Wireless Sensor Networks (WSNs)

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ABSTRACT

In recent times, there has been notable progress in the rapid advancement of IoT-based wireless technologies across various sectors. The IoT, a network facilitating independent communication among physical objects, devices, sensors, and related entities, has become pervasive. A pivotal component within the realm of IoT is the Wireless Sensor Network (WSN), which has swiftly permeated diverse real-time applications. Virtually every facet of our daily routines now witnesses the influence of IoT and WSNs, encompassing both critical and non-critical functionalities. Typically, WSN nodes are diminutive, battery-powered devices, underscoring the significance of energy-efficient data aggregation algorithms in prolonging network longevity.

Various methodologies and strategies have been proposed for enhancing the energy efficiency of data aggregation in IoT-WSN systems. This investigation delves into existing literature, particularly emphasizing wireless networking attributes that facilitate data aggregation and energy preservation.

INTRODUCTION

The advent of wireless networking technologies has led to profound changes in many areas of our daily lives. A prominent technology driving future developments is the Internet of Things (IoT). By incorporating IoT, a multitude of devices can be interconnected in the physical world, significantly altering our daily experiences.

Fundamentally, the Internet of Things involves the integration and interaction of smart devices, leading to innovative applications and technological progress. This includes items like home appliances, security cameras, and environmental monitoring sensors, which are equipped with various transceivers, microcontrollers, and communication protocols to enable data sharing and control.

Within this networked environment, real-time modules such as sensors are connected to transmit collected data to centralized repositories. This ensures cumulative storage and access for authorized users. The unique features of IoT, which leverage wireless technologies, differ from those of traditional wired or wireless systems, mainly due to the vast number of communication devices involved.

Despite the rapid technological advancements, significant challenges related to energy consumption have emerged. The exponential increase in communication and data exchange rates has led to unsustainable levels of energy use and carbon emissions.

Importance of IoT in WSN

Numerous research articles and studies have explored various energy-saving strategies for Wireless Sensor Networks (WSN) and Internet of Things (IoT) systems. This section reviews some of these significant works, focusing on their main themes and classifications:

One notable study [11] introduced a solar-powered Precision Agricultural (PA) network that employs a Wireless Sensor Network (WSN) within an IoT framework. This system supports smart agriculture by delivering real-time data on factors such as saltwater intrusion, soil moisture, water levels, wet conditions, temperature, and land status. The information is presented in a user-friendly format, enabling farmers to manage their agricultural practices more effectively.

Another research effort [14] introduced a method employing the Chaotic Whale Optimization Process to enhance energy consumption in WSN-IoT environmental activities. Comparative analysis demonstrated superior energy efficiency of this approach over conventional methods, highlighting its efficacy in integrated WSN-IoT systems.

From the standpoint of Wireless Sensor Networks (WSNs), research [15] examined several performance metrics, including delays, energy usage, jitter, throughput, and packet delivery ratios (PDR). This study assessed routing protocols by focusing on factors like latency, bandwidth, jitter, and delay, and suggested an algorithm to improve AODV routing within IoT applications.This involved integrating the internet access table and routing table into a unified structure, aiming to optimize the AODV protocol's performance in IoT scenarios, as assessed through simulation studies using the NS2 simulator.

A recent contribution [19] presented an enhanced routing protocol featuring a new data transfer system and improved Cluster Head (CH) selection technique. This novel protocol aimed to bridge the gap between WSN simulations and real-world diverse environments. Simulation results demonstrated the protocol's performance superiority over existing methods like Hy-IoT, emphasizing its potential impact on practical IoT deployments..

Challenges of WSN in IoT

The complexity of the Internet of Things (IoT) is amplified by the interaction of various devices across multiple contexts, which creates difficulties in establishing robust security measures. Current research on Wireless Sensor Network (WSN) security often addresses individual issues without adequately considering the comprehensive impacts of IoT capabilities and the concepts explored in this discussion.

Real time management

A primary challenge in resource-limited sensor networks is effective real-time management. This necessitates an intelligent, data-driven middleware capable of selectively transmitting information only when it exceeds a certain threshold. Furthermore, designing an efficient service gateway is vital, as it aims to minimize data transfer volumes through continuous analysis of user data. These elements are essential for enhancing the performance of IoT systems that operate under resource constraints.

Security and privacy

In real-world scenarios, considerations such as privacy, safety, and trust emerge as pivotal concerns. Ensuring different levels of safety presents a complex and nuanced challenge. Notably, security measures are effective in Machine-to-Machine (M2M) deployments owing to the pre-existing trust relationship between the device and the server [30].

Embracing the "IP to the field" approach imposes extra duties on sensor nodes in addition to their main functions. As a result, these sensor nodes take on new roles and face novel challenges. Three potential tasks associated with this expanded role include network configuration, security, and maintaining service quality (QoS). The subsequent discussion addresses these topics comprehensively.

Quality of service

Maintaining high-quality service (QoS) for sensor nodes depends on the collective intelligence provided by the diverse devices within the Internet of Things (IoT) ecosystem. The variety of devices allows for effective distribution of workloads among nodes with available resources. Due to the ever-changing nature of network configurations and connection attributes, ongoing attention is necessary for the QoS techniques currently accessible online.

Configuration

Besides upholding security and ensuring quality of service, sensor nodes are tasked with various other responsibilities.These tasks encompass handling networking operations when a new node joins the network, facilitating self-healing by detecting and correcting faulty nodes, and managing addresses to create scalable networks, among other responsibilities. However, the autonomous configuration capability of the latest Internet node is not standard. Hence, for optimal functionality of this network arrangement, users must install requisite software and undertake precautionary measures to prevent device malfunctions.

Confidentiality

IoT security introduces several concerns, with confidentiality ranking among the most critical. Utilizing encryption methods like Blowfish, AES block cipher, and Triple DES helps maintain data privacy [37]. However, encryption alone is inadequate for preserving data and information confidentiality.

To compromise sensitive information, attackers may conduct traffic analysis on encrypted data. Furthermore, utilizing a shared group keypad, malicious nodes could breach neighboring sensor nodes, intercept transmissions, and decrypt confidential data.

Data aggregation

As mentioned earlier, Wireless Sensor Networks (WSNs) are crucial elements of the Internet of Things (IoT) and have quickly expanded into various applications. These networks generally comprise small, battery-powered nodes and encounter issues with data aggregation that affect the overall lifespan of the network.

Various issues have been identified during data collection, notably increased energy consumption and the need for prolonged network lifespan. To ensure effective dissemination of sensed data while maintaining service efficiency, data aggregation techniques are commonly employed. The objective of these techniques is to efficiently organize and encapsulate data packets, thereby reducing energy consumption, mitigating network congestion, minimizing latency, ensuring data consistency, and addressing other pertinent concerns.

Conclusion

The continuous advancements in computer technology have greatly propelled the development of Wireless Sensor Networks (WSNs), enabling them to constantly monitor critical parameters. WSN solutions integrated with the Internet of Things (IoT) are garnering increasing popularity. However, these systems face constraints in terms of resources, power, and bandwidth, particularly in point-to-point transmission scenarios. Data aggregation emerges as a promising solution to mitigate these limitations.

A key challenge in sensor networks lies in the energy-efficient analysis of critical data. To address this, various data aggregation techniques have been devised, which are examined in this study. This review explores the literature concerning the role of IoT in WSNs, subsequently delving into multiple data aggregation strategies proposed in prior research. These approaches aim to enhance network security, prolong lifetime, improve quality of service, and conserve energy.

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