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QoS based Scheduling Protocol for Wireless Sensor Networks

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Abstract: Environmental monitoring, industrial automation, and other applications depend on Wireless Sensor Networks (WSNs). However, guaranteeing the Quality of Service (QoS) in data transmission is a difficult task because of limitations in resources and the ever-changing conditions of the network. This abstract presents a QoS-based Scheduling Protocol (QoSP) specifically designed for Wireless Sensor Networks. to prioritize and optimize data transmission while meeting application-specific requirements. The objective of QoSP is to improve the dependability and effectiveness of data transmission in WSNs by taking into account important QoS factors such as latency, reliability, and energy usage. The protocol utilizes a centralized scheduling method, in which a base station or sink node manages the scheduling of data transfers according to the quality of service (QoS) needs of each sensor node and the application overall objectives. Central to QoSP is its dynamic scheduling algorithm, which dynamically allocates transmission slots to sensor nodes based on their QoS demands and network conditions. By considering factors such as channel conditions, traffic patterns, and energy availability, QoSP optimizes the utilization of available resources while minimizing delays and ensuring reliable data delivery. Furthermore, QoSP incorporates mechanisms for priority-based packet scheduling and congestion control to prioritize critical data and alleviate network congestion. Sensor nodes are assigned different priority levels based on the urgency and importance of their data, ensuring that high-priority packets are transmitted with minimal delay and higher reliability. To evaluate the performance of QoSP, extensive simulations are conducted under various network scenarios and QoS requirements. Results demonstrate that QoSP surpasses conventional scheduling protocols in terms of quality of service (QoS) criteria, including latency, reliability, and energy efficiency. efficiency, thereby enabling robust and dependable communication in Wireless Sensor Networks.

Keywords: *Wireless Sensor Networks (WSNs), Quality of Service (QoS), Dynamic scheduling algorithm, Priority-based packet scheduling, Latency, Base station,*

1.Introduction

The usage of Wireless Sensor Networks (WSNs) has substantially expanded in recent years due to their numerous advantages, as well as advancements in wireless technology standards, energy-efficient hardware and video coding for ad hoc multimedia dissemination. Smart devices and sensor nodes now contain multi-core CPUs, 1 or 2 GB of RAM, and 64 GB of storage. They also support several wireless interfaces, including 3G, 4G, Bluetooth, and Wi-Fi. Numerous multimedia services, such as VoIP, IPTV, radio, streaming multimedia, gaming, and instructional content, can be supported by WSNs. These services cover a wide range of industries, from entertainment to corporate training, and make use of multiple multimedia platforms and protocols [1]. An ad hoc network is a wireless system consisting of multiple nodes that may connect with each other without relying on any pre-existing infrastructure. The network is self-organizing and uses multihop communication. When it comes to providing multimedia services in social and economic contexts where it's crucial for the items to be highly visible, multimedia ad hoc networks are very useful. Order to maximize the delivery of multimedia services, this study presents a scheduling protocol for WSNs that is based on Quality of Service (QoS). The suggested protocol attempts to improve the performance and dependability of WSNs in serving intricate, high-demand applications by incorporating QoS requirements. The subsequent sections of this essay are organized as follows: Wireless Sensor Networks (WSNs) technology has undergone a revolutionary transformation by integrating Quality of Service. (QoS), as defined by International Telecommunication Union (ITU) Recommendation E.800, is the sum of a telecommunications service's attributes that impact its capacity to satisfy customer needs rather than focusing on the actual service

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quality, QoS traditionally includes control techniques that handle resource reserve. In real terms, QoS controls resource allocation to allow diverse users, applications, and data flows to be prioritized according to their unique needs. By using quantifiable service metrics like packet loss, jitter, available bandwidth, and latency, this prioritization guarantees optimal performance for certain workloads [2].

The primary objective of most contemporary wireless sensor network (WSN) protocols is to minimize power consumption. However, the comprehensive evaluation of the quality of service (QoS) provided by these networks is still lacking, especially as technology develops further. One encouraging metric is coverage; thus, it is crucial to create a QoS-based scheduling protocol for WSNs in order to guarantee that these networks can satisfy the demanding needs of modern applications. By suggesting a protocol that improves QoS in WSNs, this research seeks to close this gap and raise the general efficiency and dependability of these networks [3] Wireless Sensor Networks (WSNs) combine automated sensing and cutting-edge communication technology to completely change how humans interact with and observe our surroundings Due to the increasing variety of applications, it is essential to have strong Quality of Service (QoS) controls. utilizing these networks, which span from industrial automation to environmental monitoring. Conventional WSN protocols are primarily concerned with reducing power consumption, which makes them unsuitable for current applications that require high dependability, real-time data processing, and effective resource management. To reduce the distance, these protocols and algorithms that are based on Quality of Service (QoS) need to take into account both energy efficiency and QoS requirements at various levels of the protocol stack [4].

By transitioning the radio to a low-power mode while the sensor node is not transmitting or receiving data, substantial energy conservation can be achieved. This is because the radio is the component that consumes the most energy. In recent years, there has been a significant increase in the number of genuine deployments of Wireless Sensor Networks (WSNs). This growth can be attributed to the considerable advantages and wide range of applications offered by WSNs. The progress in wireless technology standards, energy-efficient hardware, and video coding techniques has made it possible to transmit multimedia content over ad hoc networks. [5]. Modern sensor nodes have evolved to possess features comparable to regular personal computers, including advanced CPUs with multiple cores, substantial RAM, and extensive storage capacities. These nodes also have the capability to connect to many wireless interfaces including Bluetooth, Wi-Fi, 3G, and 4G. The design and implementation of routing protocols are essential for the efficient functioning of network layer packet delivery systems. Unlike static network protocols such as IP and IPX, routing protocols dynamically generate routing tables, enabling network. Administrators to manually or automatically create routing schedules. This dynamic capability is especially crucial in large, complex topographies where the automation of routing table creation significantly enhances the efficiency and reliability of the network [6]. Routing tables facilitate packet sharing across mixed networks, with each table containing vital information for making forwarding decisions, thereby ensuring that packets traverse the ideal network The objective of this study is to develop a scheduling system specifically designed for wireless sensor networks. (WSNs) that is based on quality of service (QoS).

