Sustainable IoT Networking: Enhancing Lifetime with Mobility-Aware Clustering and Energy-Efficient Routing in WSNs

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Abstract:

This study introduces the Mobility-Aware Weighted Clustering Algorithm (MAWCA) to optimize cluster head (CH) selection and enhance routing energy efficiency for mobile nodes in Internet of Things (IoT) networks. MAWCA considers multiple factors as weighted components during CH election, including node degree difference, neighbor variations, cumulative time, node mobility, and latency. Additionally, an Energy-Aware and Secure Multi-Hop Routing (ESMR) protocol, incorporating a secret sharing mechanism, is integrated to boost energy efficiency and ensure secure communication. The proposed approach includes a quantitative analysis of data links to minimize routing disruptions and improve overall network performance. By enabling secure and efficient multi-hop data routing, the method aims to provide a lightweight, high-performance solution for wireless sensor networks (WSNs) in IoT, ultimately extending network lifetime. Extensive simulations and evaluations demonstrate significant improvements in energy efficiency, security, and network stability, making this approach well-suited for resource-constrained IoT environments.

Keywords: Wireless Sensor Network (WSN), Internet of Things(IoT), Mobility-Aware Weighted Clustering Algorithm (MAWCA) and Energy-Aware and Secure Multi-Hop Routing (ESMR) protocol.

I. INTRODUCTION

Improving network efficiency and security is critical in the rapidly developing Internet of Things (IoT), where linked devices easily share data and gather information from one another. In Internet of Things ecosystems, wireless sensor networks (WSNs) are essential for gathering data from far-flung and often mobile nodes. On the other hand, battery-powered sensors' limited energy resources provide serious problems for the lifetime and efficiency of networks.

This paper offers a unique solution that combines the Energy-Aware and Secure Multi-Hop Routing (ESMR) protocol with the Mobility-Aware Weighted Clustering Algorithm (MAWCA) to address these issues. The objective is twofold: first, to maximise routing energy efficiency by intelligently choosing cluster heads (CH) for mobile nodes in Internet of Things networks; and second, to guarantee safe and effective multi-hop data routing, which will improve network performance in general.

MAWCA selects the best CHs by utilising a number of factors, such as node mobility and communication latency, to maximise routing energy usage. The ESMR protocol also incorporates security features including secret sharing methods and energy awareness to improve network efficiency and safeguard data transfer.

In addition to increasing network stability and energy efficiency, this integrated strategy also strengthens data security, which is essential for Internet of Things applications that handle sensitive data. The suggested technique seeks to reduce routing disturbance and offer a simple yet powerful solution for IoT-based WSNs by carrying out an extensive quantitative analysis of data links.

The efficacy of the suggested techniques is shown by simulations and assessments, exhibiting notable improvements in network performance, security, and energy economy. This study opens the door for improved functionality and dependability in a variety of IoT applications by contributing to the continuing efforts to build reliable and effective solutions for IoT networks.

1.1 Clustering Protocols in Wireless Sensor Networks (WSNs)

Wireless Sensor Network (WSN) Clustering Protocols In Wireless Sensor Networks (WSNs), the hierarchical, non-overlapping structure of sensor node clusters is established using clustering protocols. The self-organization of sensor networks depends on a strong clustering strategy. Clusters with almost equal radii and well-placed cluster heads can be formed with the help of efficient clustering techniques. Route discovery between cluster heads is sufficient to construct an efficient network route in a clustered network as every node is connected to a cluster head. Clustering makes multi-hop route discovery easier and transmission counts in large sensor networks lower than in flat, non-clustered networks.

WSNs have a number of difficulties, the main one being optimising network lifetime and stability. It is usually not practicable to change the batteries in hundreds or thousands of sensor nodes that have been installed. This issue is solved by clustering, which entails assembling sensor nodes into clusters. The members of each cluster elect or appoint the cluster head, who serves as the leader of each cluster. Data is gathered by the cluster head from the nodes in its cluster and sent to a destination, often the base station.

Researchers often use clustering techniques to accomplish objectives concerning the scalability and lifetime of networks. A hierarchical structure may be established by applying different clustering algorithms, which lowers the cost of communication with the base station. This method improves WSN functioning and overall efficiency while also optimising energy consumption.

