efficiency, accessibility and transparency of public administration, which affects the speed of change. But traditional digital identity management systems still have a lot of issues to overcome, such as centralised data storage, identity theft, unauthorised access, data tampering, privacy breach, and inadequate interoperability between government departments. These issues erode citizens' confidence and affect the safe and secure service delivery of e-Governance. A decentralized, immutable, transparent and cryptographically secure platform for identity management has emerged in the form of blockchain technology. Blockchain-based digital identities give citizens more control over their personal data and allow existing governments to provide secure digital identities and trusted authentication for information sharing between governments and individuals. The paper provides a detailed research on Blockchain-Enabled Identity Systems for Secure e-Governance by exploring various aspects of blockchain-based identity systems, including technologies, components, authentication mechanisms, and security features, which contribute to secure e-governance. The proposed framework combines Distributed Ledger Technology (DLT), smart contracts, cryptographic verification, permissioned blockchain networks, and decentralized identity management to create a secure identity infrastructure for public service delivery. Additionally, the paper explores the opportunities and prospects of blockchain for improving data integrity, transparency, accountability, and efficiency, and curbing fraud and administrative burden. The proposed framework clearly shows how a blockchain-based identity system can play a significant role in strengthening citizen-centric governance, especially when it comes to improving authentication accuracy, safeguarding sensitive information, simplifying the cross-departmental verification of citizens' identities, and enabling secure digital transformation initiatives within modern governments.

KEYWORDS

Blockchain, Digital Identity, E-Governance, Distributed Ledger Technology, Smart Contracts, Identity Verification, Decentralized Identity, Cryptography, Cybersecurity, Digital Government.

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1. INTRODUCTION

1.1. Background

Secure and efficient Digital Governance is crucial as the volume of digital governance grows at a fast pace. Sensitive citizen data like biometric, demographic, health, financial, education, tax, and legal files is stored and handled in vast quantities by government agencies on an ongoing basis. Traditional identity management systems are based on centralized databases, with a database that is controlled by one authority, holding identity storage and verification. While these systems make administration easier, they can be subject to cyber attack, data breaches, identity theft, and single points of failure. Additionally, disjointed government databases can create a hassle for citizens who may have to fill out paperwork multiple times to verify their identity and information, causing delays and inefficiency in government processes. Here, blockchain technology comes into place, offering a decentralized and tamper-proof solution to the management of digital identities. Through cryptographic hashing, distributed consensus, and immutable ledger technology, blockchain ensures data integrity, transparency, and secure identity verification. Permissioned blockchain networks can also improve the regulatory compliance as only authorized government agencies can be part of it, making blockchain based identity systems a potential base of secure, transparent and citizen-centric e-Governance.

1.2. Need for Blockchain-Enabled Identity Systems in Secure e-Governance

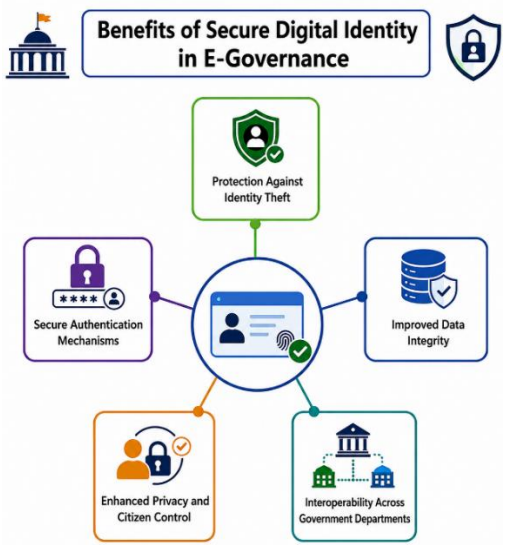

Fig 1 - Need for Blockchain-Enabled Identity Systems in Secure e-Governance

1.2.1. Protection against Identity Theft

Because of the growing number of cyberattacks against the centralized government databases, identity theft has emerged as a major challenge in digital governance. Unauthorized access to personal confidential data can lead to financial fraud, impersonation and misuse of citizen's identities. Blockchain technology solves this problem by having identity transactions recorded on an inviolable distributed ledger, where records can't be changed without consensus of the network. Utilizing cryptographic hashing, digital signatures and decentralized verification increases security

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by making it very hard to manipulate the identity, and consequently gives better protection from identity theft.

