Multi-source Information Collaborative Model for Smart Elderly Care in Heterogeneous Blockchain Networks: Postprint

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Abstract

[Purpose/Significance] The consensus algorithms and decentralization philosophy inherent in blockchain technology can effectively safeguard information coordination in social networks. The smart elderly care multi-party information coordination network represents one specific application scenario for utilizing blockchain technology to ensure social network information coordination. The application of blockchain technology in this scenario can effectively enhance the efficiency of information coordination among multiple stakeholders participating in smart elderly care, thereby providing convenience for all parties involved.

[Method/Process] Based on blockchain technology and principles, combined with the characteristics of multi-party information in smart elderly care, we construct five blockchain architectures with different structures: an elderly care governmental information sovereign-consortium chain architecture, a medical and health information consortium chain architecture, a community service information consortium chain architecture, an elderly personal health information private chain architecture, and an elderly medical and health experience information public chain architecture. According to blockchain cross-chain technology, these five architectures are integrated into a heterogeneous blockchain network for multi-party information coordination in China's smart elderly care. On this basis, we analyze the benefits and shortcomings that this heterogeneous blockchain network brings to China's smart elderly care initiatives in terms of information coordination.

[Results/Conclusion] Based on heterogeneous blockchain network technology, we propose a smart elderly care multi-party information coordination model, which enriches the application scenarios of blockchain technology.

Full Text

Preamble

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Research on Multi-Information Collaborative Models for Smart Elderly Care from the Perspective of Heterogeneous Blockchain Networks

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Abstract:
[Purpose/Significance] The consensus algorithm and decentralization principles inherent in blockchain technology can effectively guarantee information coordination within social networks. The smart elderly care multi-information collaborative network represents one specific application scenario where blockchain technology ensures social network information coordination. Applying blockchain technology in this context can significantly enhance information coordination efficiency among multiple stakeholders in smart elderly care, thereby bringing convenience to all participants. [Method/Process] Based on blockchain technology and its principles, combined with the characteristics of multi-information in smart elderly care, this study constructs five different blockchain architectures: a sovereign-alliance chain architecture for elderly care administrative information, an alliance chain architecture for medical and health information, an alliance chain architecture for community service information, a private chain architecture for elderly personal health information, and a public chain architecture for elderly healthcare experience information. Using cross-chain technology, these five architectures are integrated into a heterogeneous blockchain network for multi-information coordination in China's smart elderly care system. The benefits and limitations of this heterogeneous blockchain network for information coordination in smart elderly care are then analyzed. [Result/Conclusion] Based on heterogeneous blockchain network technology, this paper proposes a multi-information collaborative model for smart elderly care, enriching the application scenarios of blockchain technology and providing new perspectives for information coordination research in this field.

Keywords: smart elderly care; heterogeneous blockchain network; information coordination
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According to the latest population data released by the National Bureau of Statistics, by the end of 2018, China's elderly population aged 60 and above had reached 249.49 million, accounting for 17.9% of the total population [1]. As

population aging deepens and "inverted pyramid" family structures (four elderly persons, one couple, and one or two children) become increasingly common, traditional family-based elderly care models can no longer meet the growing needs of older adults. This has given rise to a new smart elderly care model led by the government, based on families, supported by community service centers, and supplemented by medical and health institutions. Smart elderly care refers to the use of advanced technologies and equipment to provide real-time, efficient, and low-cost elderly care services [2]. Its foundation lies in the high-level coordination of diverse information, including government-issued elderly care policies, medical and health information from healthcare institutions, community service information from community centers, elderly personal health information, and elderly healthcare experience information [2]. Currently, coordination among these diverse types of smart elderly care information remains imperfect. Blockchain technology, as an underlying information interaction and storage technology, provides an effective solution to this problem.