1.2 Routing Protocols in Wireless Sensor Networks (WSNs)

Wireless sensor networks (WSNs) are becoming more and more important for a variety of uses. Some applications require fast data delivery with little interruption, although many prioritise throughput above latency. Because various applications demand distinct routing protocols and network architectures, it becomes crucial to understand them. WLAN and ZigBee-based WSNs are used in a performance study to assess different routing strategies..

Routing protocols play an important role in establishing the path data takes from source to destination. Since it depends on variables including network type, channel properties, and performance indicators, choosing the best path may be challenging. A base station receives data from sensor nodes in a wireless sensor network (WSN), processes it, and decides what to do. Furthermore, sensor nodes that participate in multi-hop communication forward data while also acting as bridges to connect additional nodes to the base station.

Routing is a key activity of the network layer that essentially entails figuring out the best path from a source node to a destination node. For dependable and efficient data transfer within WSNs, it is imperative to comprehend and apply appropriate routing protocols.

II. RELATED WORKS

An enhanced multitier energy-efficient clustering protocol (EMEECP-IOT) for heterogeneous wireless sensor networks (HWSN) linked with the Internet of Things (IoT) is introduced in Yongcheng Wang's 2022 paper. On the basis of network stability, received packets, average throughput, standard deviation, and residual energy, the suggested protocol is compared to the current ones. According to simulation studies, EMEECP-IOT performs noticeably better than current protocols, increasing network longevity by 35% and lowering energy usage by 21%. This protocol, which aims to improve energy economy and network lifetime, is especially helpful for WSN and IoT applications.

R.Prema et al. The Secured Power Aware and Energy Efficient Routing Protocol (SPAEERP) was published in the European Journal of Scientific Research in 2013. It incorporates a unique cryptosystem as well as dynamic transmission power and routing decisions to achieve application-specified communication latency at low energy cost. The results of comprehensive simulation in NS2 demonstrate that the proposed SPAEERP improves QoS while utilising less power and energy. Cryptool is used to test the unique suggested cryptosystem.

In order to increase network lifetime, Muhammad Bilal et al. (2022) suggest a distributed, battery-aware clustering and routing system in their paper presented at the IEEE Wireless Communications and Networking Conference. In order to account for battery health and remaining charge during each cluster creation, this technique employs a charge utility metric. Analysis and simulations show that by optimising energy utilisation based on node battery conditions, protocols can achieve considerable lifespan increases over current ones. The study emphasises how important battery-aware design is to improving WSN longevity and efficiency.

R.Prema et al The Power Aware Routing Protocol (PARP) for Wireless Sensor Networks, which was published in Scientific Research, addresses the challenge of balancing energy efficiency and quality of service (QoS) in wireless sensor networks by dynamically adjusting transmission power and routing decisions. Simulations suggest that PARP improves QoS while decreasing power consumption.

In a 2022 work published in Sensors International, Subha R and Anandakumar H present the Improved Emperor Penguin Optimisation Algorithm-based Clustering Protocol (IEPOACP). This protocol attempts to improve the energy stability and longevity of wireless sensor networks (WSNs). During the exploration and exploitation stages, IEPOACP chooses the optimal sensor nodes as cluster heads (CHs) by replicating emperor penguins' huddling behaviour. The protocol includes techniques for generating and calculating huddle borders, temperature profiles, search agent distances, and an effective mover relocation mechanism. Compared to typical CH selection approaches, IEPOACP increases energy efficiency and network longevity by 35%, 58%, and 67%, respectively. It also enhances throughput by 21.32%, lowers latency by 26.42%, boosts packet delivery rates by 20.98%, and decreases residual energy by 18.74%.

Salim El Khediri et al., in their 2021 article published at the International Conference on Innovations in Information Technology (IIT), describe two hierarchical routing protocols: WB-TEEN and WBM-TEEN. These protocols extend the Threshold Sensitive Energy Efficient Sensor Network protocol (TEEN) by including multi-hop intra-cluster communication to balance node distribution and minimise energy usage. Simulation studies utilising the NS2 simulator reveal that WB-TEEN and WBM-TEEN beat Low Energy Adaptive Clustering Hierarchy (LEACH) and TEEN in terms of energy consumption and network lifetime. These protocols increase the network's lifespan by more than 40% by optimising sensor node power consumption.

