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Two Proposed Models for Securing Data Management for Enterprise Resource Planning Systems Using Blockchain Technology

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Abstract: An Enterprise Resource Planning (ERP) system is a software application that serves as a centralized platform to streamline and automate organizational functions and share real-time data, facilitating efficient communication and collaboration. It provides an all-inclusive approach to managing and optimizing business processes, boosting efficiency, fostering cooperation, and giving an overall picture of how the organization is operating. However, the traditional centralized databases in ERP systems pose security concerns. Blockchain Technology can be an appealing alternative as it comes with immutable and decentralized data as well as enhanced security. This study focuses on two methods of securing data management in ERP systems: Organizing the distributed information using The Ralph Kimball data model and optimizing an individual block using Database Sharding. This study does an extensive examination to determine the effectiveness of both suggested strategies, comprising a detailed evaluation that highlights the benefits and limitations of both techniques. This paper intends to patch the security holes in ERP systems to safeguard sensitive data and mitigate risks.

Index Terms: Blockchain Technology, Enterprise Resource Planning, ERP, Ralph Kimball, Dimensional Modelling, Database Sharding.

1. Introduction

Data management and security involve procedures and controls aimed at securing and managing data inside of an organization. In order to ensure the accuracy, usability, and accessibility of data, it is necessary to organize, store, and maintain it throughout its existence. Data collection, integration, storage, retrieval, and analysis are just a few of the tasks involved. The goal of data security, on the other hand, is to protect data from loss, theft, unauthorized access, and breaches. To guarantee data confidentiality, integrity, and availability, security measures, encryption, access limitations, and monitoring, systems must be put in place. Data management and security are now essential for businesses of all sizes in the age of big data and rising cyberthreats. A company's long-term profitability and survival depend on safeguarding sensitive data from illegal access, preserving data quality, adhering to rules, and keeping customer trust.

Furthermore, ERP systems are centralized piece of software made up of connected modules that work together to provide a fully integrated system for planning, managing, and controlling within an organization. ERP is essential in enabling the flow of information inside an organization by integrating all organizational processes, works, and operations. ERP is an essential part of the business that simultaneously affects every department instead of just one at a time [1]. Therefore, implementing an ERP system requires a much larger organizational shift, increasing the competitiveness of the business by strengthening its capacity to produce precise and timely information for management decision-takers [2].

On the other hand, Blockchain Technology is a distributed, decentralized digital ledger technology that is used to record and store information digitally across a number of computers, or nodes [3]. It is a distributed and immutable ledger system that records details of transactions or occurrences. It can do it in a way that is safe, open, decentralized, effective, and reasonably priced. By adopting this consensus process for updating and validating transactions among users of the Blockchain, Blockchain Technology eliminates the need for any centralized authority and mitigates the need of any middleman like Banks and Government.

Consolidating Blockchain Technology in ERP platforms' frameworks could be the cutting edge for businesses' innovations by reshaping associations. Coordinating Blockchain Technology with ERP systems will increase the chances to have genuine information interoperability for different businesses, organizations and banking administrations. Specialists demonstrate that it might change the business tasks and usefulness of organizations in a new, current way [4,5]. Tapscott and Tapscott [6] expressed that Blockchain Technology can surely turn into a massive wellspring of troublesome developments in organizations, by improving, enhancing, and robotizing business processes. Accordingly, coordinating Blockchain Technology with ERP could upgrade improvement and ultimately change the business cycles of organization. Taking on Blockchain Technology with ERP could build security, speed, and effectiveness in exchanges, straightforwardness control, and changelessness, as well as decrease costs [6,7]. In this manner, coordinating Blockchain Technology with ERP can get the trustworthiness of the exchanges put away in the data set, giving devices to construct adaptable and cost-proficient venture frameworks by utilizing its circulated record, savvy contracts, programming connectors, and agreement components, which give an improved arrangement as a combination of Blockchain and ERP [8]. Blockchain Technology also has the ability to guarantee transactions' integrity in addition to consistency, improving operational effectiveness while providing nearly immediate data transactions, reliability, and transparency; as a result, ERP systems' operations can be further optimized [9] and completely transparent services can be provided to all stakeholders worldwide [10]. Since ERP systems are centralized software, information may be accessed via a centralized register. Moreover, integrating Blockchain Technology into ERP may significantly increase manufacturing processes' flexibility, speed, and quality [11,12]. Given that ERP systems concentrate on certain businesses while integrating Blockchain Technology gives greater flexibility, this connection does not compromise security and functionality.