1.2.2. Secure Authentication Mechanisms

For the effective access of digital government services, reliable authentication is critical so that only legitimate citizens have access to them. The traditional authentication methods typically rely on centralized identity providers, which can introduce security risks or single points of failure. Blockchain authentication technology is a combination of the cryptographic public-private key infrastructure, decentralized identity verification, and smart contracts which are used to provide secure and efficient authentication of users. This will help lower the likelihood of unauthorized access, build trust in digital services and facilitate seamless authentication between various government applications.

1.2.3. Improved Data Integrity

Government records must be kept in good order to guarantee accurate and credible government administration. By storing each identity transaction in an immutable, distributed ledger in chronological order, Blockchain helps to ensure data integrity. Cryptographic hash functions are used for each transaction and ensure that unauthorized changes are quickly identified. Through this tamper-resistant design, identity data is kept accurate, consistent and always verifiable and can be audited and monitored by the government.

1.2.4. Enhanced Privacy and Citizen Control

Citizen privacy protection has been given the fundamental requirement of modern governance in the digital era. Blockchain-based identity systems enable people to take control of how their information is accessed and shared. Decentralized identifiers (DIDs), encrypted credentials and selective disclosure mechanisms enable citizens to share only the information they need to offer a service without divulging unnecessary personal data. This citizen-centric approach boosts privacy protection, reduces data exposure, increases user trust, and facilitates adherence to contemporary data protection laws.

1.2.5. Interoperability Across Government Departments

Government agencies may have different information systems, making it complex and challenging to reach secure identification across different agencies. Blockchain is a single, decentralized identity infrastructure that allows trusted information sharing between authorized government organizations. Standardized protocols and a distributed ledger can enable the secure verification of citizen identities by departments such as health, tax, education, social welfare, land administration and immigration without the need for re-submitting documents. This interoperability will provide administrative efficiency, eliminate record duplication, speed up public service delivery and boost the collaboration throughout e-Governance chain.

ISSN: 3071-5628
PP: 01-15.

1.3. Blockchain-Enabled Identity Systems for Secure e-Governance

By combining distributed ledger technology, decentralized authentication, cryptographic security, and smart contract automation, blockchain-based identity systems have emerged as a revolutionary solution in the realm of e-Governance, offering a comprehensive and innovative approach to identity management in the digital age. Blockchain eliminates single points of failure by storing identity records across many government entities with authorisation, which enhances system security, transparency and reliability, unlike traditional identity management systems with centralized databases controlled by a single entity. Each identity related transaction is validated and settles on an immutable distributed ledger by consensus, which ensures that the identity records are accurate, tamper-proof and fully auditable during their lifespan. This distributed design helps mitigate risks like cyber attacks, unauthorized data changes, identity theft, and database failures – which are frequent in centralized systems. In an identity ecosystem based on blockchains, every citizen has his or her own decentralized digital identity based on a set of cryptographic public and private keys that allow him or her to be securely authenticated and digitally signed. Authorized government agencies collect identity documents and biometric data during the registration process and create trustworthy digital credentials. The blockchain does not store any sensitive data directly on the network - only cryptographic hashes, DIDs, and metadata for verification, and sensitive information is securely stored in a digital wallet or government repository that is encrypted. Smart contracts automatically handle identity verification, credential issuance, authentication, authorization, credential renewal, credential revocation, and access control based on pre-defined governmental policies, minimizing the man-days spent on identity verification, issuing and managing credentials, and access control. In addition, the blockchain-based identity systems ensure secure interoperability between the different government departments, such as the healthcare, taxation, education, social welfare, immigration, judiciary, municipal administration and land management departments. This allows for the secure validation of citizens' identity by authorized agencies using a shared permissioned blockchain, without the need to submit documents repeatedly or have multiple identity databases. Selective disclosure mechanisms also give citizens more control over their personal information by enabling only certain attributes of their identity to be disclosed when a citizen seeks service. As a result, blockchain based identity systems offer tremendous cybersecurity, operational efficiency, transparency, accountability, privacy protection and citizen confidence, and provide a foundation for the next generation of digital governance and sustainable public service transformation, one that is secure, scalable, and citizen-centric.