R. Prema et al. published in the International Journal of Computer Applications in 2012. In this study, they presented the secured power aware routing protocol (SPARP), which enables application-specified communication latency at a low energy cost by dynamically modifying transmission power and routing decisions, as well as including a novel cryptosystem. This protocol is designed to achieve desired quality of service (QoS) metrics such as packet delivery ratio and latency, as well as to reduce the power consumption of wireless sensor nodes. The results of a rigorous NS2 simulation revealed that the proposed SPARP delivers greater QoS and reduced power usage. The unique suggested cryptosystem is tested for security using Cryptool.

Priyadarsini, C., R. Prema, et al. suggested the source sensor node, which sends a data packet to the sink node to complete a route discovery. There will be no recurring exchanges of routing information.

III. PROPOSED METHODOLOGY

This paper proposes a strategy for extending the lifespan of an IoT network by using mobile nodes to improve mobility. The suggested technique is compared to the existing multi-objective fractional gravitational search algorithm, with the purpose of increasing energy efficiency and assuring safe multi-hop data transfer against hostile activity. The results of the NS2 simulator indicate the method's efficiency. NS2 provides full features for simulating numerous protocols in both wired and wireless networks, as well as a versatile architecture that supports a wide range of network components, protocols, traffic, and routing types. The simulator generates results in two formats: NAM animation tool and X-Graphs.

3.1 CLUSTERING

The sensors in wireless sensor networks are battery-powered and have limited power. The majority of applications in this sector aim to increase network lifespan using a variety of ways. Clustering methods have shown to be particularly successful in improving wireless sensor network performance. These strategies optimise network operations to handle limited energy more effectively, increasing the network's lifespan. Surveys in any subject can offer thorough and up-to-date information. With this in mind, this paper provides a thorough examination of existing clustering algorithms.

3.2 ROUTING

One of the significant challenges in wireless sensor networks is prolonging their lifespan. Numerous methods have been proposed to extend the battery life of sensor nodes. This research focuses on using routing to enhance battery efficiency and extend network longevity. The proposed protocol is based on the mobility-aware weighted clustering technique and the energy-aware, secure multi-hop routing protocol. By integrating the fundamental principles of these two routing strategies, which propose a new protocol that significantly increases network lifespan.

3.3 PROPOSED PROTOCOL

This research establishes the mobility-aware weighted clustering algorithm (MAWCA) for identifying the best cluster head (CH) for mobile nodes in an IoT network by optimising routing energy. MAWCA weights node degree difference, neighbour inconsistencies, cumulative time, node mobility, and delay throughout the CH election process. In addition, it includes an energy-aware and secure multi-hop routing (ESMR) protocol with a secret sharing mechanism to improve energy efficiency. The suggested technique also incorporates a quantitative examination of data connections in order to reduce routing disturbance. This study proposes a lightweight solution for IoT-based wireless sensor networks (WSNs) that includes multi-hop data routing.

3.4 STEPS INVOLVED IN COMPARING MAWCA & MOFGSA

STEP 1

The user is positioned as shown in Figure 3.1 and is depicted by a green circle. We assume the source and destination are marked by blue hexagons, and the cluster heads are labeled as CH, such as CH1, CH2, CH3, etc.

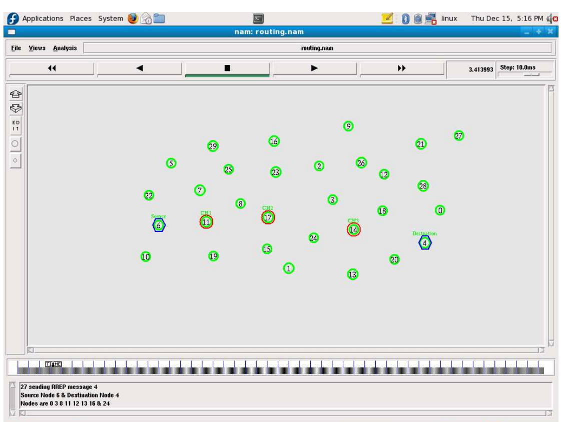

Figure 3.1 Routing (NAM Animation tool)

STEP 2

The source contains a violet circular shape representing clustering. This cluster typically forms just before data departs from the source, aiming to minimize data loss. Additionally, small dots near the source represent the data being transmitted, indicating the start of data transmission. This is illustrated in Figure 3.2.