The objective of this study is-

- To identify potential methods to integrate Blockchain Technology with ERP systems.
- To identify all probable or existing issues with existing ERP systems and briefly review the previous theoretical integration approaches of Blockchain Technology and ERP systems.
- To propose better and optimized solutions for integrating Blockchain Technology with ERP systems with the help of Ralph Kimball data model and Database Sharding.
- And to examine the level at which Blockchain Technology may be integrated with ERP systems, as well as to point out the expected shortcomings and benefits of this current research along with potential directions for future studies.

After the Introduction, this paper is divided into three sections. Literature Review in Section 2, where discussion of topics like ERP systems, Blockchain Technology, their contribution to businesses and present issues regarding ERP systems along with previous integration approaches and their shortcomings are present. Proposed Solution is covered in Section 3, where the Proposed Designs and Explanations of the solutions are given along with their features and drawbacks, as well as a brief discussion on the proposed solutions. And lastly, our research limitations and future research scops have been covered in the Conclusion section.

2. Literature Review

2.1. Enterprise Resource Planning System

Enterprise Resource Planning (ERP) is nothing but a software that is used by organizations to manage their business operations like accounting, manufacturing, buying, managing projects, handling risks and regulations, supply chain management, human resources, inventory management and so on. It helps in financial planning, forecasting, budgeting, and reporting for a company.

The integration of various business operations is made possible by the use of ERP systems. By collecting an organization's common transactional information from several sources, ERP systems remove data redundancy and guarantee accuracy with a single source. ERP systems manage every element of manufacturing, planning, and finances, adding transparency to the whole company's process. A number of departments can utilize these integrated systems, which serve as the organization's core hub for end-to-end workflows and data transfer. In essence, it covers a variety of tasks for large, medium-sized, or small organizations, as well as industry-specific adaptations.

2.2. Role of ERP in Data Management of Business

EL Amrani, Rowe, and Geffroy [1] defined ERP systems as for-profit software packages that enable cross-organizational integration via embedded business processes. These procedures frequently employ a single relational database and a number of modules. Data sharing between functional domains is made possible by the use of relational databases since it eliminates the need for repetitive data entry into several databases. Information is only gathered once during the first transaction, stored centrally, and capable of real-time updating. As a result, all levels and modules of planning are based on the same data, making planning and usage feasible for everyone.

The usage of ERP systems and other digital services is replacing manual records and transactions in day-to-day operations for businesses and even for individuals [13]. To connect cross-operational business activities, the majority of expanding enterprises and organizations are now using ERP systems. In addition to consolidating and automating the majority of business operations [14] and facilitating real-time information sharing throughout the whole organization, an ERP system assures improved and additional data, which might result in cheaper costs. ERP systems may increase organizational flexibility by lowering IT expenses, boosting the reliability of IT systems, increasing automation, cutting operational costs, getting rid of pointless operations, and enhancing the accuracy and reliability of the data [15]. This might lead to higher quality [16]. An ERP system is a must for modern businesses, particularly in regard to accounting and administrative administration. This is an indication of how drastically IT has changed accounting and business procedures [17]. The efficacy and efficiency of the organization's entire administration of activities are increased by an ERP system [15]. As a result, an ERP system increases the company's operations efficiency and effectiveness of management [15]. Additionally, it improves performance control. Cost oversight, stock reduction, improved control of inventory, and decision-making may all be facilitated by an ERP system [18]. The promotion of business educational opportunities and empowerment, a boost in staff morale, and an increase in employee satisfaction are all benefits for workers who promote such organizational transformation [15]. Therefore, ERP systems improve management skills among managers and staff while also helping organizations organize and automate their processes.

2.3. Integrating ERP with Other Technologies

Automation and digitalization are necessary because modern firms are dynamic. Industry 4.0 refers to the digitization of the industrial system since it enhances the manufacturing process's adaptability, rapidity, effectiveness, and overall quality while promoting sustainability [19]. It enables interaction among the plant and its surroundings by automating the development of a digital value chain [20]. The development of big data, cloud computing, cyber-physical systems (CPS), the Internet of Things (IoT), and Blockchain Technology has evolved into the wings of the development of smart manufacturing in the framework of Industry 4.0 [4], where different production models have arisen. Businesses may now employ integrated electronic systems for oversight, integration, and tracking operations. The necessary Industry 4.0 characteristics may be added by contemporary, intelligent ERPs. The Internet of Things (IoT) and cloud-based computing may also be integrated into i-ERPs to handle difficulties that develop locally [21] and give companies a competitive edge, immediate access to information from every device, and intelligent and more adaptable ERP systems [22]. It is also possible to integrate i-ERP with intelligent manufacturing execution systems (MES), that would offer real-time data, enhance and manage all elements of production processes, and enable choices to be made virtually quickly. According to [23], a distributed smart system with self-organizing qualities serves as the core of the complex network of smart manufacturing, which blends modern technology for manufacturing with a new generation of information technology.