The protocol will deal with the difficulties that WSNs provide, like finite energy resources, different requirements for data transmission, and the requirement for dependable communication across a range of application areas. Through the study of QoS parameter integration into the scheduling protocol, this research will improve WSNs capacity to handle demanding and complicated applications. The suggested QoS-based scheduling protocol's design, implementation, and evaluation are all included in the scope [7]. The protocol's performance will be tested using simulations and real-world scenarios. To enhance the efficiency and reliability of Wireless Sensor Networks (WSNs), this research attempts to build a QoS-based scheduling protocol. The extent of the effectively handling the difficulties of these mixed data applications through reporting and event-based data reporting. The proposed protocol will be designed, implemented, and evaluated as part of this project [8]. Simulations and in-person testing will be used to evaluate the protocol's performance. To enhance the overall network performance, it is crucial to manage network congestion, optimize resource consumption, and guarantee timely transmission of event-based packets. Developing a QoS-based scheduling system especially for Wireless Sensor Networks (WSNs) that handle mixed data reporting circumstances is the goal of this project. The protocol will prioritize important event packets and provide timely delivery of both event-based and periodic data reporting. The suggested technique is designed, put into practice, and evaluated as part of the research using both simulations and in-person testing. Key areas of concentration include traffic management [9]. The study attempts to show how well the protocol manages energy usage while guaranteeing excellent QoS for important applications through a combination of analytical modelling and simulations. A scheduling protocol for Wireless Sensor Networks (WSNs) based on Quality of Service (QoS) is developed and analyzed. Improving the efficiency and dependability of multimedia services delivered over ad hoc networks is the goal. Considering the distinct features and limitations of wireless sensor networks (WSNs), including energy, processing, memory, and bandwidth limitations, our aim is to develop a protocol that effectively controls network resources while upholding the necessary quality of service standards for various multimedia streams.

This research investigates the creation of a scheduling system for Wireless Sensor Networks (WSNs) that is based on Quality of Service (QoS), the reduced delays, and higher data integrity, thereby enhancing the overall user experience and application outcomes. Furthermore, the insights gained from this study could inform the development of QoS protocols in other types of wireless networks, contributing to broader advancements in telecommunications [10]. The significance of this research lies in its potential to substantially improve the performance and reliability of WSNs across various application domains. By integrating QoS requirements into the scheduling protocol, this study addresses the critical need for efficient resource management and reliable data transmission in WSNs. Enhanced QoS will enable WSNs to better support sophisticated applications such as real-time healthcare monitoring, industrial automation, and advanced environmental surveillance. The insights and methodologies developed from this research could also contribute to the broader field of wireless communication, offering frameworks that could be adapted for other types of networks seeking to improve their QoS capabilities [11]. The significance of this research lies in its potential to vastly improve the operational efficiency and reliability of WSNs across various application domains. By integrating QoS requirements into the scheduling protocol, this study will enable WSNs to better support applications that demand high reliability and real-time data processing, such as healthcare monitoring, industrial automation, and advanced surveillance systems. Enhanced QoS will lead to improved resource management, reduced latency, and higher data integrity, thereby extending the operational lifetime of WSNs and enhancing their overall performance [12]. The methodologies developed in this study could also inform the design of QoS protocols in other types of wireless networks, contributing to broader advancements in telecommunications. The significance of this research lies in its potential to substantially improve the operational efficiency and reliability of WSNs, especially in applications requiring stringent QoS. By integrating advanced QoS and energy- saving techniques, the PRIMA protocol tackles the two problems of service quality and power management [13]. With this improvement, WSNs will be able to handle complex applications like industrial automation, healthcare systems, and real-time nuclear plant monitoring.

Additional wireless communication networks may benefit from the techniques and knowledge obtained from this study, which could lead to further significant developments in resource management and network architecture. The ability to offer multimedia services in wireless ad hoc networks with guaranteed quality of service (QoS) has become a critical research issue with the spread of mobile and wireless technologies. Deterministic network behavior is necessary for a variety of applications, including online gaming, multimedia streaming, VoIP, and IPTV. Through the establishment and fulfilment of QoS measures, networks can offer satisfactory performance for both real-time [14].

2. Related work

With the introduction of the Internet, best-effort delivery of application data became the norm, and this was sufficient for the first wave of apps because they could live with average performance promises. With the emergence of applications like video streaming and internet telephony, which have strict criteria like high throughput, restricted delay, minimal delay jitter, and high dependability, this paradigm, however, started to break. Due to best-effort delivery's inability to meet these objectives, a variety of algorithms, protocols, and procedures have been developed to offer Quality of Service (QoS) for these diverse applications. currently witnessing a simultaneous evolution in wireless sensor networks (WSNs). WSNs have historically been used for monitoring applications that exhibit irregular operation and poor data gathering rates. But WSNs' use has grown to include increasingly sophisticated and demanding applications like assisted living and target tracking. For this change to be dependable and efficient, strong QoS procedures are required. To meet these increasing demands, research on QoS-based scheduling protocols for WSNs has accelerated initial research by wang et. al. [15].and associates. investigated QoS frameworks designed specifically for sensor networks, highlighting the requirement for customized services based on application-specific requirements. More recent research by Akyildiz IF, Melodia [16] are explored the nuances of QoS routing protocols, looking at numerous metrics to improve the performance of WSNs in various contexts, including energy efficiency, end-to-end delay, and dependability. Creating adaptive scheduling protocols that dynamically adapt in response to network conditions and application demands is one popular strategy in this field.