2. LITERATURE SURVEY

2.1. Conventional Digital Identity Management Systems

Conventional digital identity management systems are based on centralized databases controlled by government agencies or trusted authorities. These systems enable citizens to register, verify identity and use various public services using passwords, digital certificates, Public Key Infrastructure (PKI), multi-factor authentication, etc. While centralized systems have streamlined administration and services delivery, they have many drawbacks, such as cybersecurity risks, risk of single points of failure, privacy concerns, and lack of interoperability among government

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PP: 01-15.

departments. The problems have spurred scholars to explore decentralized alternatives that provide higher levels of security and citizen control of personal data.

2.2. Blockchain-Based Identity Management Frameworks

Blockchain based identity management systems are systems which use blockchain technology to deliver secure, transparent and tamper-proof identity services. Whereas in blockchain, the data is held on multiple authorized participants, each holding a copy of the identity data, which ensures data integrity and lowers the possibility of unauthorized changes. The smart contracts are designed to automate the identity verification and credential validation process, minimizing manual intervention and enhancing efficiency. Additionally, permissioned blockchain networks offer a good combination of decentralization and compliance, making them well-suited for e-Governance applications, as well as for government agencies to share information securely. Despite these benefits, there are still ongoing research questions about scalability, interoperability, and optimizing storage.

2.3. Self-Sovereign Identity and Decentralized Identity Frameworks

Self-Sovereign Identity (SSI) is a citizen-centric solution for digital identity management, empowering them to own, manage, and control their personal identity information without relying solely on centralized authorities. Decentralized Identifiers (DIDs) and cryptographic proofs are stored and distributed across the blockchain, while sensitive personal data remains securely in users' encrypted digital wallets. By allowing citizens to selectively share their data when necessary, using Verifiable Credentials, trusted organizations can provide citizens with digitally signed credentials and limit unnecessary disclosure of data, thereby increasing privacy. Using advanced privacy-preserving methods like Zero-Knowledge Proofs enhances privacy even more. But, challenges such as interoperability, governance, legal recognition and secure key recovery have yet to be resolved to enable widespread use.

2.4. Research Gap

While there is significant progress in the realization of blockchain-based identity management and decentralized authentication, there are still some research gaps to be addressed before blockchain can be allowed to roll out in national e-Governance systems to a larger extent. Existing research tends to be on single identity applications not on integrated government-wide identity ecosystems that can support multiple public services. Other factors to consider are lack of scalability, integration of non-uniform government platforms, privacy protection, governance policies, and regulatory compliance. In addition, the combination of blockchain and emerging technology like Artificial Intelligence, cloud computing, Internet of Things (IoT) and biometric authentication is not fully explored. Thus, a need exists for a comprehensive blockchain-based identity management solution that can integrate decentralized identity, smart contracts, cryptographic security, and interoperability with various identity verification methods to facilitate secure, scalable, and citizen-centric digital governance.

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PP: 01-15.

3. METHODOLOGY

3.1. Identity Registration and Verification

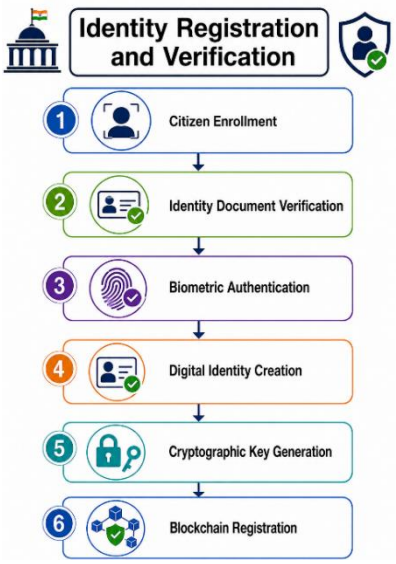

Fig 2 - Identity Registration and Verification

3.1.1. Citizen Enrollment

The first step in the process of identity registration is citizen enrollment, in which a person gives their personal information to the government authority that has been approved to create their digital identity. Basic demographic information like name, date of birth, gender, residential address, contact details and other mandatory information is gathered via digital registration portals that are secured or government service centers. To avoid duplicate registrations and proper identity management, each applicant will be given an individual enrollment ID. The information entered is checked before moving on to further information checks, thus laying the groundwork for a secure digital identity in an e-Governance system powered by blockchain technology.

3.1.2. Identity Document Verification

The citizen enrolment process is followed by a thorough verification of the identity documents submitted, which is carried out to ensure their authenticity and validity. Documents like passports, national identity cards, birth certificates, driving licenses and proof of residence are checked against official government records by government officials. Computerised verification tools can also be used to identify falsified or tampered documents. Successful verification means that only those who are citizens will be issued with digital identities, which reduces identity fraud and increases the trustworthiness of the e-Governance identity management framework.