1. Research Review

International scholars have primarily focused on the application of information technology in smart elderly care, investigating how to effectively apply IT to improve services [3-5]. Domestic research on smart elderly care is still in its infancy [6], with scholars concentrating mainly on conceptual definitions. Zuo Meiyun [7] traces the term "smart elderly care" to IBM's 2010 "smart city" vision, defining it as the use of information technology and modern technologies to support elderly life services and management across daily living, safety, medical care, rehabilitation, entertainment, and learning, enabling automatic monitoring, early warning, and proactive handling of elderly-related information to achieve friendly, autonomous, and personalized intelligent interaction. Zhu Qinghua [8] defines smart elderly care as using IoT and internet technologies to provide information platforms and intelligent services for elderly individuals and care institutions, offering effective solutions to population aging challenges. He Zhenyu et al. [9] view smart elderly care as a new model that employs advanced IoT and information technologies to deliver intelligent, connected, and personalized elderly care services. While definitions vary, consensus exists that IT development is a crucial driver of smart elderly care advancement. Ma Jie et al. [10] addressed existing problems in China's smart elderly care emergency services by constructing a three-tier emergency response information coordination system involving elderly family members, volunteers, and hospitals to improve rescue efficiency.

Information coordination is key to achieving intelligent services, helping to understand collaborative processes among multiple information subjects, identify problems, and propose improvements for better synergy [11]. For instance, Wang Jian et al. [12] analyzed coordination mechanisms in virtual academic communities from perspectives of subject, knowledge, resource, and goal coordination to improve researcher information behavior efficiency. Ma Jie et al. [13]

designed an information ecological chain model for smart city multi-stakeholder coordination based on information ecology theory. Hu Mo et al. [14] introduced boundaryless management theory to construct a smart government information coordination mechanism model. International research on information coordination theory has primarily focused on supply chains, examining inter-enterprise coordination mechanisms to enhance efficiency and intelligence [15-17].

On May 20, 2018, the Information Center of the Ministry of Industry and Information Technology released the "2018 China Blockchain Industry White Paper," stating that China's blockchain industry has taken initial shape and is rapidly applying in credit, copyright trading, and electronic evidence, potentially driving technological, organizational, and efficiency transformations in China's economic system [18]. Domestic library and information science research has mainly used libraries as application scenarios: Gao Sheng et al. [19] constructed a new hierarchical digital library architecture using blockchain to solve secure circulation of heterogeneous digital resources; Huang Mincong [20] summarized blockchain's transformative impact on libraries, advocating active adoption to improve services; Fang Yongzhuang et al. [21] argued blockchain helps libraries achieve diverse information collection, storage, and dissemination. International scholars have focused on blockchain performance: N. Kshetri [22] compared blockchain and cloud technology in cybersecurity and privacy protection, noting blockchain's advantages but warning about malicious participation due to decentralization; T. T. Kuo et al. [23] discussed blockchain applications in healthcare and proposed solutions to potential challenges.

In summary, scholars worldwide have researched smart elderly care to address aging population challenges. Current Chinese research remains nascent, with few studies examining information coordination from a blockchain perspective using smart elderly care multi-information networks as an application scenario. This paper addresses this gap by applying blockchain principles to design five heterogeneous blockchain architectures for different smart elderly care information components, integrating them into a heterogeneous network using cross-chain technology to enhance coordination efficiency.

2. Components of Smart Elderly Care Multi-Information

Based on relevant literature on smart elderly care information coordination [10, 24] and current national conditions, this study categorizes China's smart elderly care multi-information into five types according to different storage and utilization subjects: government elderly care administrative information, medical and health institution information, community service center information, elderly personal health information, and elderly healthcare experience information.

2.1 Government Elderly Care Administrative Information

Although China's smart elderly care development is in its early stages, a relevant policy framework has begun to take shape. The General Office of the State

Council, Ministry of Civil Affairs, and National Health Commission are primary policy-making bodies, issuing guidelines and notices such as the "Opinions on Accelerating Commercial Elderly Care Development" and the "Smart Health Elderly Care Industry Development Action Plan (2017-2020)." Government departments coordinate smart elderly care development macroscopically through policy measures that promote inter-departmental information coordination and collaboration with healthcare institutions, community centers, and elderly individuals. Government elderly care administrative information constitutes one component of China's smart elderly care multi-information system.