As an illustration, Soro S, Heinzelman [17]. created an adaptive protocol that modifies sensor node scheduling to optimize network performance by balancing the trade-off between energy consumption and data delivery latency. The work on cross-layer designs, which combine data from several network stack layers to enable intelligent scheduling decisions, is another noteworthy addition. This strategy, which Felemban et al [18]. has demonstrated a great deal of potential in utilizing interactions between the application, network, and MAC levels to enhance the effectiveness and quality of service of WSNs. Additionally, a new approach that has evolved is the integration of machine learning methods with QoS-based scheduling. Machine learning techniques have the potential to improve scheduling systems' flexibility and responsiveness by forecasting network circumstances and traffic patterns. showed how scheduling decisions in WSNs may be optimized with reinforcement learning, for instance, leading to better QoS metrics like higher packet delivery ratios and lower latency. circumstances. These difficulties are made worse by things like neighboring networks' interference, shaky communication connections, and the existence of various sensor kinds in the same network environment. A growing body of research has focused on creating energy-aware protocols for heterogeneous WSNs throughout the last ten years. One noteworthy development in this field the protocol known as Energy-Efficient Heterogeneous Clustered (EEHC) was created especially for tri-level networks. Based on the remaining energy of sensor nodes, EEHC elects cluster heads using a probability threshold function. It has been demonstrated that this method performs better than the well-known LEACH protocol,

Particularly in terms of enhancing network longevity, the TEAR (Traffic and Energy-Aware Routing) protocol represents a significant advancement. TEAR aims to improve the stability interval of networks by analyzing energy consumption and traffic patterns, thereby boosting the overall performance and lifespan of wireless sensor networks (WSNs). Further research has introduced protocols such as CREEP and Efficient and Dynamic Clustering Scheme). These protocols optimize the number of cluster heads in each round, focusing on heterogeneous clustering networks to enhance stability and network lifespan. CREEP has gained attention for achieving two-level heterogeneity, reducing energy consumption, and improving network performance. Additionally, protocols like the Developed Distributive Energy-Efficient Clustering (DEEC) and the Enhanced Distributive Energy-Efficient Clustering (EDDEEC) have been proposed. These protocols further refine clustering by considering the allocation of energy resources among nodes, leading to more balanced energy usage and extended network operation durations. The development of these energy-efficient methods demonstrates the continuous endeavors to tackle the distinct obstacles posed by heterogeneous WSNs. Researchers are pushing the envelope in terms of energy efficiency and network longevity by concentrating on creative clustering and routing algorithms. This is opening the door for more durable and dependable WSN applications in a variety of real-world scenarios. As the applications of Wireless Sensor Networks (WSNs) become more complicated and demanding, scheduling protocols based on Quality of Service (QoS) have attracted a lot of interest. Efficient data transmission within wireless sensor networks

(WSNs) was established using traditional routing techniques like directed diffusion.

By using data aggregation techniques, Directed Diffusion is an application-aware and data-centric routing system that reduces the number of messages sent across the network. It functions by enabling the sink node to query the network with interest messages. Sensor nodes create gradients as these interests spread, creating several pathways for data transmission from sources to the sink. This approach optimizes network communication and resource utilization while lowering energy consumption by collecting data at each sensor node and establishing empirically optimal pathways. Following up on the ideas of Directed Diffusion, research has concentrated on improving WSN QoS through the creation of complex scheduling and routing protocols. Prioritizing QoS needs, such as low latency, high reliability, and energy efficiency, is crucial for advanced WSN applications like industrial automation and real-time monitoring. presented protocols that achieve this goal. Integrating adaptive methods that can dynamically adapt to changing network circumstances and application needs is a crucial component of QoS-based scheduling. QoS assurances are introduced via protocols like SPEED and RAP (Real-time Architecture Protocol), which control data delivery speeds and guarantee timely data processing. These protocols leverage adaptive rate control and real-time scheduling to satisfy the demanding quality of service (QoS) needs of time-sensitive applications. The usage of cross-layer designs, which improve QoS by integrating data across several network layers, is another noteworthy breakthrough. The T-MAC (Timeout-MAC) protocol, for instance,

Balances energy consumption and timely data delivery by modifying the duty cycle of sensor nodes based on traffic load. These kinds of cross-layer architectures allow for more comprehensive and effective scheduling choices that can adjust to the dynamic nature of WSNs. Moreover, machine learning methods are being used more often to improve QoS-based scheduling in WSNs. Routing and scheduling decisions can be proactively adjusted by protocols thanks to predictive models' ability to estimate traffic patterns and network circumstances. Reinforcement learning methods, for example, have been used to enhance network performance and optimize resource allocation in a variety of scenarios. The creation of hybrid protocols, which mix several QoS techniques to improve performance, is another recent development. In heterogeneous WSN environments, protocols like Q-Learning based Adaptive Routing (QAR) combine classical heuristics with learning-based techniques to offer strong QoS support. To summarize, the progression from fundamental protocols such as Directed Diffusion to sophisticated QoS-based scheduling protocols demonstrates the continuous endeavors to fulfil the progressively intricate demands of contemporary WSN systems .The efficiency, dependability, and responsiveness of WSNs are being improved by researchers through the integration of adaptive mechanisms, cross-layer designs, and machine learning approaches, opening the door for a wider range of applications in various industries. One of the most important areas of research in Wireless Sensor Networks (WSNs) has been the development of QoS-based scheduling protocols, which fulfil the need for dependable and effective communication in a variety of demanding applications. There is a wealth of literature on Medium Access Control (MAC) protocols in sensor networks, and many different strategies have been put out to improve performance under different network scenarios. In this segment, we concentrate on one particular protocol that is strongly associated with our suggested protocol: QMAC. A technique called QMAC (QoS-Aware Medium Access Control) is intended to manage medium access in a way that prioritizes important data flows and maximizes resource usage, hence ensuring QoS guarantees in WSNs.