2.4. Concept of Blockchain Technology

Blockchain Technology is a distributed and decentralized digital ledger technology that allows skipping the intermediaries for transactions [24]. An anonymous individual who went by the nickname Satoshi Nakamoto created the concept of Blockchain, which served as the basis for Bitcoin as a system for peer-to-peer payments [25]. The most

well-known decentralized digital currency, Bitcoin, has demonstrated that it is possible to create confidence in a system devoid of banks or other financial institutions acting as a central clearing house for financial transactions [25].

Furthermore, Blockchain is a relational database-like electronic ledger that allows private as well as public users to publish data publicly in order to generate an impermanent, secured record of transactions. Few persons have the ability to edit or remove records since each one is time-stamped and chronologically connected to the one before it by a cryptographic signature [26]. As a result, data that has been added to a Blockchain cannot be changed or deleted, not even by the system administrator.

There are mainly two types of Blockchain networks-

1. Private Blockchain
2. Public Blockchain

Table 1. Main differences between Private Blockchain and Public Blockchain

Private Blockchain	Public Blockchain
A network administrator controls a private Blockchain, and users must provide their permission to join the network.	Public Blockchains are public networks that allow participation from all users.
A private Blockchain is a permissioned Blockchain.	Public Blockchain is permissionless.
A private Blockchain is somewhat centralized since the network is governed by one or more companies.	Public Blockchains are decentralized, meaning there is no central authority over the network.
Data on a private Blockchain is less secure than data on a public Blockchain since no one has access to the network because participation in it requires authorization.	Information on the public Blockchain is secure because it cannot be altered or revised after it has been validated on the Blockchain.

2.5. Role of Blockchain Technology and ERP integration in Business

Blockchain Technology is proven to be the sixth disruptive revolution in the computer paradigm, according to Mutambaie [27]. Blockchain establishes confidence in an untrustworthy context by being a distributed, open, secure, and immutable record-keeping system [28]. It could work with backend applications, easy-to-use web services, and middleware layers in pre-existing IT systems [29]. Additionally, incorporating Blockchain into an i-ERP system may offer a collaborative platform that would guarantee data efficiency, security, correctness, transparency, and dependability. The ability to access this data varies between Blockchain and ERP systems, despite the fact that both are "libraries" for storing data [30]. ERPs work as a central hub for all of an organization’s data and as an internal hub for all business activity [31]. According to Gartner [32], the integration of Blockchain Technology into ERP has the potential to revolutionize the industry by encouraging trust, boosting transparency, reducing friction across corporate ecosystems, perhaps cutting costs, accelerating transaction clearing, and improving cash flow. Due to the high level of access-control criteria that are maintained [33], the integration of ERP with Blockchain allows organizations to transmit various types of information quickly and securely while ensuring that the data cannot be changed or amended. Dai and Vasarhelyi (2017) drew attention to the simplicity and information security of the data collection process, which employs Blockchain and doesn't involve any human contact to create unchangeable information about transaction records [34]. Because it lowers the cost of information processing and eliminates the need for third parties to validate transactions, Blockchain has practical implications for business, management, and accounting [35]. This ensures huge advantages for all stakeholders.

Table 2. Potential benefits that can be achieved by integrating Blockchain with ERP

Improved Security	Blockchain Technology is known for its elevated level of security, as it uses cryptography to protect data from unauthorized access. This can help to reduce the risk of data breaches or leaks in an ERP system.
Increased Transparency	Blockchain Technology enables more transparency by storing every record and transaction on a decentralized ledger that is accessible to all participants. This might lead to the business's ERP system becoming more responsible and self-assured.
Improved Efficiency	Many operations and tasks inside an ERP system may be automated with the use of Blockchain Technology, which can enhance productivity and lower expenses.
Enhanced Data Integrity	Data is kept across numerous nodes due to the decentralized nature of Blockchain Technology, which can assist to improve the accuracy and dependability of the data.
Greater Flexibility	Blockchain Technology can provide greater flexibility in terms of adapting to changing business needs or processes, as it allows for the creation of smart contracts and other automated processes.
Increased Interoperability	Blockchain Technology can facilitate the integration of an ERP system with other systems and software, improving interoperability and enabling a more seamless flow of information.
Better Tracking and Traceability	Blockchain Technology can help to improve tracking and traceability of goods and materials within an ERP system, enabling businesses to have a more accurate and complete view of their supply chain.