2.2 Medical and Health Institution Information

On November 20, 2015, the General Office of the State Council issued the "Guiding Opinions on Promoting the Integration of Medical Care and Elderly Care," encouraging integration of medical and elderly care services and providing macro-level guidance for effective coordination of medical and elderly care information resources [25]. Medical institutions provide treatment, consultation, and nursing services to improve elderly quality of life and health [26]. The information generated through these services constitutes another component of the smart elderly care multi-information system.

2.3 Community Service Center Information

Community elderly care centers conveniently provide nursing, meals, housekeeping, and spiritual comfort services to elderly residents within communities, representing a critical "last kilometer" solution for smart elderly care services. Community service announcements and information accumulated through service delivery constitute another component of the smart elderly care multi-information system.

2.4 Elderly Personal Health Information

Elderly personal health information comprises physical and psychological health data. Establishing personal health archives enables medical institutions to provide precise treatment and community centers to offer personalized services. While personal health information is private, large-scale anonymized data can inform government policy-making. Thus, elderly personal health information also constitutes a component of the smart elderly care multi-information system.

2.5 Elderly Healthcare Experience Information

Many elderly individuals have lived with certain diseases for years and accumulated rich medical experience and rehabilitation insights. Collecting, storing, and processing this experiential information enables other elderly individuals with similar conditions to access valuable medical information and emotional

support from peers. Therefore, elderly healthcare experience information also constitutes a component of the smart elderly care multi-information system.

3. Blockchain Architectures for Smart Elderly Care Information Components

As blockchain application research deepens across fields, different blockchain types have emerged based on varying application requirements, with different architectural compositions. Based on decentralization degree, blockchains can be categorized as public chains (fully decentralized, accessible to all), alliance chains (multi-centered, requiring registration and permission), and private chains (weakly centralized, accessible to registered individuals/organizations) [27]. Public chains feature openness and transparency, alliance chains prioritize efficiency, and private chains emphasize security and traceability [28]. Based on governance models, blockchains can be classified as sovereign chains (respecting national sovereignty under regulatory oversight) and other chains (non-sovereign or supranational, unregulated) [29].

For this study: elderly care administrative information requires authoritative oversight and security, suiting a sovereign chain architecture with multiple authorized publishing entities, also aligning with alliance chain characteristics; medical and health information requires efficient circulation and security, fitting an alliance chain; community service information similarly suits an alliance chain; elderly personal health information requires secure, traceable storage, fitting a private chain; and elderly healthcare experience information benefits from wide dissemination, fitting a public chain.

3.1 Sovereign-Alliance Chain Architecture for Elderly Care Administrative Information

The sovereign chain concept originated from Guiyang's Blockchain Development and Application White Paper and has attracted national attention [30, 31]. Elderly care administrative information, uniformly issued by national and local government departments requiring authoritative oversight, suits a sovereign chain architecture. With multiple publishing entities and authorized visitor access, it also aligns with alliance chain characteristics. The sovereign-alliance chain architecture for elderly care administrative information is shown in Figure 1 [Figure 1: see original paper].

Figure 1 illustrates a five-layer architecture: application, contract, consensus, network, and data layers. The data layer (bottom) comprises data blocks, timestamps, chain structure, hash functions, Merkle trees, and ECC (elliptic curve cryptography) encryption to ensure security, traceability, and integrity. Given the authoritative, non-tamperable nature of administrative information, an alliance chain model facilitates internal information flow. The network layer consists of P2P networks, TCP/IP protocols, and propagation protocols. The consensus layer includes PBFT (Byzantine Fault Tolerance), DBFT (NEO consen-

sus), and sovereign chain-specific sovereign consensus management algorithms. The contract layer comprises smart contract scripts, templates, and legal regulations. The application layer (top) interfaces directly with users, providing services through modules including document publication, policy interpretation, laws and regulations, service guides, online consultation, misconduct reporting, and elderly care service platform navigation.