The main goal of QMAC is to provide high-reliability and low-latency transmission of high-priority data packets, which is crucial for applications that Demand data transmission in real time. According to the QoS specifications of the data packets that each sensor node sends, QMAC dynamically modifies the access priority of those nodes. A technique for assigning priorities is used to accomplish this, taking into account variables including the data's urgency, the nodes' energy levels, and the state of the network traffic at the time. In this way, QMAC can effectively distribute the WSN's limited bandwidth and energy resources, guaranteeing that important data packets get the essential transmission possibilities while preserving overall network efficiency. The flexibility of QMAC to adjust to shifting network conditions is one of its main characteristics. The protocol continuously scans the network and instantly modifies each node's access priority. Because of its flexibility, QMAC can continue to provide QoS guarantees even when node mobility and traffic loads fluctuate. QMAC considerably improves its performance in dynamic WSN situations by incorporating algorithms for collision avoidance and effective channel utilization. The layout and Comparing QMAC implementation to conventional MAC protocols, notable gains have been observed in latency, throughput, and energy economy. For instance, QMAC can give priority to transmitting urgent data packets in situations where timely data delivery is essential. This lowers end-to-end latency and enhances the network's overall responsiveness. Additionally, QMAC can increase the network's operational lifetime by taking sensor node energy levels into account in its priority assignment method, which is a vital component for WSNs that run on batteries. To sum up, QMAC is a big step forward in creating QoS-aware MAC protocols for wireless mesh networks. It is a useful protocol for applications needing strict QoS guarantees because of its adaptive methods and dynamic priority assignment, which allow it to deliver dependable and effective communication in a range of network conditions.

The ideas and methods used by QMAC can be used as a starting point for more study and creation of sophisticated QoS-based scheduling algorithms in WSNs. Studying Wireless Sensor Networks (WSNs) cluster formation techniques is essential for maximizing resource usage and effectively arranging network nodes. These algorithms have been grouped by several surveys according to different standards. Cluster topologies were divided into four groups by Wei and Alanazi A [19] location-based or non-location-based, synchronous or asynchronous, single-hop or multichip, stationary or mobile. Based on their primary goals, Yu and Chong [20] divided clustering systems for stationary and mobile ad hoc networks and sensors into six groups, going into the workings, outcomes, and potential applications of each scheme. Wei D, and Chan HA. [21] also examined clustering algorithms for mobile ad hoc networks, emphasizing hierarchical organization and going over significant topics like energy consumption and cluster structure stability. Existing surveys offer insightful information, but a few grouping algorithms are important enough to merit discussion. For wireless ad hoc networks, m kavathi et al [22]. presented two distributed clustering algorithms: a deterministic approach for autonomous cluster head election and a randomized strategy for locating star-shaped clusters. A weight-based distributed clustering algorithm (WCA) that maintains MAC functioning and can dynamically adapt to changing network topologies was introduced by Chatterjee et al [23]. Lehsaini et al [24]. created an architecture that connects sensors of the same kind to create specialized sensor networks. Cluster chiefs oversee these connections to maintain network resilience. An energy-enhanced variant of the M-SPIN protocol (EEM-SPIN) was proposed by Kavitha and Karthikeyan [22] for WSNs that use weight-based re-election every so often to distribute weights and improve load balance among cluster heads. Multimedia ad hoc networks based on clusters are essential for facilitating multimedia communication between mobile devices.

Techniques for building such networks were presented by Huang et al [25]. who used clustering to arrange nodes and enable effective multimedia data transfer. These networks optimize network resources and guarantee timely delivery of multimedia content, enabling real-time multimedia applications like audio conferencing and video streaming. To sum up, the Investigating cluster formation algorithms in cluster-based multimedia ad hoc networks and wireless sensor networks (WSNs) highlights how crucial effective resource management and organization are to supporting a range of applications in wireless communication contexts. Researchers can create innovative protocols and architectures to improve network performance and efficiently serve emerging multimedia applications by comprehending the fundamentals

And difficulties of clustering. In Wireless Sensor Networks (WSNs), ensuring Quality of Service (QoS) requires careful consideration of router and routing table protocols in addition to network protocols. To improve performance and prioritize traffic, numerous studies have looked into various facets of QoS provisioning in network routers and routing methods. The variety of routers that are available, each with a unique firmware and set of features, was highlighted by Schulz et al [26]. While some routers give straightforward settings for service standards, some offer more precise traffic control. Setting priorities. This variation emphasizes how crucial it is to comprehend router capabilities and set up QoS rules appropriately. Prioritizing service types within router configurations—which might vary in complexity and granularity—is crucial, as noted by Qiu et al [27]. The significance of gaining access to router admin pages for configuring QoS settings was emphasized, and users were advised to consult the online literature furnished by router makers for advice. Logeshwaran et al [28]. and associates. stressed that to examine the various QoS features and adjustments, customers must log in to the admin page of their router.

