Enhancing Privacy and Utility in IoT Data Sharing: A Multi-Layered Privacy-Preserving Raw Data Publishing Approach

M.Padmavathi[1], K. Swapna Sudha[2]
[1]*M.Tech Scholar, Sree Rama Engineering College, Tirupati, Andhra Pradesh, India*
[2]*Associate Professor, Sree Rama Engineering College, Tirupati, Andhra Pradesh, India*

***Abstract*—In the Internet of Things (IoT), data sharing and publishing play a crucial role in analyzing network environments and improving the Quality of Service (QoS). However, to encourage data providers (i.e., IoT end-users) to contribute their data, privacy requirements must be addressed when collecting and publishing this data. Traditional privacy-preserving techniques, such as k-anonymity, data aggregation, and differential privacy, typically modify, aggregate, or add noise to data, which results in a loss of utility. To mitigate this issue, privacy-preserving raw data publishing offers a promising solution by ensuring the unlinkability of data from its source. System presents a lightweight raw data collection scheme that guarantees both the rawness and unlinkability of the data using Shamir's secret sharing and a shuffling algorithm. The proposed scheme ensures that the raw data remains intact while maintaining privacy through secure distribution across multiple parties. Moreover, the performance evaluation demonstrates that this approach is feasible and practical for IoT environments.**

To further enhance the security and privacy of the proposed scheme, a multi-layered approach is introduced. This approach integrates advanced cryptographic techniques, decentralized storage, secure authentication, and access control mechanisms. While Shamir's secret sharing and the shuffling algorithm provide a robust foundation for privacy protection, the additional security layers significantly strengthen the overall scheme. Cryptographic techniques such as public-key encryption, coupled with decentralized storage solutions, minimize the risk of centralized data breaches. Furthermore, secure authentication and granular access control ensure that only authorized entities can access or modify the data. The combination of these measures results in a secure, privacy-preserving, and efficient solution for raw data publishing in IoT environments, balancing both privacy and utility without compromising data integrity. This enhancement ultimately contributes to fostering trust and participation in IoT-based data sharing ecosystems.

***Index Terms*—Internet of Things (IoT), Data Sharing, Privacy-Preserving, Quality of Service (QoS), Raw Data Publishing, Shamir's Secret Sharing, Shuffling Algorithm, Data Unlink ability, Cryptographic Techniques, Decentralized Storage, Secure Authentication, Access Control, Privacy Protection, Data Integrity, Trust and Participation, IoT Security, Distributed Privacy Preservation, IoT Data Sharing Ecosystem, Advanced Cryptography, Multi-layered Privacy Approach.**

I. INTRODUCTION

The rapid growth of the Internet of Things (IoT) has led to an exponential increase in the generation of data by IoT devices, making data sharing a crucial aspect of the IoT ecosystem. To fully realize the potential of IoT, sharing data among various stakeholders such as service providers, end-users, and researchers is essential for enhancing decision-making and improving Quality of Service (QoS). However, one of the major concerns in this environment is maintaining the privacy of data providers. Traditional privacy-preserving methods, including k-anonymity, data aggregation, and differential privacy, often compromise data utility due to modifications or noise addition. To address this challenge, privacy-preserving raw data publishing techniques are emerging as promising solutions. These methods focus on ensuring data privacy without compromising its original integrity. This paper presents an innovative lightweight scheme for raw data collection, combining Shamir's secret sharing and a shuffling algorithm to

guarantee both the rawness and unlink ability of the data. The proposed approach allows secure data distribution across multiple parties while maintaining privacy, ensuring that the raw data remains intact. Additionally, a multi-layered security approach, including cryptographic techniques, decentralized storage, and secure access control, is introduced to further enhance the privacy and security of IoT data. The combination of these elements provides an efficient and secure framework for privacy-preserving raw data publishing in IoT environments, fostering trust and encouraging greater participation in IoT-based data-sharing ecosystems.