3.1.3. Biometric Authentication

Biometric authentication enhances the identity registration system by requiring verification of the physical attributes of each citizen. These data are captured safely with the aid of certified biometric devices and matched with the existing government records, if available. Biometric attributes are unique to each person and offer a very reliable way to verify identity, and greatly minimise the risk of identity theft or duplicate enrolment. Biometric information is protected while in

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PP: 01-15.

transit and when stored, using secure encryption methods, in order to ensure citizen security and privacy.

3.1.4. Digital Identity Creation

A decentralized digital identity is created after successful verification of the person's personal data and biometric information. This digital identity has a unique decentralized identifier (DID) which constitutes the citizen's trusted identity in the blockchain network. Instead of keeping sensitive personal data on the blockchain, only encrypted identity references and cryptographic proofs are stored with confidential data still securely held in authorized repositories or digital identity wallets. This not only helps to protect citizens' privacy, but also allows them to verify their identity securely and give greater control over their personal information.

3.1.5. Cryptographic Key Generation

For secure authentication and data protection the system provides each citizen with a pair of cryptographic keys. The private key will only be known to the citizen for digital authentication and electronic signatures, while the public key will be used for identity verification and secure communication. Advanced cryptographic algorithms make it safe only the authorizations are allowed to access or approve the transactions connected with the identity. Public-key cryptography enhances the security and reliability of the transmission of confidential information, integrity and the inability to repudiate, which makes it very difficult to access the information without authorization or manipulate the identity of the sender.

3.1.6. Blockchain Registration

The last phase of the identity registration process is the actual registration of the verified digital identity on the permissioned blockchain network. The blockchain does not store details of personal information, but rather identity hash, decentralized identifiers, public keys, timestamps, and transaction metadata, which are all encrypted. The transactions are verified by the blockchain consensus mechanism before they are recorded on the distributed ledger. This non-tamperable registration process guarantees security, transparency, and efficiency, allowing trusted identity verification across different government agencies, while simultaneously providing a clear audit trail and safeguarding against unauthorized changes.

3.2. Blockchain-Based Identity Management Architecture

The proposed Blockchain Based Identity Management Architecture aims to ensure a secure, transparent, decentralized and scalable solution for the management of citizen identities in contemporary e Governance systems. Architecture comprises several layers that are interconnected and operate together to assure trusted identity registration, authentication, authorization and secure sharing of information between government departments. At the bottom-end, Citizen Interaction Layer allows citizens to register their identities, submit official documents, update personal data and access different government services through secure web portals, mobile applications or government service centers. The information gathered is sent to the Identity Verification Layer, where it is used to

ISSN: 3071-5628
PP: 01-15.

verify identity documents, to do biometric authentication, and to validate the authenticity of citizen credentials with one or more government databases. After successful verification, the Digital Identity Management Layer generates a unique decentralized digital identity (DID) and securely generates cryptographic public-private key pairs for each citizen who registers. Then, the architecture uses a Blockchain Network Layer with permissioned blockchain nodes operated by trusted government entities to provide consensus for identity transactions, upon which the encrypted identity hashes, digital signatures, timestamps and transaction metadata are permanently recorded on the distributed ledger. Only cryptographic evidence, not complete personal data, is being stored on the blockchain, thus, the privacy of citizens is effectively maintained, and data is preserved as either being true or being immutable. On top of this, the Smart Contract Layer automates the identity verification, credential issuance, authorization, access control, identity update and revocation process in line with government pre-defined policies, without manual intervention. Lastly, the Government Service Integration Layer enables secure citizen identity verification from multiple public sector entities, such as healthcare, taxation, education, social welfare, land administration, immigration and law enforcement, by relying on standardized blockchain interfaces, without the need to hold multiple identity databases. The proposed multi-layered architecture greatly improves interoperability, reduces identity crime, removes duplication in verification processes, boosts cybersecurity, makes it easier to maintain transparency, and empowers citizens to have more control over their personal information while making delivery of digital government services more efficient, reliable and trustworthy.