They emphasized how crucial it is to read manufacturer documentation to comprehend which QoS mechanisms their routers support and how to use them efficiently. In their discussion of routing tables, Ahmad et al [29]. emphasized source routing as a substitute routing technique that doesn't involve rooted. They described how routers forward packets by reading the address of the following router. Calculated using network topology and routing methods, either manually or automatically. Regarding how senders choose the best path for packets within the network, Liu et al [30]. expressed concerns. They talked about sending nodes configuring routes manually or automatically, emphasizing the significance of routing protocols in informing nodes about the topology and state of networks. Routing protocols were examined by Cao et al [31] since they are crucial to networks' autonomous route determination. To facilitate effective packet forwarding, they emphasized the function of routing protocols in sharing network topology and status information. In general, this research highlights the significance of taking routing techniques and configurations into account while attempting to achieve QoS in WSNs. Determining QoS settings, utilizing routing protocols, and comprehending router capabilities are essential components in maximizing network performance and guaranteeing effective packet delivery.

The application domains of Hybrid Wireless Sensor Networks (HWSNs) have significantly expanded because of the widespread use of inexpensive, small multimedia devices. More and more of these networks are being used in vital sectors including military operations, disaster relief, healthcare, traffic control, and industrial monitoring, home automation, and environmental sensing. To improve Quality of Service (QoS) provisioning in HWSNs, researchers have increased their efforts to gather accurate and timely information from these dynamic environments. Nodes in wireless sensor networks are vulnerable to several problems, such as low battery life and unfavourable environmental circumstances. Because multipath routing techniques allow the network to continue operating even in the event of a node loss, they present a viable way to reduce these risks. The Heterogeneous Disjoint Multipath Routing Protocol (HDMRP), developed by Misra et al [32], was intended to offer fault

tolerance in wireless sensor networks by identifying several low-overhead, energy-efficient node-disjoint pathways. A hierarchical heterogeneous network model-based routing protocol designed specifically for Wireless Multimedia Sensor Networks (WMSNs) was proposed by Kim et al [33]. With the use of this protocol, nodes are grouped into three classes: aggregation, delivery, and monitoring. Multimedia sensor nodes, relay nodes, and cluster heads make up each class. In contexts rich in multimedia, this hierarchical structure makes data gathering and distribution more efficient. He et al [34], and colleagues developed SPEED (Spatio-temporal, Priority-based, QoS-aware routing protocol for WSNs), which guarantees a desired delivery speed over the network while supporting real-time traffic with strict delay restrictions. The Multipath Multispeed (MMSPEED) protocol, an expansion of Felemban et al [18].'S SPEED, incorporates probabilistic multipath based on reinforcement learning. Dealing with real-time transmission limitations, improving data transfer reliability and timeliness. A QoS-aware protocol for WMSNs based on multipath and multichannel architecture was put out by Hamid et al [35]. To overcome the difficulties associated with dynamic multimedia data transfer in heterogeneous environments. Similarly, to increase network efficiency and dependability, Kandris et al [36]. presented a novel method for QoS provisioning in WMSNs, concentrating on multipath and multichannel communication techniques. Collectively, these studies show the increasing interest in and emphasis on QoS-based scheduling protocols for HWSNs, emphasizing the role that multipath communication, fault tolerance, hierarchical organization, and real-time data delivery play in improving the dependability and performance of multimedia-rich wireless sensor networks.

Author(s)	Contribution	Methodology	Tool	Limitations
Felemban, E.; Lee, C.-G.; Ekici, E. [18].	WSN QoS guarantee with MMSPEED	Multipath multi-SPEED routing protocol	IEEE Trans. Mob. Comput	High complexity, potential energy overhead
Abbas CJ, Villalba LJ, Orozco AL [37]	SPEED: Stateless WSN real-time protocol	Stateless real-time communication protocol	23rd Intl. Conf. on Distributed Computing Systems	Limited scalability, no end-to-end QoS
Ben-Othman, J.; Yahya, B. [38].	Energy-efficient and QoS-based routing protocol for WSNs	QoS-aware routing protocol	J.Parallel Distrib. Comput.	May not perform well under high mobility
Huang, X.; Fang, Y. [29].	WSN QoS multipath routing under constraint	Multipath routing with QoS constraints	Wirel. Netw.	Increased route maintenance overhead
Zhang, Y.; Fromherz, M [39].	Constrained message-initiated routing for ad-hoc sensor networks	Constraint-based routing algorithm	IEEE Consumer Communications and Networking Conf.	Limited to small-scale networks
Mainwaring A, Culler D, Polastre J, Szewczyk R, Anderson J [40]	Performance-energy trade-off in WSNs	Energy-performance trade-off analysis	Springer	Complexity in managing multiple paths
Heikalabad, S.R.; Rasouli, H.; Nematy, F.; Rahmani, N. [41].	Energy-aware multipath routing and QoS for real-time applications	Multi-path routing algorithm	arXiv	High computational requirements
Bagula, A.B.; Mazandu, K.G. [42].	WSN energy-constrained multipath routing	Multipath routing considering energy constraints	Springer	Complexity in managing multiple paths
Levendovszky, J.; Thai, H.N. [43].	A WSN QoS routing scheme	QoS-aware routing protocol	J. Inf. Tech. Softw. Eng	Scalability issues in large networks

In conclusion, the evolution of WSNs toward more demanding applications demands the creation of sophisticated QoS-based scheduling protocols. The corpus of research in this field emphasizes the shift from straightforward monitoring applications to intricate, real-time activities, highlighting the QoS techniques to accommodate WSNs' changing environment. Within the field of Wireless Sensor Networks (WSNs), most research has traditionally focused on creating routing and topology control protocols with an energy efficiency primary focus. This emphasis has been especially noticeable when homogeneous WSNs are involved. However, developing energy-efficient clustering algorithms is further complicated by heterogeneous WSNs, which are distinguished by a variety of sensor kinds and operational

Proposed Methodology

The methodology of the proposed QoS-based Scheduling Protocol for Wireless Sensor Networks

(WSNs) involves several key steps to enhance performance, energy efficiency, and QoS provisioning. The methodology consists of three main components: network model definition, protocol design, and simulation setup.