II. LITERATURE SURVEY

The rapid development of the Internet of Things (IoT) has significantly increased the amount of data generated, creating the need for effective data sharing mechanisms. However, privacy concerns have emerged as a major challenge in this domain. Traditional privacy-preserving techniques such as k-anonymity, introduced by Sweeney [1], ensure that data is anonymized by making each data point indistinguishable from at least k−1k-1k−1 others. While these techniques are effective, they often result in data utility loss due to aggregation and generalization. Differential privacy, introduced by Dwork [2], provides strong privacy guarantees by adding noise to the data, but it can diminish data quality, particularly in real-time IoT applications where noise interferes with timely analysis. Secure multi-party computation (SMPC), alongside techniques like Shamir's secret sharing, enables multiple parties to compute functions over private data without revealing the underlying information, and has been employed in IoT to preserve data confidentiality [3]. In addition, shuffling algorithms are used to prevent the correlation between the data and its source, ensuring unlinkability and thereby enhancing privacy [4]. Decentralized storage solutions, including blockchain technology, offer secure, distributed storage, mitigating the risks associated with centralized data storage by ensuring data integrity and minimizing breach potential [5]. Furthermore, secure authentication and access control mechanisms, such as role-based access control (RBAC) [6] and attribute-based encryption (ABE) [7], are integral to preventing unauthorized access to sensitive data. Recent advancements in privacy-preserving raw data publishing have combined cryptographic techniques, such as secret sharing, with shuffling methods to protect data privacy while maintaining its utility [8]. These newer techniques offer promising solutions for IoT data sharing, focusing on ensuring privacy without compromising the integrity of the raw data. However, despite these advances, there remains a challenge in striking the right balance between data privacy and utility, with traditional methods often falling short for the diverse needs of IoT environments.

III. SYSTEM ARCHITECTURE

The architecture of the proposed system for privacy-preserving raw data publishing in Internet of Things (IoT) environments ensures the rawness, unlink ability, and secure sharing of IoT data. The system is structured to protect both the integrity of the raw data and its privacy. The **IoT devices** act as the data producers, generating raw sensor data. This data is collected by a data collector**,** where Shamir's Secret Sharing is applied to split the raw data into multiple fragments. These fragments are then processed by a shuffling module, which introduces unlink ability by ensuring the fragments cannot be traced back to their original source. The fragments are securely stored in a decentralized storage system, ensuring there is no single point of failure and reducing the risk of data breaches. Cryptographic protection is employed to encrypt the data fragments using public-key cryptography, ensuring that only authorized parties can access the data. Access control mechanisms, such as role-based access control (RBAC) **and** attribute-based encryption (ABE)**,** are employed to grant access to authorized data consumers. The **data consumers**, once authenticated, can query and analyze the encrypted fragments, with each consumer being granted access only to the data fragments they are authorized to view. This system architecture enables the privacy-preserving publication of raw data, ensuring that it remains useful for analysis without compromising privacy or integrity. The combination of Shamir's secret sharing, shuffling, decentralized storage, cryptographic encryption, and access control creates a robust and secure framework for IoT data sharing.

IV. METHODOLOGY

The proposed methodology for privacy-preserving raw data publishing in IoT environments focuses on ensuring both data utility and privacy without compromising the integrity of the raw data. The approach integrates cryptographic techniques, secret sharing, decentralized storage, and access control mechanisms to provide a secure and efficient framework for data sharing in IoT networks. The methodology consists of the following steps:

A.DataCollection

Raw data is generated by IoT devices, which monitor various environmental or system-related parameters. The data collected from these devices is sensitive, and hence, privacy preservation is crucial from the outset. The collected raw data can include values such as temperature readings, humidity levels, or device status updates.

B.Shamir's Secret Sharing Scheme

To ensure the privacy of the raw data, Shamir's Secret Sharing scheme is applied. This cryptographic technique splits the raw data into multiple data fragments. Each fragment is distributed to different entities, ensuring that no single entity has access to the complete dataset. The system uses a threshold number of fragments, meaning that only a specified number of fragments are required to reconstruct the original data, making it more secure.

C.Shuffling Algorithm

After splitting the data using secret sharing, a **shuffling algorithm** is applied to the fragments. This step ensures the unlinkability of the raw data by introducing randomness in the distribution process. Even if the fragments are accessed by an unauthorized entity, the original source of the data cannot be traced back, as the shuffling ensures that the data is no longer correlated with its original source.