3.3. Smart Contract-Based Authentication Framework

Once identities are registered, blockchain smart contracts are used to run authentication requests in an automated manner, without the need for central authorities to verify and authorize. A smart contract is a program that is deployed on a permissioned blockchain and has an embedded set of authentication rules, access control policies, and verification procedures set by authorized government agencies. Whenever a citizen tries to access an e-Governance service, the citizen's decentralized identifier (DID), cryptographic credentials, and digital signature are sent to the blockchain network with an authentication request. The smart contract automatically checks the credibility of the submitted certificates by comparing the cryptographic evidence with the identity records that are taken from the blockchain, which are not subject to tampering and are guaranteed to be accurate. In this process, the digital signature is checked with the citizen's public key, and where necessary, biometric authentication or multi-factor authentication can be done as an extra security step. Once all the authentication conditions are met, the smart contract provides access to the desired government service and logs the successful authentication onto the blockchain ledger. Inconsistencies in the credential, expired credentials, revoked credentials, unauthorized access attempts are all detected, the authentication request is rejected immediately, the transaction is logged for audit and security analysis permanently. As each authentication is a permanent immutable blockchain transaction, government agencies get full transparency, accountability and traceability of all activities related to the identity. Smart contracts executed in a decentralized manner simplify the verification process, speed up the execution, ease administrative burden, and deter unauthorized changes of

ISSN: 3071-5628
PP: 01-15.

authentication data. In addition, smart contracts allow for secure collaboration between different government departments, by offering a shared authentication system with standardized blockchain interfaces. This is because various public service organizations like healthcare, taxation, education, social welfare, land administration, immigration and other agencies can verify citizen identity efficiently without having to keep redundant identity databases. The proposed smart contract-based authentication system, therefore, contributes to the robust cybersecurity, reliable services, privacy protection for citizens through cryptography, identity fraud prevention and quick, transparent and trustworthy authentication in modern e-Governance based on blockchain.

3.4. Performance Evaluation

Various security and operational performance parameters are used to assess the proposed blockchain-based identity management framework to evaluate its effectiveness in securing, ensuring reliability and efficient delivery of identity management services for e-Governance services. The evaluation focuses on key parameters including authentication accuracy, identity verification time, transaction throughput, response time, privacy protection, data integrity, scalability, interoperability, and resistance to cyberattacks. The accuracy of authentication refers to the framework's success in authenticating citizens accurately and in stopping illegal attempts at authentication. Identity verification time is the assessment of how much time it takes to verify identities and allow access to government services, which means that the system being proposed must facilitate real-time service delivery. Transaction throughput measures how many transactions related to identity (including registration, authentication, credential updates, etc.) can be served over a certain amount of time. Response time refers to how efficient smart contract operations are when it comes to authentication requests and blockchain validation. The security of the framework is assessed by its resistance to identity theft, replay attacks, data tampering, unauthorized modifications, and distributed cyberattacks, via the use of cryptographic protection and decentralized consensus mechanisms. The success of decentralized identifiers, encrypted credential storage, selective disclosure and secure cryptographic authentication at preserving sensitive citizen information is measured in assessing privacy preservation. Data integrity is achieved by making sure that once after an identity record is written to the blockchain ledger, it cannot be changed. The scalability analysis captures the ability of the permissioned blockchain network to accommodate and handle more citizens and a higher volume of authentication requests with little or no performance impact. Interoperability assesses ID sharing between multiple government departments using standard interfaces to blockchains and smart contracts, to eliminate the need for redundant identity verification processes. Furthermore, the efficiency is evaluated based on administrative workload, service processing time, transparency and auditability in comparison to traditional centralized identity management systems. The overall assessment shows that the proposed blockchain-based framework offer a great improvement of the reliability of authentication, boost cybersecurity, protect citizen's privacy, mitigate identity fraud, boost transparency and provides faster and more efficient identity management service. The overall results of these performance measures demonstrate the effectiveness of the proposed framework for the design and implementation of secure, scaleable and citizen-centric digital identity management in modern e-Governance environments.

ISSN: 3071-5628
PP: 01-15.