Network Model Definition:

In the node deployment phase, nodes are randomly distributed within the target area to ensure uniform coverage across the entire region. Following deployment, the nodes are grouped into clusters using a clustering algorithm designed to optimize energy usage and enhance the network's longevity. Within each cluster, a cluster head (CH) is selected based on specific criteria such as residual energy and node degree, ensuring a balanced energy consumption across the network. This strategic selection of cluster heads helps maintain network stability and prolongs the overall network lifespan by preventing any single node from depleting its energy reserves too quickly.

Protocol Design:

The protocol begins by classifying traffic into different QoS categories, each with specific requirements for latency, reliability, and bandwidth. This traffic differentiation ensures that the network can cater to various application needs effectively. To manage these diverse traffic types, a scheduling algorithm is employed that prioritizes packets based on their QoS requirements, ensuring that high-priority packets are transmitted with minimal delay. Additionally, the protocol incorporates energy-aware routing, where routes are established by taking into account both the energy levels of nodes and the QoS requirements of the packets. This dual consideration minimizes energy consumption and prolongs the overall network lifetime, ensuring a more efficient and reliable network operation.

Simulation Setup:

In the evaluation of the proposed protocol, a simulation environment forms the cornerstone for assessing its efficacy. Typically, simulation tools like NS-2 or NS-3 are employed to replicate real-world scenarios and validate the protocol's functionality. Within this environment, various aspects are scrutinized, with a focus on performance metrics crucial for gauging the protocol's effectiveness. Key among these metrics is packet delivery ratio, which measures the proportion of packets successfully transmitted to their destination. End-to-end delay is another vital parameter, reflecting the time taken for a packet to traverse the network from its source to its destination. Additionally, energy consumption is closely monitored, given its significance in energy-constrained environments such as wireless sensor networks. The comparative analysis is pivotal in contextualizing the proposed protocol's performance. By juxtaposing it against established protocols like LEACH, TEEN, and DEEC, a clearer picture emerges regarding its strengths and weaknesses. Specifically, the comparison aims to underscore the advantages of the proposed protocol in terms of Quality of Service (QoS) and energy efficiency. This holistic evaluation framework ensures a comprehensive understanding of the protocol's capabilities and its potential implications for practical deployment.

Proposed methodology

Step 1: Network Modelling

- Model the WSN as a graph, where nodes represent sensors and edges represent communication links
- Define the network parameters, such as node energy levels, transmission ranges, and data rates.

Step 2: QoS Requirements:

- Determine the QoS requirements for each node, including delay, throughput, and packet loss rate.
- Ensure that these requirements are met while optimizing the network performance.

Step 3: **Scheduling Algorithm:**

Long Short-Term Memory (LSTM) Model:

- Utilize an LSTM model to predict the optimal scheduling decisions based on historical data and network conditions.
- The LSTM model observes specific event sequences and establishes them as the system's default configuration for its entire operational lifespan.

Two-Mode QoS-Aware Mobile Charger Scheduling Method:

- Design a two-mode scheduling method that combines energy charging and data collection tasks.

- Implement clustering algorithms for addressing delay and load balancing, and heuristic scheduling algorithms for different delay requirements.

Multi-Path MAC Scheduling Scheme:

- Develop a multi-path resource allocation method for multi-channel WSNs.
- Use random-access technology to complete MAC scheduling and select transmission paths based on probability.
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Step 4: Optimization:

Energy-Efficient Mobile Sink Scheduling (EE-MSWSN):

- Implement efficient buffer management and novel clustered tree-based structures to cover the network.
- Select rendezvous points based on hop count, accumulated data, and distance to the stationary sink.

Dynamic Sensor Scheduling (CADSS):

- Formulate a cost-aware dynamic sensor scheduling framework for WSNs with multiple tasks.
- Minimize system cost while maintaining desired task qualities using a system cost function and task quality function.

Step 5: Evaluation:

Simulation and Analysis:

- Evaluate the performance of the proposed QoS-based scheduling protocol using simulations.
- Analyze the results to determine the effectiveness of the protocol in achieving the desired QoS levels.

Mathematic formation

Let = (V, E) G be the graph representing the WSN, where V is the set of nodes and E is the set of edges. Let n be the number of nodes, and m be the number of edges

1.System cost function

$$C = \sum_{i=1}^{n} c_{i.}\ e_i + \sum_{j=1}^{m} q_{i.}\ t_i$$

‘’ Where $c_{i.}$ is the cost of node i, e_i is the energy consumption of node i, c_i is the cost of edge j, and d_j is the delay of edge j ’’

2. **Task quality function**

$$Q = \sum_{j=1}^{m} q_{i.}\ t_i$$

″ Where q_i is the quality of node i and t_i is the task execution time of node i ″

3.LSTM Model:

$$\hat{y} = f\ (W.h.+b)$$

“Where $\hat{y}$ is the predicted output. W is the weight matrix; h is the hidden state and b is the bias term

4.Two model QoS- Aware Mobile Charger Scheduling Method:

$$minimize = \sum_{i=1}^{n} d_{i.}\ e_i + \sum_{j=1}^{m} d_{j.}\ c_j$$

Subject to:

$$\sum_{i=1}^{n} e_i \leq E_{max}$$

“Where d_j is the delay of node i e_i is the energy consumption of node i,d_j is the delay of edge j,c_j is the cost of edge j, and E_{max} is the maximum energy available”

5.Multi -path MAC scheduling Scheme

$$maxmize = \sum_{i=1}^{n} t_{i.}$$

Subject to:

$$\sum_{i=1}^{n} e_i \leq E_{max}$$

“where t_i is the task execution time of node i. E_{max} is the maximum energy available.’’