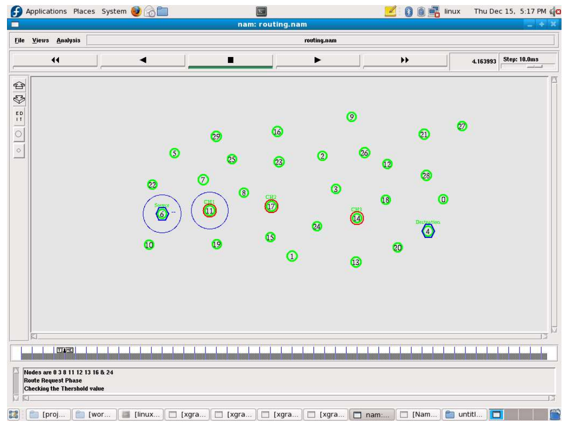

Figure 3.2 Formation of cluster

STEP 3

The routing protocol selects the optimal path for transferring data from the source to the destination. As depicted at the bottom of Figure 3.3, nodes 0, 3, 8, 11, 12, 16, and 24 illustrate this routing phase. This method is expected to be the most efficient for data transfer. During routing, the distance between each node and its neighboring node should be minimized, along with the blinking value. Initially, data is sent to establish the best route for transmission. Once the routing protocol identifies the optimal path, only the original data will be transferred.

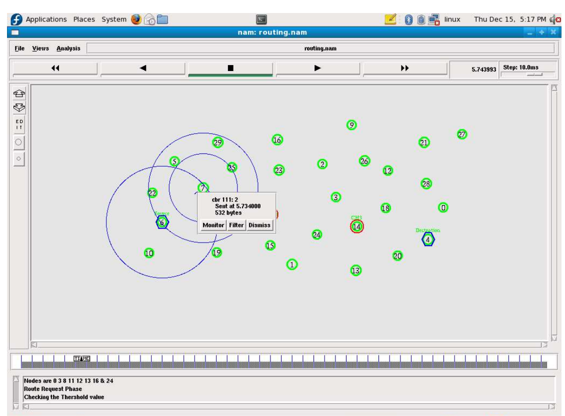

Figure 3.3 Routing protocol

STEP 4

The main role of the cluster head is to oversee data transfers and identify which users are moving data beyond the communication range. The cluster head is the point from which we can determine data transmission energy, node lifespan, packet delivery rate, and packet loss. In this instance, data is being transferred through node 7, and we receive information about the data, such as its size (532 bytes). Data cannot be sent as a single packet; it must be divided into packets after being converted to bytes. The transmission duration is 5.73 seconds, with a constant bit rate of 111. This information is saved in a file with a ".tr" extension, where "t" stands for trace. The entire process is recorded in this file from start to finish, as depicted in Figure 3.4.

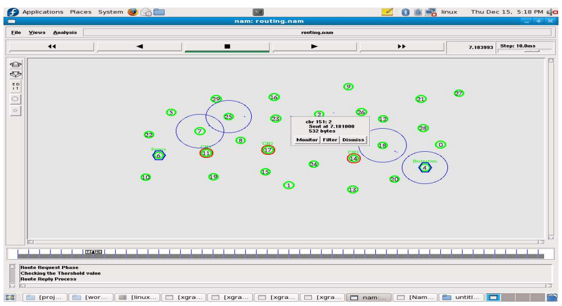

Figure 3.4 Checking the data Information

STEP 5

Figure 3.5 illustrates the precise routing path that data follows to reach the designated node 4, passing through nodes such as node 7 and node 25. The current processes, including the route request phase, threshold value verification, and route reply process, are displayed in the simulation at the bottom.

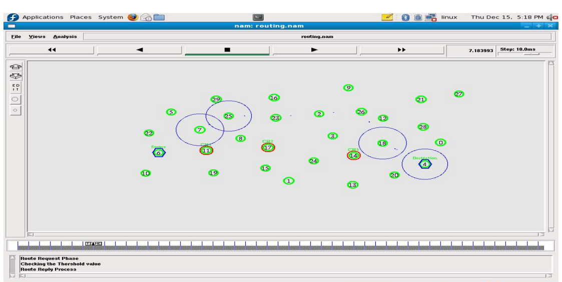

Figure 3.5 Path of Routing

IV. SOFTWARE IMPLEMENTATION AND CODINGS

NS-2 Software

NS2 (Network Simulator Version 2) is an event-driven simulation application designed to investigate the dynamics of communication networks. It simulates both wired and wireless network technologies, including as routing methods, TCP, and UDP. NS2 enables users to describe network protocols and mimic their behaviour.

