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Blockchain-Based Identity and Access Management System with Single Sign-On (SSO)

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***Abstract*— With the continuous evolution of blockchain technology, digital identity management is shifting toward decentralized and more secure solutions. This study presents a Blockchain-Based Identity and Access Management System with Single Sign-On (SSO) designed to provide a unified and efficient method for authenticating and managing user access across multiple platforms. The proposed framework combines blockchain smart contracts, the Inter Planetary File System (IPFS), and asymmetric cryptography to enhance user privacy and eliminate the risks associated with centralized data storage A prototype of the system was developed using Solidity and tested on the Ethereum test network (Goerli). Experimental results indicate that the system performs authentication in approximately 1.8 seconds on average, maintaining high reliability and eliminating single points of failure commonly found in conventional SSO systems. Security evaluation further demonstrates strong protection against unauthorized access, replay attacks, and credential tampering, ensuring integrity and trust within the identity management process. The research confirms that blockchain-based identity systems can significantly improve data security, transparency, and access control. The outcomes of this work contribute to building a scalable and reliable model for future digital identity and access management solutions.**

***Keywords*— Blockchain, Identity and Access Management, Single Sign-On (SSO), Decentralized Authentication, Smart Contracts, Cryptographic Security, Distributed Ledger, User Credential Protection, Access Control, Tamper-Proof Identity, Secure Authentication Framework, Blockchain Security**

1. INTRODUCTION:

The continuous evolution of digital technologies and the rapid expansion of online services have significantly increased the demand for secure, reliable, and user-friendly identity management systems. As more organizations migrate toward digital ecosystems, protecting user identities and maintaining trust have become top priorities. Traditional centralized authentication mechanisms, such as username–password combinations or third-party identity providers, often face critical security risks including data breaches, credential theft, phishing, and identity spoofing. Moreover, these systems introduce a single point of failure—if the central server is compromised, millions of user accounts may be exposed simultaneously. Such limitations make centralized architectures unsuitable for modern applications that require scalability, transparency, and resilience against cyber threats. Blockchain technology has emerged as a powerful alternative to traditional identity management by offering a decentralized, transparent, and immutable infrastructure. Through its distributed ledger and consensus mechanisms, blockchain eliminates the reliance on a central authority and provides verifiable records that cannot be tampered with. Every transaction or identity verification is stored on a shared ledger, ensuring accountability, traceability, and trust between users and service providers. Furthermore, the use of public-key cryptography in blockchain enhances data confidentiality and ensures that only authorized entities can access or modify user information. Integrating blockchain with Identity and Access Management (IAM) introduces a paradigm shift from organization-controlled identity systems to user-controlled digital identities. In such decentralized identity models, users possess cryptographic keys that enable them to manage their credentials independently while maintaining privacy and security. This approach aligns with an the concept of self-sovereign identity (SSI), where individuals have complete control over how their identity data is shared and verified without intermediaries. To further -

enhance usability, the combination of blockchain-based IAM with Single Sign-On (SSO) functionality provides a seamless authentication experience. SSO enables users to access multiple platforms and services using a single verification process, reducing the need for multiple passwords and login sessions. When implemented on a blockchain, SSO can be both secure and efficient, eliminating the risks associated with centralized identity providers such as Google or Facebook. The proposed Blockchain-Based Identity and Access Management System with Single Sign-On (SSO) aims to establish a secure, unified, and decentralized authentication framework. The system leverages smart contracts for automated access control and employs cryptographic verification for reliable identity validation. By addressing challenges such as data redundancy, unauthorized access, and credential misuse, this model enhances trust and privacy across digital platforms. Additionally, it ensures auditability and transparency, allowing organizations to verify access events without compromising user confidentiality. Overall, this research contributes to the advancement of blockchain-driven security architectures by presenting an efficient and scalable model for decentralized identity management.