2.6. Issues with ERP and Previously Approached Design Models for Integrating Blockchain with ERP

Concerns about data security and confidentiality, along with the limited flexibility to adapt to changing business needs or processes, and difficulties in transferring data from legacy systems, only add to the challenges of implementing an ERP system. The licensing and pricing structures can also be complex, with limited vendor support or resources for Blockchain integration. The system's scalability and ability to accommodate growth, as well as the efficiency of its performance and its ability to integrate with external stakeholders or partners, also pose challenges. Data inconsistencies or errors, limited visibility and transparency, and difficulties in troubleshooting technical issues are additional concerns that can arise when implementing an ERP system.

Organizations prioritize implementing change to an already established setting, retrofitting, and streamlining operating procedures, which makes ERP implementation complex [36]. Each corporation that installs ERP systems must deal with the system's expense and intricacy, irrespective of their scale [37]. The colossal issues involve implementing ERP systems without thoroughly comprehending and considering all company concepts [37].

ERP systems can be costly to implement and keep up, particularly for small to medium-sized companies. The typical spending per user for an ERP project is $9,000, according to 2022 ERP research [38]. The cost of an ERP implementation for a mid-sized business can vary greatly, with expenses ranging from $150,000 to $750,000 [39]. This is due to a variety of factors such as the number of users that will be utilizing the system and any additional costs that may be incurred [39]. According to a research paper, the failure rate of ERP implementation tends to be high due to the substantial financial expenses associated with implementing ERP projects [40]. An ERP system's high implementation costs were listed as the 12th most frequent problem in a study report, based on how frequently they occur [41]. Organizations also incur hidden costs when providing training to employees on ERP issues and challenges [41]. Integration of ERP with different software systems together is an expensive process, typically costing three to ten times more than implementing a single ERP software system [41]. This expensive cost is a result of the fees paid by system integrators, who are specialized in integrating different software systems, as well as the time-consuming and challenging process of reengineering current processes to function with the new system [41]. Additionally, since the customizations must be re-coded each time the ERP system is updated, it leads to enhancement of costs and makes the overall process labor-intensive [42]. Extensive customizations were also found to have long-term financial effects [42]. If an organization using cloud ERP is dissatisfied with a service provider, it can be challenging for them to switch vendors because doing so can be expensive and time-consuming for a variety of factors, including legal, technological, and more [43]. Cloud-based systems, which are operated and maintained by the provider, often have cheaper initial expenses and are more accessible than on-premises systems [44]. Unlike on-premises systems, which demand a greater upfront cost for permanent use, cloud ERPs are typically charged on a monthly per-user subscription basis [44]. The perceived initial cost savings of cloud-based systems may not be long-lasting, though, as the costs related to each distribution strategy tend to converge over time [44]. Additionally, based on the vendor, the cost of upkeep and assistance may be covered or charged individually [44].

ERP systems offer a high degree of customizability, which can be both an advantage and a disadvantage. On one hand, customization allows organizations to tailor the system to their specific requirements, enhancing its utility and effectiveness. However, on the other hand, this customization process can be time-consuming and costly to set up and maintain [45]. Furthermore, the integration of ERP systems with other systems and software can pose challenges, especially if these systems are not compatible with each other [46]. However, even if an ERP system is properly customized and integrated, its benefits may not be fully realized without an effective user training program. Previous studies have demonstrated that traditional training mechanisms often fall short of providing meaningful learning experiences to users, leading to neutral or low levels of user satisfaction [47]. This lack of training can be problematic, as uninformed users may struggle to use the system correctly, potentially resulting in confusion and imprecision, which in turn could undermine user satisfaction and the credibility of the system itself [47].

ERP systems frequently hold sensitive corporate information, therefore it's critical to make sure the system is safe and that the data is shielded from intrusions or breaches [48]. ERP systems are becoming more open due to the rapidly expanding e-business, and new decisions are required to ensure information security [49]. The creation of a sustainable model starting with system architecture is the first step in assuring information security [49]. In a recent survey by the IDC group, 1,100 organizations were asked to list their top concerns when considering moving their enterprise systems to the cloud. Of these organizations, 50% responded that security and confidentiality of the data were their top worries [50]. Larger enterprises have several security issues when using cloud-based ERP because they feel uneasy storing their sensitive and confidential data there since they must give the supplier authority to handle the data [51]. Additionally, in order for ERP systems to work efficiently and keep up with changing company requirements, continuous updates and maintenance are required. This may be an expensive and time-consuming procedure [52]. Another recent study proposed a framework for increasing security for ERP systems by implementing multi-factor authentication but again there remains a security hole when it comes to modifying data as it will still be a centralized system [13].