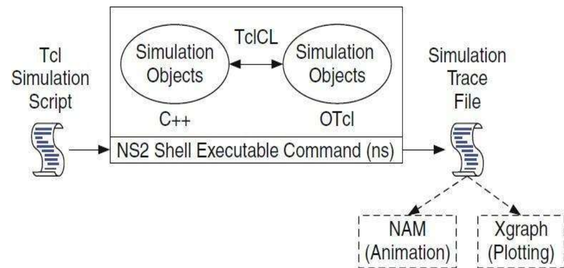

Figure 4.1 Basic Architecture of NS2

NS2 uses an executable command, "ns," which accepts a Tcl simulation scripting file as input. It produces a simulation trace file that may be used to make graphs and animations. NS2 has two main languages: C++ (for the backend) and OTcl (for the frontend). TclCL bridges C++ with OTcl, allowing for communication and functionality between the two.

NAM Animation Tool

Nam is a Tcl/TK-based animation application that displays network simulations and packet traces. It enables topology layout, packet-level animation, and data analysis. Nam was first created at LBL and has now progressed through the VINT project to become an open-source project on Sourceforge. To manage massive animation datasets, only minimum information is maintained in memory, with event commands fetched from a file as needed. Users create trace files including topological data and packet traces, which are commonly created by NS.

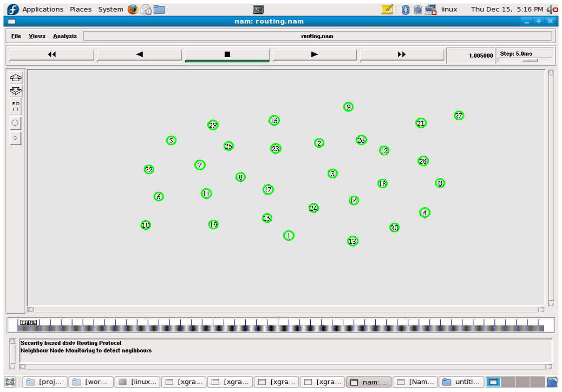

Figure 4.2 NAM Animation Tool

X-Graph

X-Graph is a charting tool included in the ns-allinone package that generates graphical representations of simulation results. Users can create output files from their Tcl programs to use as datasets in X-Graph. Figure 4.3 shows how easy it is to create graphs and employ traffic generators to visualise network performance using this tool.

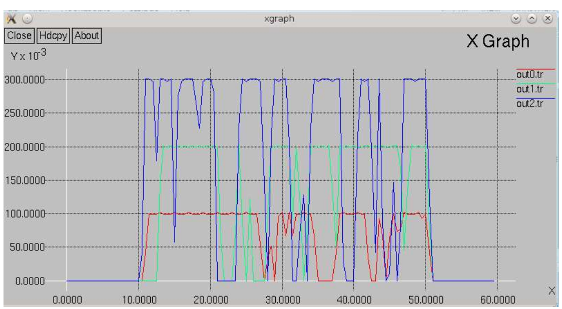

Figure 4.3 Use X-Graph for Plotting Graphs in NS2

V. RESULT AND DISCUSSION

Comparison of MAWCA and MOFGSA Protocols

This paper proposes the Mobility-Aware Weighted Clustering Algorithm (MAWCA), which uses routing energy to select the ideal cluster head (CH) for mobile nodes in an IoT network. MAWCA evaluates degree difference, cumulative time, node mobility, and delay throughout the CH election process. We use many simulation rounds to compare MAWCA to the Multi-Objective Fractional Gravitational Search Algorithm (MOFGSA) in terms of performance parameters such as Packet Delivery Rate (PDR), network energy, packet loss rate, and network longevity.

In addition, we implement an Energy-Aware and Secure Multi-Hop Routing (ESMR) protocol for constrained WSNs. This protocol partitions network nodes into inner and outer zones depending on distance and clusters them using the k-nearest neighbours (k-NN) approach. Clusters are organised hierarchically to make data routing easier, balancing energy usage with dependable data forwarding, and offering a secure multi-hop routing approach against assaults.

Parameters Compared Graphically

1. Network Lifetime

The graph shows the number of rounds on the x-axis and network lifetime on the y-axis. Figure 5.1 indicates that the proposed method significantly extends network lifetime compared to the existing system, with values of 13,000 and 19,000 respectively.

