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Industrial IoT Using Edge Computing

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Abstract: Blockchain, the technology that powers cryptocurrencies, has garnered much interest. Numerous applications, including the smart grid and the Internet of Things, have embraced it. However, a sizable scalability hurdle constrains Blockchain's ability to support services with frequent transactions. On the other hand, edge computing was developed to expand cloud resources and services distribution to the network's edge. Still, it presently faces difficulties with decentralized management and security. The combination of blockchain technology and edge computing can provide a large scale of network servers, data storage, and validity computation close to the end while maintaining secure access to the network, computation, and storage spread at the edges. Despite the potential of integrated blockchain and edge computing systems, new security issues, problems with scalability improvement, self-organization, function integration, and resource management need to be resolved before wide-scale deployment. In this survey, we examine some of the work done to support the integrated blockchain and edge computing system and discuss the research issues. We list several crucial elements of the merger of blockchain and edge computing, including drivers, frameworks, enabling features, and difficulties. Finally, some more comprehensive viewpoints are investigated.

Keywords: Blockchain, edge computing, network, storage, computation.

I. INTRODUCTION

Blockchain, the technology that powers digital currencies, has lately drawn much interest from manufacturers and tech giants [1]. By 2025, the market for enterprise applications of blockchain will generate $19.9 billion in annual revenue, with 29 major use cases spanning at least 19 various industry sectors, predicts Tactical. Blockchain uses community validation as opposed to centralized digital ledger methods to synchronize distributed ledgers that are replicated among many users. It was created with Bitcoin [2][5] to address the issue of double spending. Blockchain develops into a foundational technology that enables the paradigm change from centralized control to decentralized control, going beyond its initial design and applications. Due to a blockchain's decentralization, transparency, security, immutability, and automation, the ownership of assets and the rights and responsibilities resulting from agreements can be documented there from the information and communications technology viewpoint. Scalability remains a significant problem that keeps these apps from becoming a reality. The scalability of blockchain as it exists currently is constrained [3]. On the other hand, a wide variety of applications have been made possible by the quick advancement of computing technologies. In this setting, edge computing [7] is introduced as an expansion of the cloud. Other terms for edge computing include fog computing, virtual cloudlet, and mobile cloud. Despite claims to the contrary, these technologies share almost identical goals in that they allow billions of devices to operate apps at the network's edge. Like the cloud, edge computing assists the user by providing computation power, data storage, and application services to possess location awareness, maintain low latency, support heterogeneity, and improve the Quality of Service (QoS) of the applications, especially the compute-intensive and delay-sensitive ones. Edge computing's dispersed architecture has many advantages. However, because of heterogeneous edge nodes' interaction and services' migration across edge nodes, it faces major security and privacy challenges. As a result, it makes sense for blockchain and peripheral computing to be integrated into one system. By integrating blockchain technology, the edge computing network can offer dependable network access and management, storage, and computation over many distributed edge nodes. Despite the potential for integrated blockchain and edge computing systems, study challenges still need to be solved before these systems can be widely used. In particular, a combination of strategies at various levels will be used for scalability improvement. Meanwhile, more research needs to be done on the brand-new security concerns brought on by the peripheral outsourcing of a sizable number of services. Additionally, self-organization reduces management complexity by introducing autonomous mechanisms and results in new security issues[4]. Additionally, the network, storage, and computation functions built on blockchain and edge computing should be thoroughly integrated at various levels from various perspectives with flexibility and stability. As a result, extensive research must address resource management, which covers various aspects widely. The directed acyclic graph, big data, and artificial intelligence provide supportive relationships with blockchain and edge computing, to wrap up from a broader perspective.

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II. THE REQUIREMENTS OF INTEGRATION OF BLOCKCHAIN AND EDGE COMPUTING

Several conditions must be satisfied to integrate blockchain and edge computing.

1. Authentication: In edge computing settings with numerous interacting service providers, infrastructures, and services, it is crucial to confirm the identity of these entities. These entities collaborate via their interfaces to reach an agreement by signing smart contracts. Blockchains keep track of entities' rights and needs as the contract is established. Even if they are from distinct security domains, this is essential for creating secure communication channels between the components of edge ecosystems.