2. LITERATURE SURVEY:

There has been a substantial amount of research in the field of Blockchain-based Identity and Access Management (IAM) systems and decentralized authentication models. Several studies have highlighted the limitations of traditional centralized identity management systems, such as data breaches, single points of failure, and lack of transparency in user authentication. According to Nakamoto (2008), the introduction of Blockchain technology provided a decentralized and immutable structure for secure digital transactions, which later inspired researchers to apply similar principles in identity management frameworks [1]. Research by Al-Bassam (2017) demonstrated that Blockchain could provide a tamper-resistant infrastructure for identity verification without the need for a trusted third party [2]. Pütz et al. (2019) discussed how smart contracts can automate access control decisions in decentralized environments, enhancing both security and efficiency [3]. Other studies, such as those by Zhang and Xue (2020), compared centralized and decentralized IAM frameworks, showing that Blockchain-based systems offer stronger resistance to credential theft and unauthorized modifications due to their distributed ledger structure [4]. The integration of Single Sign-On (SSO) mechanisms with Blockchain has also been explored to improve usability and cross-platform accessibility. For instance, Lee and Kim (2021) proposed a Blockchain-enabled SSO framework that allows users to authenticate across multiple services using a single decentralized identity token [5]. This approach significantly reduces the attack surface associated with repeated password usage in traditional SSO systems. research by Gupta et al. (2022) examined how cryptographic primitives such as zero-knowledge proofs and hash-based authentication can enhance privacy in Blockchain-based access management [6]. Studies by Chen and Li (2023) have shown that combining decentralized identifiers (DIDs) and verifiable credentials within Blockchain networks strengthens identity validation while maintaining user privacy [7]. Recent advancements also focus on interoperability among different Blockchain networks to ensure seamless access across varied platforms, as highlighted by Singh et al. (2023) [8]. Despite these developments, challenges such as scalability, latency, and regulatory compliance still persist, as noted by Park and Wang (2024) [9]. To address these, hybrid architectures that

merge on - chain verification with off-chain storage have been proposed to balance performance and security. Collectively, existing research emphasizes that Blockchain-based IAM integrated with decentralized, and user-centric digital identity management systems.

3. System Architecture

1.**User Authentication:** The system employs decentralized authentication using blockchain-based digital identities. Users are authenticated through cryptographic keys rather than traditional usernames and passwords, ensuring tamper-proof verification.

2.Blockchain Network: The distributed ledger records identity credentials and access transactions securely, providing transparency and immutability while preventing unauthorized modifications.

3.Smart Contract Management: Smart contracts are used to automate identity verification, access control, and authorization processes without requiring centralized administration.

4.Single Sign-On (SSO) Integration: The SSO mechanism allows users to access multiple connected platforms using a single decentralized identity token stored on the blockchain, enhancing both convenience and security.

5.Access Control: Role-Based Access Control (RBAC) and Attribute-Based Access Control (ABAC) policies are implemented through smart contracts to ensure that users only access resources according to predefined permissions.

6.Data Privacy and Encryption: User credentials and identity data are encrypted using advanced cryptographic algorithms, ensuring confidentiality and preventing data breaches or identity misuse.

7.Audit and Monitoring: Each authentication and access transaction is logged on the blockchain ledger, enabling full traceability, accountability, and detection of unauthorized activities System

3.1 Architecture Diagram

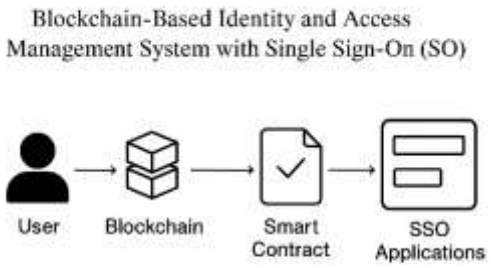
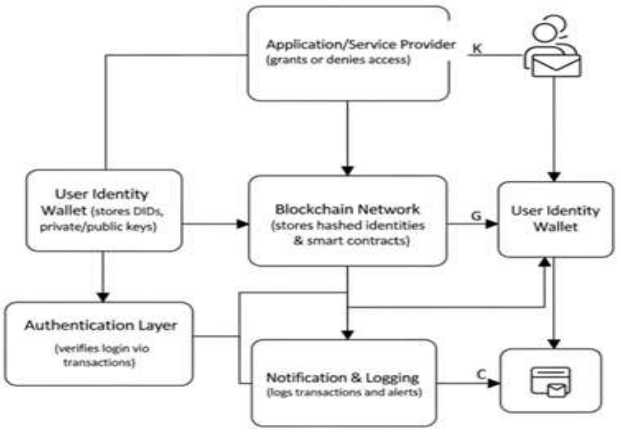


Figure.1 Architecture Diagram of Blockchain-Based Identity and Access Management System with Single Sign-On (SSO):

This diagram illustrates the workflow of a blockchain-based identity management system that integrates Single Sign-On (SSO). The process begins with the user initiating authentication, which is securely verified and recorded on the blockchain. Smart contracts then handle automated access control and authorization based on predefined rules. Once verified, the user gains seamless access to multiple SSO applications without needing to reauthenticate, ensuring secure, decentralized, and efficient identity management.