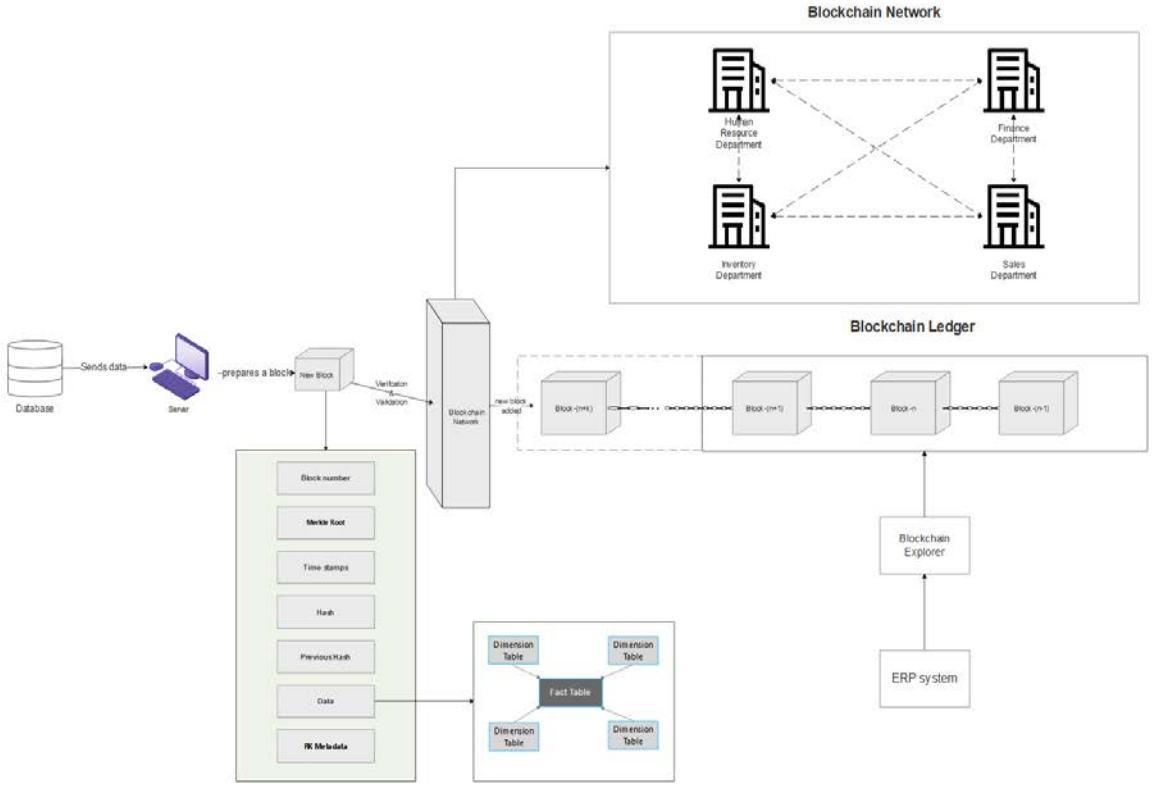

Fig. 1. Proposed Solution with Ralph Kimball Data Model.

Blockchain Technology has emerged as a potential solution to address these concerns by providing a secure and transparent ledger for data storage and sharing. By leveraging Blockchain Technology, ERP systems can ensure the integrity and immutability of data, thus minimizing the risk of data tampering or fraud. Furthermore, Blockchain-enabled ERP systems can facilitate secure and efficient information sharing among different parties, such as suppliers, customers, and other stakeholders.The below-mentioned approaches were previously proposed for integrating Blockchain Technology with ERP systems:

(a) Deploying i-ERP Systems with Built-in Blockchain Functionality: When integrated Blockchain capabilities for i-ERP systems are introduced, they will either function as a layer that complements the existing i-ERP systems or be incorporated into those systems themselves [53].

(b) Blockchain as a Service (BaaS) with ERP Systems for Deploying an Ecosystem: A series of cloud-based hosting services known as Blockchain as a Service (BaaS) enables companies to create, host, and operate their very own distributed ledgers, smart contracts, and nodes inside a cloud environment that is owned and operated by cloud-based vendors [53]. To put it in another way, BaaS acts as a bridge between enterprises and Blockchain platforms. A few of the well-known businesses that provide BaaS are Microsoft, IBM, Oracle, and SAP [53]. BaaS, or vendors manage all the tasks and activities necessary to maintain the infrastructure's security, operability, and accessibility in order to give developers convenience and guarantee the security and dependability of their applications for Blockchain [53]. They do this by simplifying the operation process and reducing deployment costs.