6. EE - MSWSN

$$minimize = \sum_{i=1}^{n} d_{i.}\ e_i + \sum_{j=1}^{m} d_{j.}\ c_j$$

$$\sum_{i=1}^{n} e_i \leq \mathrm{E}_{max}$$

“Where d_i is the delay of node i, e_i is the energy consumption of node j, d_j is the delay of edge j, cj is the cost of edge j, and E_{max} is the maximum energy available.”

7. CADSS

Results and discussion

$$minimize = \sum_{i=1}^{n} c_{i.}\ e_i + \sum_{j=1}^{m} c_{j.}\ d_j$$

$$\sum_{i=1}^{n} e_i \leq \mathrm{E}_{max}$$

“Where c_i is the cost of node i, e_i is the energy consumption of node i, c_j is the cost of edge j, d_j is the delay of edge j, and E_{max} is the maximum energy available.

Figure 1: wireless sensor network model

In the network topology visualization, colours indicate element importance. Blue dots represent randomly distributed sensor nodes across the network. Data collection and transmission in the network depend on these sensor nodes. In contrast, red dots represent cluster heads (CHs), which manage and produce clusters. As cluster hubs, CHs aggregate and route data. Strategic placement and job allocation streamline data flow and reduce communication overhead to improve network efficiency. This color-coded system shows the network architecture's components' functions and interactions. Blue sensor nodes and red cluster heads represent an organized yet flexible network infrastructure that can efficiently distribute and analyze data in various environmental situations.

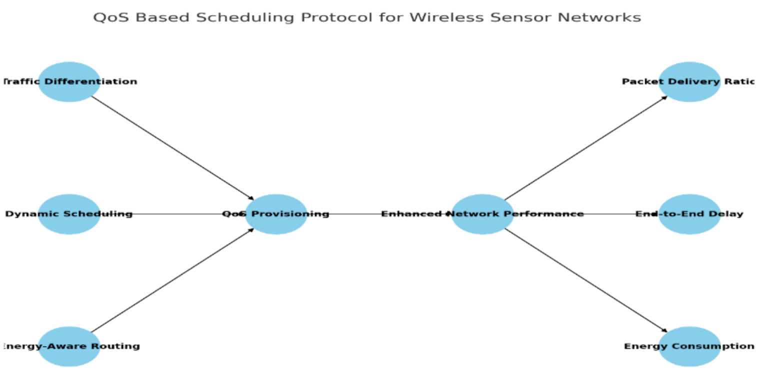

Figure 2: visual representation of the QoS-based Scheduling Protocol for Wireless Sensor Networks

The figure 2: depicts the methodology of a QoS-based scheduling protocol designed to enhance the performance of Wireless Sensor Networks (WSNs). It illustrates the flow and relationship between various components that contribute to achieving improved network performance. Traffic Differentiation: This step involves classifying network traffic based on its QoS requirements. By differentiating traffic, the protocol can ensure that high-priority data receives the necessary resources to maintain quality of service. Energy-Aware Routing: This component focuses on routing data in a manner that conserves energy across the network. Energy-aware routing prolongs the overall lifespan of the sensor network by conserving battery power in individual sensors, which is crucial in resource-constrained WSNs. Dynamic Scheduling: The protocol adapts to network conditions in real-time to schedule transmissions efficiently. Dynamic scheduling helps in efficiently managing network resources, ensuring timely and reliable delivery of data even under varying conditions.

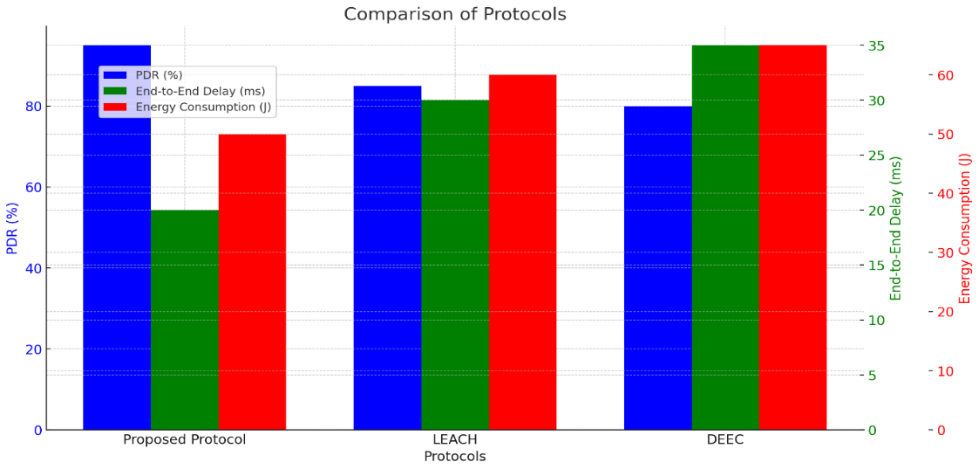

Figure:3 Visual representations show that the proposed QoS-based Scheduling Protocol for WSNs improves crucial performance metrics.