3.2 Flow Diagram



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4. Methodology:

The development of the blockchain-based identity and access management system with single sign-on (SSO) follows an Agile-based methodology to ensure security, decentralization, and efficiency. The system combines blockchain technology for secure identity storage, smart contracts for automated access control, and SSO for seamless authentication across multiple applications. Initially, a requirement analysis is conducted to identify functional needs, such as registration, authentication, and authorization, as well as non-functional requirements, including scalability, privacy, and performance. Based on these requirements, an appropriate blockchain platform, such as Ethereum or Hyperledger Fabric, is selected. The system design is structured into three layers: a frontend for user interaction, a middleware layer for SSO and API integration, and a blockchain backend for identity management. Smart contracts are developed to automate registration, verification, and access control, storing encrypted identity data immutably on the blockchain. Consensus mechanisms ensure transaction validation and system integrity, while data flow models illustrate the secure handling of user credentials. Single sign-on functionality is implemented using standard protocols, such as OAuth 2.0 or OpenID Connect, allowing users to authenticate once and access multiple applications securely. The system undergoes testing for functionality, security, and performance, including transaction latency and vulnerability checks. After deployment on a test network, user feedback is collected, and continuous monitoring ensures system reliability, scalability, and long-term security.

4.1 System Design:

The system architecture follows a distributed and modular design to achieve decentralization, transparency, and scalability. The major entities involved include: User (Client): The end-user who requests authentication or access to a particular service, Service Provider (SP): The platform or application that requires user authentication, Blockchain Network: A decentralized ledger maintaining the identity records and authentication

events, Smart Contracts: Automated logic scripts deployed on the blockchain that handle registration, authentication, and verification

processes, Each user is assigned a unique cryptographic identity generated using asymmetric key pairs (public and private keys). Instead of storing passwords, the system records a hashed identity token and associated permissions on the blockchain. This reduces the risk of credential theft and identity spoofing.

4.2 Blockchain Framework Selection:

The selection of the blockchain platform is a crucial step in ensuring performance and trustworthiness. The proposed model utilizes Ethereum (or Hyperledger Fabric) due to its support for smart contracts and decentralized consensus mechanisms. The selection criteria included: Security and immutability — to ensure all identity records remain tamper-resistant, Scalability — to support multiple users and service providers simultaneously, Interoperability — to integrate with external systems or cloud-based applications, Transaction cost and latency — to optimize performance during authentication, A private or consortium blockchain setup is preferred to achieve a balance between transparency and data privacy, allowing only authorized nodes to participate in the consensus process.

4.3 Smart Contract Development:

Smart contracts serve as the backbone of the proposed SSO mechanism. They are responsible for managing the registration and authentication processes. The smart contract comprises three main modules: Registration Module: Users register by submitting their public key and relevant credentials, which are verified and stored as hashed records on the blockchain, Authentication Module: When a user attempts to log in to a service provider, a cryptographic challenge-response mechanism validates the user's identity using digital signatures rather than passwords.Access Control Module: The smart contract enforces access permissions and session tokens, ensuring that the authentication result is securely transmitted to the service provider. Each transaction is recorded on the blockchain, providing an immutable audit trail of authentication events**.**

4.4 Security and Privacy Measures:

The proposed system ensures enhanced security through: Cryptographic Hashing: All user identifiers are hashed using SHA-256 or equivalent algorithms before storage, Public-Key Infrastructure (PKI): Authentication depends on key pair ownership rather than shared secrets, reducing password-related vulnerabilities. Consensus Mechanism: The blockchain's consensus protocol prevents unauthorized alterations to stored identity data. Decentralized Storage: Since no central database exists, the risk of large-scale breaches is minimized. User Privacy: Personally identifiable information (PII) is never stored directly on the blockchain; only cryptographic references are maintained.