This previous research addressing the integration of ERP and Blockchain, however, still has some shortcomings. The suggested and assessed deployments need to be further refined by correctly planning, analyzing, and implementing in order to be usable in organizations. Since Blockchain Technology implies a full transition to a decentralized and distributed paradigm, this constraint is also the second one. Also, due to the nascent nature of this technology, it is necessary to gather more empirical data in order to assess the effectiveness of both Blockchain and ERP systems.

3. Proposed Solution

Based on the extensive literature review we have carried out, there were many indicators of integrating Blockchain Technology and ERP system with already existing services but there was very little discussion about the data itself and how it should be handled throughout the integration. To optimize the data orientation, the concept of Ralph Kimball Data Model was taken into consideration to integrate both technologies. Database Sharding was also taken into account regarding reducing and optimizing the storage needed to store the data in a possible optimized manner inside

Blockchain Ledger. With the help of Ralph Kimball Data Model and Database Sharding in consideration, two possible solutions were proposed which are mentioned below. Both solutions were proposed for Private Blockchain.

The proposed solution-1 entails the integration of Blockchain Technology into an Enterprise Resource Planning (ERP) system, aiming to organize data with the help of dimensional modelling.

And the proposed solution-2 describes an alternative approach of integrating Blockchain Technology into an Enterprise Resource Planning (ERP) system with an optimization of a block's data size through the option of Database Sharding.

3.1. Proposed Solution-1

3.2. Design Explanation

In this approach, the ERP system will retrieve data from the Blockchain with the help of Blockchain Explorer, where each block inside Blockchain Ledger will house an individual fact table, along with connected dimension tables, in accordance with the Ralph Kimball model. When an ERP system requests recent data, it will search the Blockchain ledger for the matching fact table to retrieve the requested data.

Fact table: A fact table contains the core data that you want to analyze, such as sales, revenue, or customer interactions. It typically consists of a set of numeric measures (such as the quantity sold, the price, or the total revenue) and a set of foreign keys that link to the dimension tables. For example, "How much income did we make by products and market in the most recent quarter?" may be answered using the fact table, which is made to provide business information about the measurements.

Dimension table: A dimension table contains descriptive data about the factors that affect the measures in the fact table, such as time, product, or location. It typically consists of a set of attributes that describe the dimension, such as the product name, the product category, or the product price. The dimension table is used to group, filter, and aggregate the data in the fact table. For example, product dimension table can be used to group sales data by product and to calculate the total revenue for each product.

3.3. Features

The incorporation of the Ralph Kimball model into the approach of integrating Blockchain into an ERP system for organizing data can offer several possible benefits, including:

- ✓ **Structured Data Organization:** The Ralph Kimball model provides a well-established and recognized approach for data organizing, which can offer a structured framework for organizing data in the ERP system. By applying the Ralph Kimball model, the fact table and connected dimension tables in each node of the Blockchain can be organized in a standardized manner, facilitating data retrieval and utilization.
- ✓ **Data Integration:** The Ralph Kimball model highlights data integration, which can help ensure that data from various sources within the Blockchain network can be effectively integrated into the fact and dimension tables. This can enable the ERP system to fetch data from Blockchain nodes and incorporate it into the distributed information warehouses in a consistent and coherent manner.
- ✓ **Data Consistency:** The Ralph Kimball model emphasizes maintaining consistent data across the fact and dimension tables, which can help ensure data integrity and accuracy in the distributed information systems. This can be particularly important in a Blockchain-based approach where data is distributed across multiple nodes, and consistency in data representation and organization can contribute to the overall reliability of the system.
- ✓ **Data Retrieval and Analysis:** The Ralph Kimball model is designed to facilitate efficient data retrieval and analysis, which can enhance the ability of the ERP system to fetch and utilize data from the Blockchain. The organized fact and dimension tables can provide a structured and optimized approach for querying and analyzing data, enabling efficient data processing and decision-making within the ERP system.

3.4. Drawbacks

Though this integration has several expected limitations also, such as:

- × **Complexity:** Implementing the Ralph Kimball model in a Blockchain-based ERP system can add complexity to the system architecture and data management processes. Managing fact and dimension tables in each Blockchain node and ensuring consistency and integration of data across the network, may require additional effort and complexity in system design and implementation.
- × **Scalability:** The Ralph Kimball model may pose scalability challenges in a Blockchain-based approach, as each node in the Blockchain network may need to maintain its own set of fact and dimension tables. As the number of nodes and data volume increases, the management and coordination of distributed fact and dimension tables may become more challenging, potentially affecting system scalability.
- × **Flexibility:** The Ralph Kimball model provides a structured approach for data organizing, which may not be fully flexible to accommodate the unique characteristics of Blockchain Technology. The distributed and immutable nature of Blockchain data may require modifications or adaptations to the Ralph Kimball model to

effectively handle Blockchain-specific features, which may impact the flexibility and adaptability of the system.

