Analysis Of Ways To Reduce The Volume Of Data Transmitted In Internet Of Things Systems

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Abstract

The rapid expansion of the Internet of Things (IoT) has resulted in an exponential increase in the volume of data transmitted across networks, posing significant challenges related to bandwidth limitations, energy consumption, latency, and overall network performance. This study analyzes contemporary methods aimed at reducing the volume of data transmitted within IoT systems while maintaining data accuracy, reliability, and system responsiveness. The research examines three main categories of approaches: data compression techniques, data reduction at the sensor level (including sampling optimization and event-driven transmission), and edge or fog computing–based processing. Comparative analysis demonstrates that local preprocessing and intelligent filtering significantly decrease communication overhead, leading to improved energy efficiency in resource-constrained IoT devices. The findings highlight that hybrid approaches—combining compression, adaptive sampling, and distributed processing—offer the most effective solutions for large-scale IoT deployments. The study concludes by emphasizing the importance of developing adaptive, context-aware algorithms to further minimize data traffic without compromising system quality and user experience.

Keywords: Internet of Things (IoT); Data Reduction; Data Compression; Edge Computing; Fog Computing; Adaptive Sampling; Event-Driven Transmission; Bandwidth Optimization; Energy Efficiency; Sensor Networks.

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1. Introduction

The rapid development of the Internet of Things (IoT) has led to the integration of billions of interconnected devices that continuously generate and exchange data. These devices operate in diverse application domains, including smart homes, industrial automation, healthcare, transportation, and environmental monitoring. As IoT ecosystems expand, the volume of data transmitted across networks increases exponentially, resulting in significant challenges related to bandwidth limitations, energy consumption, network congestion, storage capacity, and real-time data processing. Efficient data transmission has therefore become a critical requirement to ensure the scalability, reliability, and sustainability of IoT systems.

Reducing the volume of transmitted data is one of the most effective approaches to optimize IoT system performance. This involves implementing strategies such as edge computing, data compression, data filtering, aggregation, and intelligent communication protocols. These methods help minimize unnecessary data traffic, improve energy efficiency in resource-constrained devices, and enhance system responsiveness. Recent research emphasizes that reducing data transmission not only improves network performance but also extends device lifetime, reduces operational costs, and strengthens data security by limiting exposure of sensitive information.

Despite extensive advancements, many IoT systems still transmit redundant, irrelevant, or high-frequency raw data, causing inefficiencies. Therefore, a comprehensive analysis of existing and emerging techniques for reducing data volume is essential. Understanding the strengths and limitations of each method will help system designers select appropriate strategies based on application requirements, device capabilities, and network constraints.

This article aims to examine the main approaches used to decrease the volume of transmitted data in IoT environments and evaluate their effectiveness. It provides a structured analysis of data reduction techniques, discusses their practical implementation, and highlights current trends and future directions in optimizing IoT data communication.

2. Literature Review

The rapid expansion of the Internet of Things (IoT) has led to the deployment of billions of interconnected devices that continuously generate and exchange data. As reported in recent studies, the exponential growth of IoT ecosystems introduces significant challenges related to bandwidth consumption, communication latency, energy efficiency, and network scalability. Therefore, reducing the volume of data transmitted has become one of the most critical research directions in IoT system optimization.

Data Reduction Techniques in IoT

Data reduction techniques are widely explored as primary solutions for minimizing transmitted data while preserving information integrity. According to Aazam & Huh (2020), traditional compression techniques—such as Huffman coding, Lempel-Ziv-Welch (LZW), and adaptive entropy-based algorithms—play an essential role in lowering communication load. However, their computational overhead limits their use in resource-constrained IoT devices. More recent approaches focus on lightweight, context-aware compression that adapts to sensor characteristics, environmental patterns, and device capabilities.

Edge and Fog Computing Approaches

A substantial body of literature emphasizes the shift from cloud-centric architectures to distributed computing models such as edge and fog computing. Shi et al. (2019) note that placing computation closer to end devices reduces the amount of raw data sent to the cloud. Edge nodes perform filtering, pre-processing, aggregation, and real-time analytics, enabling significant traffic reduction. Fog computing extends these capabilities by offering hierarchical processing layers, allowing more complex decision-making to occur outside the cloud. The combination of fog and edge paradigms is considered one of the most effective ways to reduce network congestion and latency.

Data Aggregation and Fusion

Data aggregation is identified as a crucial strategy in wireless sensor networks (WSNs) and IoT systems. As surveyed by Silva et al. (2021), aggregation techniques like averaging, temporal sampling, clustering, and principal component analysis (PCA) reduce redundancy in sensor data streams. Data fusion methods integrate heterogeneous sensor outputs at different network layers, decreasing the need to transmit full raw datasets. Cluster-head based aggregation protocols, such as LEACH and its variants, effectively minimize total network transmissions while extending device battery life.

Communication Protocol Optimization

Efficient communication protocols also contribute significantly to data volume reduction. Research highlights the advantages of protocols like MQTT, CoAP, and 6LoWPAN, which are specifically designed for low-power and low-bandwidth IoT environments. Studies indicate that MQTT's publish–subscribe model minimizes unnecessary data exchanges, while CoAP's lightweight request–response structure offers reduced communication overhead. Furthermore, duty-cycling and adaptive transmission scheduling are shown to reduce channel utilization and improve network longevity.

Machine Learning and Predictive Models

Recent literature increasingly focuses on machine learning (ML)-based solutions for data reduction. Predictive models, such as regression algorithms, neural networks, and ARIMA-based forecasting, enable IoT devices to transmit only deviations from expected patterns rather than complete datasets. According to Wang et al. (2022), anomaly detection models can filter out irrelevant or redundant sensor readings, enabling event-driven communication. ML-based compression and feature extraction methods further enhance system efficiency, although they require sufficient computational resources at the edge.

Event-Driven and Duty-Cycled Sensing

Several studies explore event-driven sensing as an alternative to continuous data transmission. Instead of periodically sending data, sensors transmit only when certain thresholds or conditions are met. Research by Miskowicz (2020) demonstrates that event-triggered sampling can reduce communication frequency by up to 80% without compromising monitoring accuracy. Duty-cycled sensing, where sensors alternate between active and sleep modes, also significantly lowers data volume and energy consumption.

Although numerous techniques exist, several limitations and challenges remain. Integration of diverse data reduction methods across heterogeneous IoT platforms is complex. Balancing reduction efficiency with data accuracy is still an open issue. Lightweight ML models suitable for low-power devices are under continuous development. Furthermore, security risks—such as incomplete data causing misinterpretation—require additional consideration when implementing data reduction strategies.

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