4. RESULTS AND DISCUSSION

4.1. Experimental Setup

In order to assess the capability of the proposed blockchain based identity management framework to provide secure, transparent and efficient identity management in e-Governance ecosystem, it was implemented within a permissioned blockchain environment. The experimental architecture comprised several blockchain nodes for authorized government departments: healthcare, taxation, education, social welfare, land administration, and immigration. Dogs collaborated to maintain the distributed ledger and to validate identity-related transactions using a consensus mechanism known as Practical Byzantine Fault Tolerance (PBFT), which ensured fault tolerance and speedy transaction confirmation. In the course of experimentation, fictional citizen records were established and for each citizen a Decentralized Identifier (DID) was issued along with a couple of cryptographic public and private keys for secure authentication and digital signature verification. Sensitive personal data is safely kept off-chain in secure vaults, and only the cryptographic hash values, decentralized identifiers, timestamps and transaction data are permanently recorded on the blockchain to maintain data integrity and privacy. Smart contracts have been created and put into place in order to automate the registration of identities, verification and validation of credentials, authentication, updating identities, and authorizing access to the identity without the need for manual intervention. All authentications were made via these smart contracts, which checked digital signatures, verified cryptographic credentials, and allowed only verified citizens to access. Vibrant communication channels, encrypted data transfers, public-key infrastructure (PKI), and blockchain audit trails also formed part of the experimental environment, enhancing the system's overall cybersecurity. Several security and operational measures were used for the performance evaluation, such as authentication accuracy, identity verification time, transaction throughput, response time, fraud detection capability, privacy preservation, interoperability between government departments, scalability, data integrity and service efficiency. The proposed framework was systematically compared to a conventional centralized identity management system under similar conditions to show the effectiveness. The comparative analysis concentrated on enhancements in authentication reliability, susceptibility to cyber attacks, transparency, auditability, administration workload and efficiency on service delivery. The experimental results proved that the amalgamation of permissioned blockchain, smart contracts, cryptographic security mechanisms, and decentralized identity management greatly improves the security, scalability, and trustworthiness, while also improving the performance of modern e-Governance identity management systems.

4.2. Performance Comparison

Table 1: Performance Comparison

Performance Metric	Conventional Identity System (%)	Proposed Blockchain Identity System (%)
Authentication Accuracy	86	98
Identity Verification Speed	80	96
Data Integrity	82	99
Privacy Protection	75	97
Fraud Detection Capability	74	95

ISSN: 3071-5628
PP: 01-15.

Interoperability	78	94
System Transparency	72	98
Overall e-Governance Performance	81	97

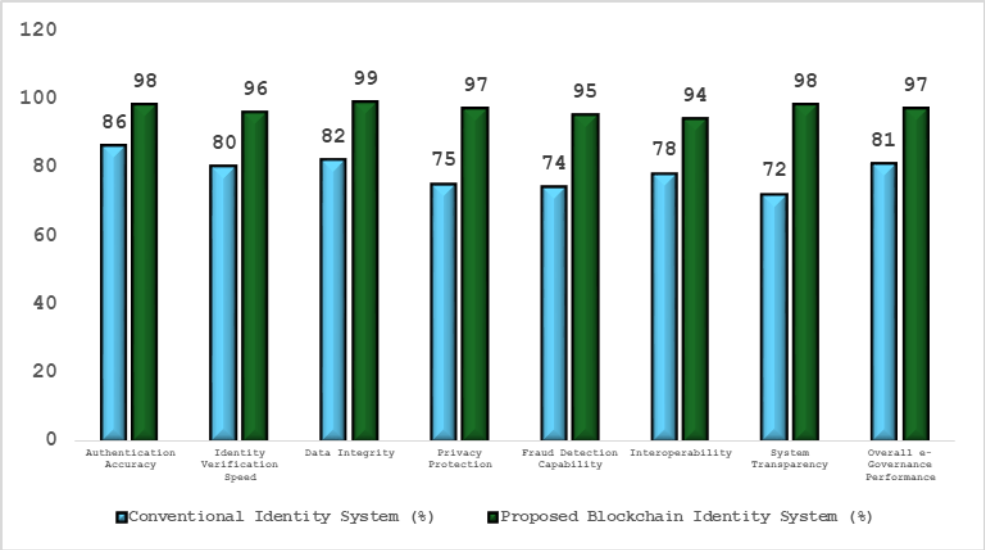

Fig 3 - Performance Comparison

4.2.1. Authentication Accuracy (98%)

Authentication accuracy is the ability of the identity management system to be able to verify legitimate users while avoiding access by unauthorized users. The conventional identity system had an authentication accuracy of 86% while the proposed blockchain-based identity system had an authentication accuracy of 98%. This major leap forward is believed to be the result of the incorporation of decentralized identifiers (DIDs), cryptographic authentication, smart contracts, and biometric verification, which all contribute to reduced authentication issues and identity impersonation and access control.