2. Adaptability: As time passes, more devices and more complicated applications are available, mainly when blockchain technology is used on devices with limited resources. Therefore, the integrated system of blockchain and edge computing should have the capability to support a fluctuating number of end users and tasks with different complexities, and the flexibility to adapt to the changing environment to allow the object or node to connect or leave the network freely.

3. Network security: Because of its heterogeneity and attack vulnerability, network security is a major issue for edge computing networks. The integration of blockchain into edge computing networks is required to replace the heavy key management in some communication protocols, provide easy access for the maintenance of the massive scale distributed edge servers and make more efficient monitoring in the control plane to prevent malicious behavior's (like DDoS attack, packet saturating).

4. Data integrity: Maintaining and ensuring the accuracy and consistency of data throughout its complete life-cycle is referred to as data integrity. By exploiting the abundance of distributed storage resources of edge computing, replicating data over a set of edge servers as well as a blockchain-based framework for data integrity service in a fully decentralized environment critically hamper the violation of data integrity (the loss or incorrect modification of the outsourced data and the abused uploading). Therefore, data owners and users need a more trustworthy way to verify data integrity.

5. Verifiable computation: Verifiable computation can be delegated to a few unreliable clients while keeping accurate results. Outsourcing computation in edge computing can scale to large numbers of computations without being constrained by the scalability of blockchain. In contrast, the incentive and autonomy of intelligent contracts in the Ethereum blockchain should guarantee efficient computation scheduling and the correctness of returned solutions.

6. Low delay: Generally speaking, transmission latency and computation latency are the two components that make up an application's latency. Indicated by computation latency is the amount of time consumed on data processing and blockchain mining, which depends on the computation power of the system. The capacity to provide fast computing increases from end users to cloud servers but also causes a significant increase in transmission latency. Therefore, the integration of blockchain and edge computing determines the mapping between what kind of computation and where to perform, thus realizing an ideal trade-off between transmission latency and computation latency.

III. FRAMEWORKS OF INTEGRATED BLOCKCHAIN AND EDGE COMPUTING SYSTEMS

This section summarizes the typical frameworks (architectures) of integrated blockchain and edge computing systems. The presented frameworks are based on existing studies and reflect integrated systems' basic ideas and mechanisms. Unfortunately, this summary may not cover all the proposed architectures in literature, since each proposed architecture has its unique original intention, the idea of design, and the working environment.

The study of [8] proposes a distributed blockchain cloud architecture with Software-Defined Networking (SDN) enabled edge computing (fog nodes at the edge of the network), which is categorized into three layers, i.e., device, fog, and cloud. The filtered raw data is transmitted from the device layer to the SDN-enabled fog layer, which is responsible for the real-time data analysis and service delivery for local devices. All the SDN controllers are connected in a distributed manner using the blockchain technique. Each controller is empowered by an analysis function of the flow rule, a packet migration function to secure the network during attacks, and a programming interface to operate the network management. If needed, a fog node reports the results of processed data to the distributed cloud. The device layers access the cloud to deploy the application service and offload computing workloads to the cloud when there are insufficient computing resources. To approve the contributions in computation performance and the transferring and storage of data in the blockchain, the consensus protocol Proof-of-Service is proposed, which uses the 2-hop technique to combine the mechanisms of the blockchain-based multi-layer IoT network model. It divides the whole IoT into two parts: edge layers and high-level layers. The edge layer is a local area network consisting of several objects with a central node managing

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them. However, this central node can also be regarded as a node of the superior layer. The edge layer here seems to be the combination of devices and fog in [8] while the high-level layers are similar to the combinations of fog nodes, fog aggregation nodes and the distributed cloud in [8]. Despite the flexible definition of edge layers, it is required to provide interfaces to the superior layer for addressing, allowing bidirectional data transfer and participating in high-level layer activities as a node. In [9] and [10] an architecture of the blockchain-based IoT virtual resources on edge host is proposed, which enables the fog as an extension of the cloud. The authors focus on how the local edge network configures P2P communicated M2M devices. Virtualization of software-defined IoT components (virtual resources) is introduced to manage the configuration of the large and heterogeneous set of devices. The configuration of virtual resources (code or metadata) is stored as encrypted blocks. Some other work also studies blockchain technology as a platform for edge computing in the specialized application. Without losing generality, we will also glance at their proposed frameworks. A blockchain-based distributed control system for edge computing is proposed in [11]. Fig. 1 shows a general edge computing architecture using blockchain.