- **Implementation and Maintenance Effort:** Implementing and maintaining the Ralph Kimball model in a Blockchain-based ERP system may require additional effort in terms of system development, customization, and ongoing maintenance. This may include designing and implementing appropriate data extraction, transformation, and loading (ETL) processes, ensuring consistency and integrity of data across the Blockchain network, and managing updates and changes to the model as needed.
- **Data Redundancy:** The denormalization of data used by Ralph Kimball's model can result in some data duplication. Denormalization includes storing data repeatedly in order to speed up queries and optimize analytical procedures. Within the framework of dimensional modeling, this duplication is deliberate and serves a purpose.

3.5. Proposed Solution-2

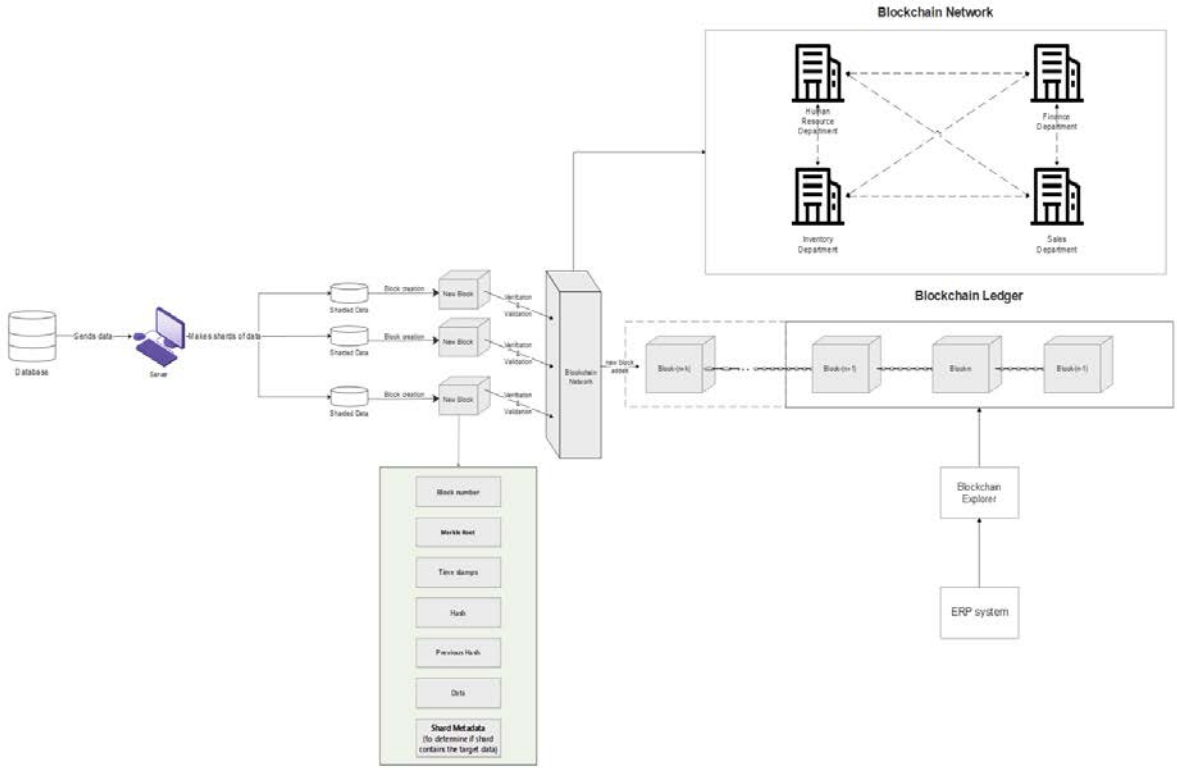

Fig. 2. Proposed Solution with Database Sharding.

3.6. Design Explanation

In this approach, the ERP system will retrieve data from the Blockchain with the help of Blockchain Explorer in the same way as solution-1 but there will not be any dimensional modelling to organize the data. Instead, each block inside Blockchain Ledger will contain a shard of the source data. And when an ERP system requests data, it will search the Blockchain ledger using Blockchain Explorer to retrieve the requested data.

For example, a department's server will fetch the data from local storage which then will be converted into shards of data to minimize load for a single block in Blockchain Ledger, after creation of a new block, it will be validated and verified by the Blockchain Network and then will be added to the Blockchain ledger.

The process of searching for a specific target data within a sharded system necessitates knowledge of the shard in which the data is stored. The implementation of metadata integration inside each block satisfies this criteria. This metadata's main function is to offer crucial details that facilitate the identification and retrieval of the desired data using a variety of tried-and-true Database Sharding techniques.