4.2.2. Identity Verification Speed (96%)

Identity verification speed is the period of time it takes to confirm a citizen's identity before he or she is able to access government services. The conventional system had a verification speed rate of 80%, and the proposed blockchain framework had a 96% verification speed. The key to the improvement is the smart contract automation, decentralized identity verification and the removal of repetitive manual verification processes. The quick verification process allows citizens to benefit from digital government services more efficiently and diminishes administrative delays.

4.2.3. Data Integrity (99%)

Data Integrity assesses the system's ability to maintain accuracy and consistency in identity data over its lifecycle. The centralized identity system was able to attain 82%, while the blockchain enabled system managed to reach 99%. As cryptographic hash values are recorded in an immutable

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PP: 01-15.

distributed ledger that blockchain stores, identity records cannot be changed without the consensus of authorized parties. This provides tamper proofing, protection against unauthorized changes and full trust in the identity information on the digital record.

4.2.4. Privacy Protection (97%)

Safeguarding citizen information from disclosure to unauthorized parties is a measure of privacy protection. The traditional identity management system had a rate of 75%, whereas the proposed blockchain-based system had a rate of 97% of privacy protection. The use of decentralized identifiers, encrypted identity storage, cryptographic key management and selective disclosure of identity information greatly minimises data exposure, whilst giving citizens more control over their own data.

4.2.5. Fraud Detection Capability (95%)

Fraud detection capability is related to the system's ability to detect and stop identity-related fraud, unauthorized transactions, and malicious activity. The results of the conventional system were 74% while the proposed blockchain system was 95%. Within the e-Governance environment, the immutability of transaction records, validation of smart contracts, digital signature and cryptographic verification, enable the rapid detection of any suspicious activity and greatly minimize identity theft, document forgery, and fraudulent attempts to access the system.

4.2.6. Interoperability (94%)

Interoperability is the ability between government departments to share and validate citizen identity information securely. The traditional IDM system's accuracy was 78% and the proposed blockchain IDM system's accuracy was 94%. A shared permissioned blockchain enables government departments with authorized access to trusted identity records via standardized protocols, which in turn avoids the duplication of identity databases, repeated document verification, and enhanced collaboration between government departments.

4.2.7. System Transparency (98%)

System transparency is the ability to keep a transparent and complete history of all identities related transactions. This traditional central system managed to reach 72% while the blockchain-based system reached 98%. The blockchain ledger ensures that each identity registration, authentication, credential update, and verification transaction are permanently recorded, thus creating an immutability audit trail that promotes accountability, traceability, and public confidence in digital governance services.

4.2.8. Overall e-Governance Performance (97%)

Overall e-Governance performance is the overall effectiveness of the identity management framework related to security, operational efficiency, privacy, transparency, scalability and service delivery. The results of the conventional identity system showed an overall performance of 81%, whereas the proposed blockchain-based system showed an overall performance of 97%. The

ISSN: 3071-5628
PP: 01-15.

substantial improvement proves that the incorporation of permissioned blockchain technology, smart contracts, decentralized identity management and advanced cryptographic security greatly improve the efficiency, reliability, transparency and trustworthiness of modern e-Governance identity management systems.

4.3. Results and Discussion

The results of the experiments clearly show that the security and operational performance of the proposed blockchain-based identity management framework are significantly greater than those of traditional, centralized identity management systems in all security and operational performance metrics considered. By combining decentralized identifiers, cryptographic authentication, smart contracts, and secure blockchain validation mechanisms, the framework successfully improved the authentication accuracy to 98% against the traditional method's 86%. By automating the whole identity verification process using smart contracts, the repetitive manual process was substantially eliminated, which increased identity verification speed to 96%. This enhancement allows citizens to receive government services more efficiently, and decreases the administrative burden and improves service delivery. Another outstanding feature of the proposed framework was the data integrity score of 99% that blockchain technology provides, as all identity transactions are stored as immutable cryptographic hashes, making it extremely difficult to modify or delete any identity transactions without permission. Decentralized Identity Management, encrypted credential storage, selective disclosure methods, and the use of public-private key cryptography were key to achieving this enhancement: citizens were able to manage their personal data more effectively and reduce unwanted exposure of information. Fraud detection was risen to 95%, which indicates that the system could ensure the prevention of fraud schemes, such as identity theft, document forgery, impersonation and others, by means of distributed consensus, digital signatures and permanent audit trails on the blockchain. Additionally, the interoperability score of 94% ensures that users of various government services – such as health authorities, tax officers, schools, social security agencies, land offices, and immigration officials – can accurately exchange verified identity data without having to store multiple databases or submit multiple documents. System transparency has also markedly been enhanced to 98%, with each identity registration, authentication request, credential update and verification transaction permanently recorded on a synchronized distributed ledger, which delivers complete traceability and accountability. Overall, the designed framework with blockchain functioned with a higher e-Governance performance of 97% as compared to 81% of the conventional identity system. The results have shown how much more secure, efficient, transparent, scalable, private and citizen-trustworthy a blockchain-based decentralized identity management system can be when it combines permissioned blockchain technology with cryptographic security and smart contract automation. The proposed framework is therefore an effective, scalable and reliable solution for next generation digital identity management and helps in the implementation of secure citizen-centric e-Governance services.