3.2 Alliance Chain Architecture for Medical and Health Information

Medical and health information is generated, stored, managed, and utilized by medical institutions requiring efficient, secure circulation, making it suitable for an alliance chain architecture, as shown in Figure 2 [Figure 2: see original paper].

The application layer includes modules for medical services, patient expenses, electronic medical records, disease surveillance, planned immunization, medical laboratory monitoring, health examinations, and real-time emergency monitoring platforms. The contract, network, and data layers are similar to the sovereign-alliance chain architecture. The consensus layer comprises PBFT and DBFT algorithms.

3.3 Alliance Chain Architecture for Community Service Information

Community service information, issued by community elderly care centers with specific institutional sources requiring efficient, secure circulation, also suits an alliance chain architecture, as shown in Figure 3 [Figure 3: see original paper].

This architecture shares similar contract, consensus, network, and data layers with the medical and health information alliance chain but differs in its application layer, which focuses on elderly services. Modules include community health records, meal services, emergency call and location monitoring, remote medical consultation, transportation, community updates, appliance repair, entertainment, and housekeeping services.

3.4 Private Chain Architecture for Elderly Personal Health Information

Elderly personal health information should offer three permission levels based on individual preferences: confidential, partially public, or non-confidential. Regardless of the level, secure storage and traceability are required, making a private chain architecture appropriate, as shown in Figure 4 [Figure 4: see original paper].

The application layer includes modules for health preservation information, personal medical expense records, personal health records, allergen profiles, chronic disease tracking, and personal exercise data management. Following private chain consensus characteristics, this architecture employs PAXOS and RAFT consensus algorithms. To maximize privacy protection, the network follows a

permission-minimization principle, with users limited to organizational and individual entities.

3.5 Public Chain Architecture for Elderly Healthcare Experience Information

Elderly individuals with long-term diseases possess valuable knowledge about authoritative medical institutions, therapeutic methods, and physiological/psychological experiences during disease progression. This experiential information, when widely disseminated, helps newly diagnosed elderly individuals access first-hand medical information and emotional support. Therefore, a public chain architecture is suitable, as shown in Figure 5 [Figure 5: see original paper].

The application layer includes modules for therapeutic methods, physiological/psychological reactions, patient matching, medical experiences, preventive measures, authoritative institution names, and early symptom warnings. The consensus layer employs POW (Proof of Work), POS (Proof of Stake), DPOS (Delegated Proof of Stake), and RIPPLE consensus algorithms suitable for public chains.

4. Heterogeneous Blockchain Network for Smart Elderly Care Multi-Information Coordination

Smart elderly care multi-information coordination involves collaboration among five information types: administrative, medical, community, personal health, and healthcare experience information. The previous section designed five distinct blockchain architectures tailored to each type's characteristics. However, this creates a new challenge: redundant transactions and computations across different architectures consume substantial power and storage resources. Heterogeneous blockchain network technology addresses this through cross-chain technology, enabling inter-chain information coordination [32].

Smart elderly care multi-information coordination can be viewed as a complex social network. Based on different information storage and utilization subjects, this study constructed five coordination architectures, all built on blockchain technology whose decentralization principles help break boundaries between architectures. Cross-chain coordination relies on blockchain consensus algorithms, achieving consensus mechanisms through cryptography and computer science integration. This paper employs heterogeneous blockchain network technology to construct a network for China's smart elderly care multi-information coordination, enhancing coordination efficiency. The network is shown in Figure 6 [Figure 6: see original paper].

Figure 6 illustrates a heterogeneous blockchain network comprising a main chain and multiple side chains. Respecting China's network and national sovereignty, this study selects the elderly care administrative sovereign-alliance chain as the

main chain, with medical alliance chains, elderly health private chains, community service alliance chains, and elderly healthcare experience public chains as side chains. Cross-chain transactions between side chains and the main chain are achieved through blockchain cross-chain technology, enabling information coordination across different architectures. The main chain connects to virtual main chains (most commonly Ethereum) through bridging.

