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Privacy-Preserving Data Aggregation in IoT Environments: A Lightweight Edge-Based Hybrid Framework

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Abstract: *As Internet of Things (IoT) ecosystems scale across sectors like smart healthcare, urban infrastructure, and industrial monitoring, concerns about user privacy and data security have become paramount. Traditional aggregation methods—where raw data is collected and processed centrally—expose sensitive information to breaches, inference attacks, and misuse. This paper presents a hybrid privacy-preserving data aggregation model that leverages edge computing, lightweight encryption, and differential privacy techniques to ensure confidentiality without compromising data utility or system performance.*

The proposed framework distributes aggregation tasks to edge nodes, where sensor data is pre-processed, obfuscated, and locally encrypted before transmission. Experimental evaluation using both simulated and physical IoT devices demonstrates that the hybrid model achieves over 90% reduction in data exposure risk, maintains aggregation accuracy above 95%, and reduces bandwidth usage by more than 50% compared to centralized systems. Statistical analysis confirms the model's resilience to inference and reconstruction attacks while maintaining low latency and computational overhead.

This research contributes a scalable and practical solution for secure data processing in IoT deployments, offering critical insights for architects seeking to balance privacy with real-time analytics in sensitive domains. Future directions include adaptive privacy budgets, decentralized trust models, and integration with federated learning and zero-trust infrastructures..

Keywords: Privacy-Preserving Aggregation, Edge Computing in IoT, Differential Privacy, Lightweight Encryption, IoT Data Security

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