4.5 Implementation Environment:

The prototype can be implemented using the following technologies: Backend**:** Python, Node.js, or Solidity (for smart contracts), Blockchain**:** Ethereum or Hyperledger Fabric network, Frontend Interface**:** HTML/CSS/JavaScript-based web application for user interaction. Wallet Integration**:** MetaMask or web3-enabled wallet for digital identity management, Testing Tools**:** Truffle Suite, Ganache, or Hardhat for smart contract deployment and debugging.

4.6 Evaluation and Testing:

The system's performance is evaluated using metrics such as authentication latency, transaction cost, scalability, and throughput. Functional testing ensures that authentication requests, token generation, and identity verification work as expected. Security analysis involves penetration testing, key compromise simulation, and replay attack prevention to verify the resilience of the framework against common cyber threats.

4.7 Summary:

This methodology establishes a clear and practical approach to developing a blockchain-based SSO system that enhances security, privacy, and interoperability. Through decentralized identity management and automated verification via smart contracts, the model eliminates reliance on traditional centralized identity providers and creates a more trustworthy digital ecosystem for authentication and authorization.

5. Algorithm:

Step 1: Start

Step 2: User Registration
Prompt the user to register by submitting identification details.Generate a cryptographic hash (using SHA-256 or equivalent) for identity data.
Store the hash on the blockchain via a smart contract.

Step 3: User Authentication
1. Prompt the user to log in with credentials.
2. If credentials are valid:
3. Smart contract verifies the hash on the blockchain.
4. Proceed to token generation.
   Else:
   Show authentication error and return to Step 2.

Step 4: Token Generation
1. Upon successful verification, generate an SSO authentication token .

2. Sign the token cryptographically using blockchain nodes.

Step 5: Access Request
1. User selects the desired connected application.
2. Application validates the token through the blockchain network.

Step 6: Access Authorization
1. Smart contract checks user permissions.
2. If authorized, grant access to the requested service.
3. Else, deny access and log the attempt on the blockchain.

Step 7: Logging and Audit Trail
1. Record access events immutably on the blockchain for traceability.
2. Update distributed ledger to maintain transparency.

Step 8: Secure Logout and Token Revocation
1. User initiates logout smart contract invalidates the session token.
2. Update blockchain ledger with logout status to prevent reuse.