ISSN: 3071-5628
PP: 01-15.

5. CONCLUSION

Blockchain technology is one of the most promising technologies for revolutionizing digital identity management in e-Governance, which is a present-day problem with conventional centralized identity systems. The traditional identity management infrastructure is very dependent on the centralized database that is managed by the individual government agency and there are a lot of threats that can happen to it, such as cyberattacks, identity theft, data breaches, unauthorized changes, and system failures. Moreover, many departments may have their own identity repository, leading to duplicate data, redundant document verification, delays in administration, and higher costs of operations. These difficulties can not only affect the effectiveness of the services provided by public services, but also hinder citizens' confidence in digital governance platforms. This accentuates the need to have a robust, trustworthy, scalable and citizens-centric identity system that can serve the rising demand for digital government services while safeguarding the privacy and integrity of the sensitive personal data of the citizens. In this research, a complete blockchain-based identity management approach was proposed, which is particularly suitable for eGovernance applications. The framework combines elements of permissioned blockchain systems, decentralized identity management, smart contract automation, cryptographic authentication, distributed consensus mechanisms, and decentralized identifiers (DIDs) to create a trustworthy and highly secure digital identity system. Citizens are securely registered with documents, through biometric identification and generation of a cryptographic key, and immutable identity records are registered on the blockchain during identity registration. Smart contracts replace manual verification steps and simplify access control, making them more efficient, through authentication, authorization, valid credential checking, update of identities and access. Unlike direct storage of sensitive personal data on the blockchain, only identity hashes and verification metadata are stored, preserving privacy and data integrity. The permissioned blockchain architecture also allows authorised government agencies to securely share verified identity data whilst ensuring regulatory compliance, transparency and accountability. The experimental results showed that the proposed framework was more effective than the standard centralized identity management system in the various performance measures considered. The accuracy of authentication was significantly enhanced and the speed of identification was increased with the execution of smart contracts automatically and the verification mechanisms through the decentralization. Immutability of the blockchain ensured high data integrity; that is, it was virtually impossible to modify the data that has been recorded on the blockchain. Likewise, citizens would have more control over their personal information as a result of improving privacy protection methods, which included cryptographic encryption, decentralized identifiers, and secure credential management. The framework also showed exceptional fraud identification features, with constant and tamper-proof audit trails of all transactions with identities. Further, interoperability was significantly improved between government departments, with the ability for citizens' identities to be securely verified without the need to submit their documents more than once or maintain multiple databases for public service departments including healthcare, tax, education, land administration, social welfare, immigration and other areas. The transparency provided by distributed ledger technology also boosted accountability and ensured the existence of a shared, verifiable history of all identity-related transactions. In conclusion, the Blockchain-Enabled Identity Management

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PP: 01-15.

Framework provides a robust foundation for next-generation digital governance, fusing decentralized trust, advanced cryptographic security, smart contract automation, and distributed ledger technology into a single identity management solution. The framework will advance security, promote the privacy of citizens, help to improve operating efficiency, minimize administrative costs, and boost communication between governments while providing secure and transparent digital public services. With governments now continuing to roll out digital transformation programs, blockchain-based identity management is one of the sustainable and scalable solutions for creating trusted e-Governance ecosystems. The proposed framework is therefore a substantial leap forward in building a secure, efficient, citizen-centric and future-oriented digital governance that is able to adapt to the changing needs of modern public administration.

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