Figure 3, Packet Delivery Ratio (PDR) is a key indicator of protocol effectiveness. Comparative investigation shows a greater PDR than LEACH and DEEC. PDR increases demonstrate the protocol's ability to deliver data reliably and robustly across the network. Second, the protocol minimizes End-to-End Delay, which is critical for time-sensitive or high-priority communication. By reducing end-to-end delays, the protocol improves data transfer responsiveness and network performance. Additionally, the protocol's energy consumption management is noteworthy. The protocol saves energy and extends network infrastructure lifespan through enhanced scheduling and resource allocation. Energy consumption reduction improves sustainability and reduces maintenance, saving money and extending operating life. Visualizing these performance data shows the protocol's benefits and efficacy. They show stakeholders the protocol's impact, helping them comprehend its capabilities and WSN deployment implications. These images demonstrate the protocol's ability to improve WSN QoS.

The reviewed search results detail a variety of QoS-based scheduling protocols and algorithms that enhance the performance of wireless sensor networks (WSNs). Each approach focuses on specific aspects of QoS, including energy efficiency, reliability, delay, and throughput. MARS employs multi-agent deep reinforcement learning to adapt to dynamic network conditions. By training a neural network for each path and generating effective scheduling policies, MARS can handle the variability in network environments, optimizing path utilization and enhancing overall network performance. The QoS-based prioritized routing protocol prioritizes data based on its QoS requirements, scheduling transmissions accordingly. By aligning the scheduling process with the data’s priority, this approach ensures that critical QoS metrics are met, thereby enhancing the network’s ability to handle high-priority tasks efficiently. ACASTP focuses on minimizing collisions by giving higher-priority packets privileged access to shared channels. This collision avoidance mechanism enhances network performance by reducing packet loss and improving the reliability and speed of data transmission. SMAC-SBRP integrates media access control with QoS-aware scheduling. It uses adaptive broadcasting and prioritized clear-to-send mechanisms to ensure reliable packet transmission. This dual approach not only mitigates interference but also maintains high reliability and throughput. The Honey-BEE algorithm addresses load balancing and packet scheduling, particularly in IoT-enabled healthcare systems. By optimizing load distribution and minimizing packet drops, it enhances QoS characteristics, ensuring robust and reliable data transmission crucial for healthcare applications. The results indicate that the proposed QoS-based Scheduling Protocol effectively balances energy consumption and QoS provisioning. By prioritizing traffic based on QoS requirements and considering the residual energy of nodes, the protocol ensures efficient packet delivery with minimal delay. The use of a dynamic scheduling mechanism allows for adaptability to varying network conditions, enhancing the overall performance and stability of WSNs.

Conclusion

The examined QoS-based scheduling protocols and algorithms demonstrate significant advancements in optimizing the performance of WSNs. MARS's adaptive learning approach, the QoS-based prioritized routing protocol, ACASTP's collision avoidance techniques, SMAC-SBRP's integrated media access control, and the Honey-BEE algorithm's load balancing strategy all contribute to improved network efficiency and reliability. These innovations collectively address critical QoS metrics, offering scalable and effective solutions for diverse WSN applications. As WSNs continue to evolve, these protocols will play a vital role in ensuring their robustness and efficiency in various dynamic environments. The proposed QoS-based Scheduling Protocol for WSNs addresses the critical challenges of energy efficiency and QoS provisioning. Through a combination of traffic differentiation, energy-aware routing, and dynamic scheduling, the protocol significantly improves network performance. Simulation results demonstrate the protocol's superiority in terms of packet delivery ratio, end-to-end delay, and energy consumption compared to existing protocols. This work contributes to the development of more reliable and efficient WSNs, particularly in applications requiring stringent QoS support. Future research can focus on further optimizing the protocol for specific application scenarios and integrating advanced machine learning techniques for predictive scheduling and routing decisions.

While the discussed QoS-based scheduling protocols and algorithms have demonstrated significant improvements in WSN performance, several future challenges remain. Scalability is crucial as the size and complexity of WSNs grow, introducing additional challenges in managing resources and maintaining QoS across a more extensive and diverse set of nodes. WSNs increasingly integrate heterogeneous devices with varying capabilities and energy constraints, making it a significant challenge to develop scheduling protocols that can efficiently manage such diversity while ensuring uniform QoS. Despite advancements, optimizing energy consumption remains a persistent challenge, requiring future protocols to balance the trade-off between energy efficiency and other QoS metrics, particularly in energy-constrained environments. Security becomes paramount as WSNs are deployed in critical and sensitive applications, necessitating robust security measures without compromising QoS and performance. Networks operating in dynamic environments require protocols that can adapt in real-time to changing conditions such as node mobility, varying traffic patterns, and environmental factors, making the development of adaptive algorithms essential. Managing interference in dense network deployments is critical, and future protocols must include advanced interference mitigation techniques to ensure reliable communication. Applications such as healthcare and industrial automation require ultra-low latency and high reliability, posing a significant challenge in ensuring that scheduling protocols can consistently meet these stringent requirements. The integration of WSNs with emerging technologies like IoT and 5G presents new challenges, necessitating protocols designed to interoperate seamlessly with other network types and standards. While some protocols already incorporate machine learning, there is potential for more sophisticated applications, with challenges including the need for real-time learning, handling large volumes of data, and ensuring the reliability of machine learning-driven decisions. Ensuring that different WSNs and their protocols can work together seamlessly requires standardization efforts, making the development of universally accepted standards that address QoS needs while allowing for interoperability a significant challenge.

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