Database Sharding: A horizontal data division in a relational database or in a search engine is known as a "database shard," or simply "a shard." To distribute the load, each shard is stored on a different database server instance. Some database data persists across all shards, whereas other data is limited to a single shard.

3.7. Features

The usage of Database Sharding with Blockchain might offer potential benefits, including:

- ✓ **Performance:** Through the concurrent execution of queries and transactions made possible by the distribution

of data over numerous shards, response times are shortened. Sharding lessens the strain on individual database servers, avoiding bottlenecks and enhancing system performance in general.

- ✓ **High Availability:** Sharding improves availability and fault tolerance. Other shards can continue to operate in the event of a server or shard failure, ensuring uninterrupted access to the remaining data. For even more data redundancy and availability, sharding can be used with replication strategies.
- ✓ **Efficient Resource Utilization:** Sharding allows for efficient resource management across several servers. Each server processes a smaller portion of the data when the data is split up into shards, which lowers the memory and storage needs of individual servers and improves resource efficiency.
- ✓ **Cost-effectiveness:** Sharding has the potential to be a financially advantageous method of handling massive databases. Sharding enables businesses to employ less expensive and more scalable cloud-based infrastructure or common hardware in place of buying a single, powerful server.

3.8. Drawbacks

However, this integration comes with several expected limitations too, such as:

- × **Complexity of Implementation:** Sharding adds more complexity to the design, implementation, and maintenance processes. It necessitates careful design and study of the data distribution, query routing, and sharding strategies. Sharding principles and methods must be thoroughly understood by developers and administrators.
- × **Performance Variations:** Sharding can boost performance but it can also cause inconsistencies. Some shards may face larger loads than others due to uneven query patterns or unbalanced data distribution, which will result in performance disparities. To maintain constant performance across shards, managing task balance and improving query routing become essential.
- × **Shard Maintenance and Rebalancing:** The process of adding or removing shards, as well as redistributing data among shards, can be labor- and resource-intensive. It takes careful planning and execution to manage shard distribution, ensure data integrity during shard changes, and redistribute data when the number of shards varies.
- × **Increasing Block Count:** As rather than storing one database at a time in an individual block, partitions of the database are being spread across multiple shards, for storing the shards the amount of block will increase as the amount of shard increases

3.9. Discussion

From the above discussion we see that, the integration of Blockchain into an ERP system, along with the adoption of the Ralph Kimball Data Model for organizing distributed fact and dimension tables, presents a promising approach with potential significance. The utilization of Blockchain Technology can offer benefits in terms of decentralization, transparency, data integrity, and security, while the Ralph Kimball Data Model is anticipated to provide a structured framework for organizing data in a distributed manner along with increased data consistency, easier data retrieval and analysis. Also, in stark contrast to the previous models, this solution may encompass a structured framework that addresses the prevalent issue of disorganized data within ERP systems, ultimately mitigating data discrepancies. A distinctive feature of this approach lies in the incorporation of dimensional modelling techniques, which is believed to ensure optimal data structuring within the Blockchain Ledger. By adopting this methodology, the ERP system can gain the ability to efficiently retrieve data by selectively searching for specific fact tables. Consequently, the system may experience enhanced data retrieval efficiency and improved overall performance which previously proposed models lack.

Furthermore, the integration of Blockchain into an ERP system with memory optimization through Database Sharding is believed to be essential to reduce the load on a single block in Blockchain by keeping a range of data and making it easy to find data in Blockchain through an ERP system by using tried-and-true techniques regarding Database Sharding. Also, it is expected to provide improved availability and has the potential to be a financially advantageous method in terms of handling massive databases. And, distinguished by the employment of Database Sharding, this approach is anticipated to resolve numerous drawbacks and present compelling features such as database partitioning, efficient resource utilization and fault tolerance, thus surpassing the capabilities of the previous proposed models.

4. Conclusion

Despite facing time and resource constraints that made practical implementation unfeasible within the scope of our study, we have laid the conceptual diagrams for potential future implementations and provided valuable insights into addressing data security challenges in ERP systems. Future researchers should prioritize the practical application of evaluating the effectiveness of both models in real ERP systems, as our work offers an insightful exploration of their potential strengths and weaknesses. Collecting empirical data and conducting performance evaluations will provide valuable information about their actual performance and scalability. Moreover, conducting security assessments and vulnerability testing is crucial to determine the resilience of these models against potential threats.

Further research efforts should also explore hybrid approaches that combine the strengths of both models to overcome their limitations. Such endeavors could lead to the development of a more robust and adaptable data management framework for Blockchain-based ERP systems, allowing for efficient scaling while maintaining optimal data security.

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