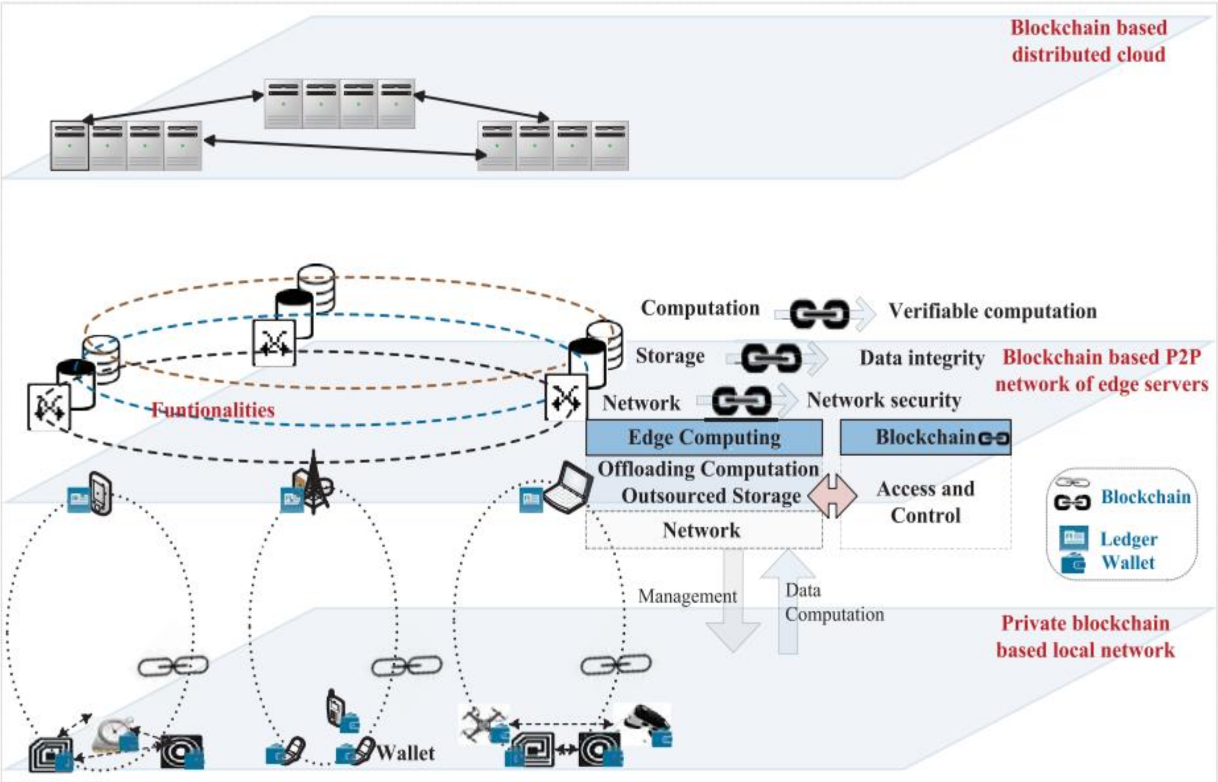

Fig 1: Integrated blockchain and edge computing systems.

IV. CONCLUSION

Furthermore, integrating blockchain and edge computing can address some key challenges associated with traditional centralized systems, such as security risks, high latency, and scalability issues. By processing data at the network's edge, these systems can reduce the amount of data that needs to be transmitted to centralized servers, improving performance and reducing the risk of data breaches. Additionally, the decentralized nature of blockchain can provide increased transparency and accountability, enabling more efficient and secure supply chain management, healthcare, and finance applications. However, some challenges must be addressed when implementing integrated blockchain and edge computing systems, such as interoperability, data privacy, and regulatory compliance. These challenges require careful consideration and planning to develop and implement the systems securely and effectively.

Overall, the integration of blockchain and edge computing has the potential to transform the way we process and manage data, leading to new and innovative applications that can improve efficiency, transparency, and trust in various industries. As these technologies evolve and mature, we expect further advancements and exciting opportunities in this area.

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