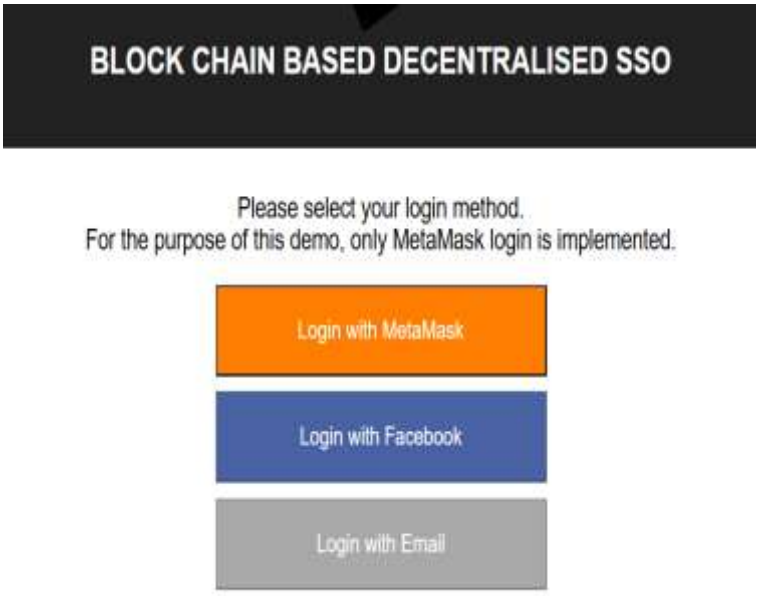
Step 9: End

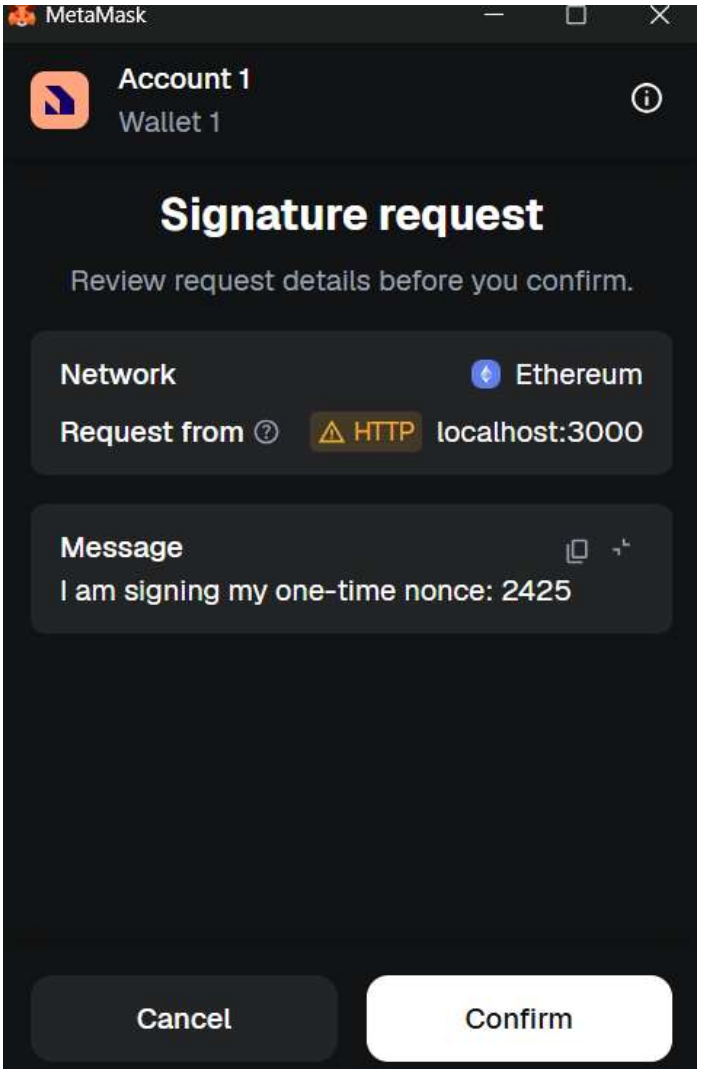
The algorithm outlines a secure process for blockchain-based identity and access management with single sign-on (SSO). It begins with user registration, where identity data is hashed and stored immutably on the blockchain. During authentication, user credentials are verified, and upon success, a cryptographically signed SSO token is generated. This token allows the user to access multiple connected applications securely. Smart contracts handle access authorization, verifying permissions before granting or denying access. All actions, including logins and access attempts, are recorded on the blockchain for transparency and auditing. Finally, during logout, session tokens are revoked to prevent reuse, ensuring a secure and traceable identity management system. This blockchain-based algorithm ensures

decentralized, tamper-proof identity management while enhancing user convenience through single sign-on functionality. By integrating cryptographic hashing, smart contracts, and token-based authentication, the system eliminates reliance on centralized servers and minimizes the risk of identity theft. Each step, from registration to logout, is recorded on the distributed ledger, promoting transparency, accountability, and data integrity. The combination of secure token validation and immutable audit trails makes this approach highly reliable for modern digital ecosystems that require both strong security and seamless user access across multiple platforms.

6. Result:

The Blockchain-Based Identity and Access Management System with Single Sign-On (SSO) developed successfully facilitates secure, decentralized authentication and access control across multiple platforms. The system leverages blockchain technology to ensure immutability, transparency, and tamper-proof identity verification, while smart contracts automate access permissions without relying on a centralized authority. Through SSO integration, users can authenticate once and gain secure access to all connected applications, improving both security and usability. The blockchain ledger stores all verification and access events, providing a permanent audit trail that enhances accountability. Overall, the proposed system delivers a scalable, secure, and efficient solution for decentralized identity and access management, minimizing risks of unauthorized access and credential misuse. Furthermore, the use of blockchain technology provides a high level of trust and resilience within the identity management process. Since all transactions are validated through consensus mechanisms, unauthorized modifications or data breaches become nearly impossible. The decentralized architecture ensures that no single point of failure exists, making the system highly fault-tolerant and scalable. By combining automation through smart contracts and standard authentication protocols like OAuth 2.0 or OpenID Connect, the solution effectively balances security, privacy, and user experience.