Heterogeneous blockchains essentially represent alliance chains employing cross-chain technology [33]. Through multi-architecture, highly scalable alliance chains enabling multi-node governance and member collaboration [34], the network achieves cross-chain information coordination, secure transactions, and privacy protection for China's smart elderly care multi-information system.

5. Advantages and Bottlenecks of the Heterogeneous Blockchain-Based Coordination Model

5.1 Advantages

(1) The model retains traditional blockchain advantages while mitigating high energy consumption and storage issues. Traditional blockchain offers: decentralization/weak centralization, eliminating single-point-of-failure risks and enhancing security; immutability through distributed ledger recording, ensuring high credibility; traceability through timestamps. The heterogeneous blockchain model maintains these three advantages, ensuring secure, tamper-proof, traceable information for higher-quality coordination. Traditional blockchain consensus requires substantial computational power, consuming significant electricity. Cross-chain technology eliminates redundant consensus computations across side chains, reducing both energy consumption and storage requirements.

(2) Compared to cloud technology-based coordination, the heterogeneous blockchain model offers superior privacy protection. Elderly individuals often lack strong information security awareness. Without technological protection, their data may be exploited by fraudsters, causing financial loss and reducing willingness to participate. Through improved consensus algorithms, the heterogeneous blockchain model provides enhanced privacy protection compared to traditional cloud-based approaches.

5.2 Bottlenecks

5.2.1 Legal Framework for Potential Malicious Attacks and Derived Risks Blockchain's POW consensus ensures immutability and data consistency, but traditional POW mechanisms face 51% attack risks where users controlling majority computational power could tamper with data. While currently unlikely, this remains a concern without legal safeguards. As a blockchain-derived technology using cross-chain mechanisms, the heterogeneous blockchain model faces similar risks, requiring ongoing exploration of legal and technical

countermeasures.

5.2.2 Lack of Effective Negotiation and Incentive Mechanisms During information coordination, when information publishers must sacrifice interests (e.g., medical institutions with differing coordination permissions facing potential losses), effective negotiation and incentive mechanisms are currently lacking. Multi-party node participation and collaboration are essential for cross-chain coordination. Government-led establishment of negotiation and incentive mechanisms, clarifying rights and obligations of network nodes, represents the most direct solution.

5.2.3 Lack of Unified Smart Contract Standards The heterogeneous blockchain model aims to integrate information across architectures, with smart contracts playing a crucial role. However, smart contracts currently lack unified standards [35]. As combinations of code and scripts without inherent constraints, standardizing smart contracts is an urgent challenge.

Conclusion

Smart elderly care can effectively address China's growing elderly population needs. As family structures become "inverted pyramids" and elderly population proportions increase, smart elderly care is poised to become China's primary elderly care model. This study examined information coordination perspectives, first identifying five smart elderly care information components: administrative, medical, community, personal health, and healthcare experience information. Leveraging blockchain's advantages in information storage and circulation, five distinct blockchain architectures were designed based on decentralization degree and component characteristics: sovereign-alliance chain for administrative information, alliance chains for medical and community information, private chain for personal health information, and public chain for healthcare experience information. Using cross-chain technology with the administrative sovereign chain as the main chain and others as side chains, a heterogeneous blockchain network for smart elderly care multi-information coordination was constructed. The model's advantages and disadvantages were analyzed to explore new coordination models and enhance efficiency.

The study's limitation lies in assessing the authenticity and usefulness of elderly-provided experience information in the public chain architecture, which will be the focus of future research.

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Author Contributions:
Hu Mo: Conceived the research topic and framework, wrote the paper;
Ma Jie: Provided revision guidance and finalized the manuscript.

Note: Figure translations are in progress. See original paper for figures.