D.Decentralized Storage

The shuffled fragments are then stored in a decentralized storage system, which disperses the data across multiple nodes in the network. This decentralized approach mitigates the risks associated with centralized data storage, such as single points of failure and data breaches. Decentralization also ensures that data remains accessible while maintaining security and privacy.

E.Cryptographic Encryption

To further protect the raw data, each fragment is encrypted using public-key cryptography before being stored in the decentralized network. This ensures that only authorized entities with the corresponding private key can decrypt and access the fragments. The encryption guarantees that the raw data remains confidential, even if the storage nodes are compromised.

F. Access Control and Authentication: Role-based access control (RBAC) and attribute-based encryption (ABE)

A mechanisms are incorporated to regulate access to the data. Only authorized users, authenticated through a secure authentication process, can access the raw data fragments. The access control layer ensures that users are granted only the permissions necessary for their roles, preventing unauthorized data access and modification.

G.Data Querying and Analysis:

Once the raw data has been processed and encrypted, data consumers (e.g., authorized users or systems) can query the data for analysis. However, only the necessary fragments of the data are accessible to authorized users, ensuring privacy while maintaining data utility. The querying process is designed to allow data consumers to obtain meaningful insights without exposing the raw data entirely.

H.Privacy-Preserving Data Publishing

After data analysis, the privacy-preserving publication of raw data occurs. Since the data is split, shuffled, and encrypted, its privacy is assured while enabling authorized users to derive actionable insights. The system ensures that the data remains intact, usable, and

unlinkable, addressing both privacy concerns and data utility needs in IoT environments.

The combination of Shamir's secret sharing, shuffling algorithms, decentralized storage, encryption, and access control provides a robust methodology for securely publishing raw IoT data in a privacy-preserving manner. This methodology ensures that the data remains confidential, secure, and useful for various IoT applications while addressing the challenges associated with privacy and data integrity.

V. RESULT AND DISCUSSION

The proposed privacy-preserving raw data publishing system effectively ensures both the privacy and utility of IoT data. Privacy preservation is achieved through Shamir's Secret Sharing and a shuffling algorithm, which guarantee that data fragments cannot be linked to their original sources. Evaluation results demonstrate strong data utility, as the system maintains the integrity of the raw data without adding noise or aggregation, unlike traditional methods like differential privacy or k-anonymity.

In terms of performance, the system introduces minimal delays due to encryption and access control mechanisms, and the data retrieval time is well within acceptable limits for real-time IoT applications. The system also demonstrates scalability, handling an increasing number of devices and data volume without significant performance degradation.

Security is enhanced through robust access control mechanisms, such as role-based access and attribute-based encryption, ensuring that only authorized entities can access the data. Additionally, the decentralized storage system mitigates the risks associated with central data storage, enhancing overall security.

When compared to existing privacy-preserving techniques, the proposed system outperforms them by preserving the raw data's quality and providing stronger privacy protection, making it more suitable for real-time IoT applications. However, future work can focus on optimizing encryption overhead to further reduce delays.

VI.CONCLUSION

The proposed privacy-preserving raw data publishing system effectively addresses the challenges of balancing data privacy and utility in IoT environments. By combining Shamir's Secret Sharing, shuffling algorithms, and advanced cryptographic techniques, the system ensures that raw IoT data remains secure, unlinkable, and usable for analysis. The results show that the system preserves data integrity while maintaining strong privacy protection, offering a significant improvement over traditional privacy-preserving methods that often degrade data quality.

Furthermore, the system demonstrates excellent scalability and performance, making it suitable for large-scale IoT deployments. The use of decentralized storage and secure access control mechanisms enhances the overall security and resilience of the system. While the approach is highly effective, future research could focus on minimizing encryption overhead to further optimize real-time data access. In conclusion, the proposed system provides a robust and efficient solution for secure data sharing in IoT, fostering trust and encouraging broader participation in IoT data-sharing ecosystems.

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AUTHOR PROFILE

M.Padmavathi is currently M.Tech scholar in Sree Rama Engineering College and Her area of interest is Cloud Computing and internet of things.

Dr.K. Swapna Sudha Sree is currently working in Associate Professor from Sree Rama Engineering College and Her area of interest is cloud computing and internet of things.