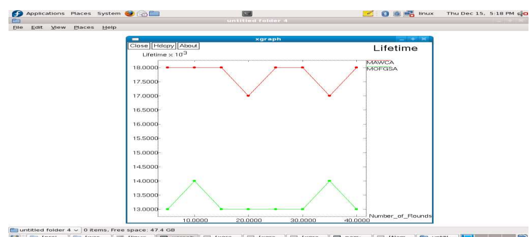

Figure 5.1 Comparison of Network Lifetime

2. Energy Consumption

This graph depicts the number of rounds on the x-axis and energy consumed by the network on the y-axis. Figure 5.2 clearly shows that the proposed approach uses less energy than the current system.

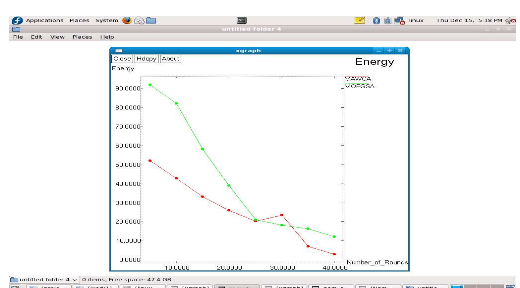

Figure 5.2 Energy consumption

3. Packet Delivery Rate (PDR)

PDR is the ratio of successfully received data packets to those sent by the sender. Figure 5.3 demonstrates that the proposed work is more efficient than previous methods.

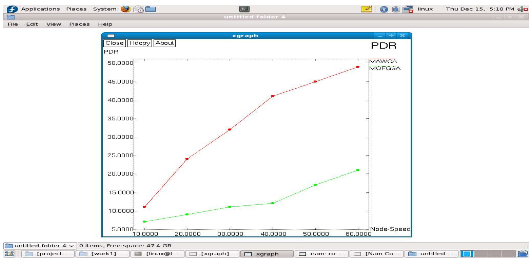

Figure 5.3 PDR

4. Packet Loss

Packet loss refers to data packets lost during transmission due to issues like network congestion or hardware problems. Figure 5.4 illustrates that the proposed system experiences less packet loss compared to the existing system.

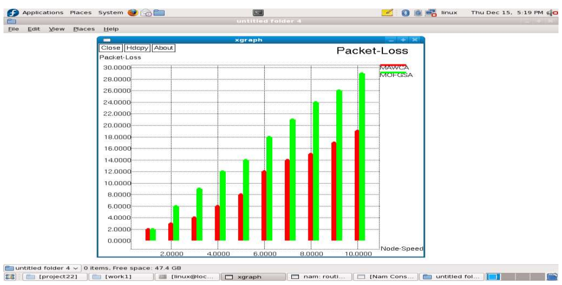

Figure 5.4 Packet loss

V. CONCLUSION & FUTURE WORK

Furthermore, we use an Energy-Aware and Secure Multi-Hop Routing (ESMR) protocol for This paper introduces the Mobility-Aware Weighted Clustering Algorithm (MAWCA), which optimises the selection of cluster heads (CH) for mobile nodes in IoT networks by effectively using routing energy. MAWCA uses a variety of parameters in the CH election process, including node degree difference, neighbour discrepancies, cumulative time, node mobility, and latency. Furthermore, to improve energy efficiency and assure secure communication, the study incorporates an Energy-Aware and Secure Multi-Hop Routing (ESMR) protocol with a secret sharing mechanism. The suggested technique additionally conducts a quantitative analysis of data connections to reduce routing interruption and hence improve overall network performance. The lightweight approach is intended to provide effective and secure multi-hop data routing in IoT-based wireless sensor networks (WSNs), hence greatly increasing the network's operational lifespan. Comprehensive simulations and assessments show significant gains in energy economy, security, and network stability, making MAWCA and ESMR ideal for resource-constrained IoT scenarios.

Future Work

Future research will focus on improving the resilience and scalability of the suggested methods. Key areas of study will include investigating adaptive mechanisms that can dynamically react to changing network circumstances, as well as incorporating machine learning approaches for predictive analysis and automated decision-making. Furthermore, expanding the protocols to handle heterogeneous IoT devices and studying their performance in large-scale deployments will be crucial for future applications. Collaboration with industry partners to verify suggested solutions in real-world circumstances is also an important step towards actual deployment and optimisation.

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