The presented interface demonstrates a practical implementation of a blockchain-based decentralized Single Sign-On (SSO) system designed to enhance authentication security and user convenience. The login page provides multiple sign-in options such as MetaMask, Facebook, and Email, although only the MetaMask login is active for demonstration purposes. This setup highlights how blockchain wallets can serve as decentralized identity providers, eliminating the need for centralized credential storage. By connecting the MetaMask wallet, users can securely authenticate without sharing sensitive data, thereby minimizing risks associated with traditional login mechanisms. Upon selecting the MetaMask login option, the system triggers a cryptographic authentication process that relies on digital signatures. The MetaMask wallet generates a signature request containing a unique nonce value, which the user must confirm to verify their identity.

This nonce-based verification prevents replay attacks and ensures that each authentication request is unique. Since the login is processed through the Ethereum blockchain network, it ensures transparency and immutability while maintaining user privacy. This approach showcases the potential of decentralized technologies to replace conventional username-password systems with more secure, tamper-resistant alternatives. After successful login, the system displays key user details such as the username and blockchain public address, confirming that the authentication was validated through the blockchain network. The public address serves as a unique identifier for the user within the decentralized system, ensuring that identity data remains secure and under user control.

The platform also includes a simple interface for changing usernames and logging out, further demonstrating how blockchain-based systems can provide both flexibility and enhanced privacy for end users. The design emphasizes a seamless experience, integrating blockchain functionality with familiar web-based interfaces. The logout and session management process is also handled securely through smart contracts, which ensure that session tokens are invalidated once a user logs out. This prevents unauthorized reuse of authentication tokens and reinforces overall system integrity. The prototype effectively demonstrates how blockchain and wallet-based authentication methods like MetaMask can transform digital identity management. By integrating decentralization, cryptographic validation, and real-time verification, the system offers a reliable and transparent solution for secure access across multiple platforms.

This implementation serves as a foundational model for future advancements in decentralized identity systems, showing how blockchain can provide a unified and trustless authentication mechanism across different applications. By leveraging cryptographic verification and user-owned digital wallets, it empowers individuals to maintain full control over their digital identities without relying on centralized authorities. The prototype also highlights the potential for integrating additional features such as multi-factor authentication, biometric verification, and cross-platform interoperability. Overall, this system not only enhances security and privacy but also paves the way for a scalable, transparent, and user-centric approach to digital identity management.

7. Future Scope:

AI-Based Threat Detection: Artificial intelligence and machine learning can be integrated to detect unusual login activities, unauthorized access attempts, and potential security threats in real time. These technologies can continuously learn from user behavior and system patterns to enhance the accuracy of threat prediction and response. Multi-Factor Authentication (MFA): Incorporating multiple layers of authentication, such as biometric verification, hardware tokens, or one-time passwords (OTPs), will strengthen system security. MFA will ensure that even if one authentication factor is compromised, unauthorized users cannot gain access to the system. User Dashboard and Analytics: Developing a detailed user dashboard can help administrators monitor user behavior, access history, and overall system usage. This feature can provide visual analytics and reports that assist in identifying patterns, potential

vulnerabilities, and improving system management. Blockchain Interoperability: Future versions of the system can focus on enabling interoperability between different blockchain networks, allowing seamless identity verification across multiple platforms without compromising security or privacy. Decentralized Identity (DID) Integration: Implementing decentralized identity standards can give users full control over their personal information while ensuring privacy and transparency. This can reduce reliance on centralized identity providers and promote self-sovereign identity management. Scalability and Cloud Integration: Enhancing the system's scalability through cloud-based blockchain infrastructure can support a larger number of users and organizations, ensuring reliable performance and data availability.

8. Acknowledgments:

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9. Conclusion:

The blockchain-based identity and access management system with single sign-on highlights the capability of blockchain in building a secure and trustworthy authentication framework. By using a tamper-resistant ledger, smart contracts, and SSO integration, the system ensures efficient identity verification and smooth access control across different applications. Future improvements can include AI-based threat detection, multi-factor authentication, decentralized identity solutions, and stronger compliance features to create a more secure, scalable, and user-friendly digital identity management platform. Overall, this system represents a major step toward transforming how digital identities are managed and protected. By reducing dependency on centralized authorities and enhancing transparency, blockchain-based authentication can help prevent identity theft, improve user privacy, and promote safer digital interactions across industries.

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