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Optimizing Multimedia Data Delivery in Wireless Multimedia Sensor Network: A QoS-Driven Routing Protocol Design

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Abstract:- In recent years, there has been a shift towards utilizing wireless sensor networks (WSN) for multimedia applications, even though these networks were originally designed for transmitting small data volumes. In order to satisfy the increasing need for improved throughput and real-time performance when handling multimedia content, it becomes essential to streamline and enhance the routing protocols. In this document, we introduce a routing algorithm called Honey Badger optimization Algorithm (HBOA). This algorithm is designed to minimize end-to-end packet delay and reduce packet loss in wireless sensor networks (WSN). Instead of selecting shortest path to the destination HBOA selects optimised high throughput path to transport multimedia packets ovet the nertwork. Furthermore, it incorporates a network void-bypass mechanism to enhance network reliability when it encounters gaps in the network. Energy management is integrated to enhance the longevity of sensor nodes by adjusting the radio transmission coverage to a distance that sensor nodes can efficiently reach. The simulation results when compared with existing routing protocols demonstrate that HBOA achieves a 8% reduction in end-to-end delay and a 18% decrease in packet loss ratio while effectively managing energy consumption when compared to alternative algorithms. Load balancing occurs as a result of energy management, which makes the remaining energy of sensor nodes uniformly dispersed throughout the entire network. Through Simulation, the performance of HBOA is also compared to that of AGEM, TPGF, GPSR, and AODV.the esults suggests the HBOA performance better under conditions that are similat to these, such as low packet end-to-end- delay, low packet loss, and load balancing of routing channels.
Keywords: Wireless multimedia sensor network, Energy efficiency, Packet optimization, end-to-end delay optimization

1. Introduction

Wireless Sensor Networks (WSNs), as described by Yick et al. in 2008, represent a category of physical monitoring systems comprising self-organized and interconnected sensors distributed across an extensive coverage area. These sensors employ specialized communication protocols for gathering, transmitting, and processing sensed information. The data is then transmitted through multi-hop routing to reach the designated sink. The sink serves as the central hub for data processing, computation, and network control. Administrators can establish communication with the sink using conventional networks like the Internet. Conventional WSNs have traditionally been designed to collect, process, and transmit scalar data such as temperature, pressure, humidity, or location. These networks operate with limited bandwidth for transmission.

However, with the growing complexity of monitoring environments, scalar data alone falls short in meeting the requirements for detailed environmental monitoring. Therefore, there is an increasing need to incorporate support for media-rich content like images, video, and audio to enhance data collection and achieve more precise environmental monitoring. Recent advancements in technology have substantially lowered the hardware costs for devices such as cameras and microphones. Concurrently, there have been improvements in bandwidth capabilities, enhancing wireless communication capabilities. In this context, Wireless Sensor Networks (WSNs) have begun to transition into Wireless Multimedia Sensor Networks (WMSNs). These networks are capable of storing, real-time processing, correlating, and fusing multimedia data from diverse sources, as discussed by Akyildiz et al. in 2007. Research suggests that WMSNs have the potential to greatly enhance environmental sensing capabilities and provide more detailed descriptions of environmental events.

Wireless Multimedia Sensor Networks (WMSN) represents a significant and promising technological advancement with the potential to enhance existing WSN applications while opening the door to a range of innovative multimedia applications. These include multi-camera surveillance (as discussed by Natarajan et al. in 2015), visual target tracking (explored by de San Bernabe et al. in 2015), location-based multimedia services (as highlighted by Akhlaq Ahmad et al. in 2015), and situation awareness (as described by Wang in 2015). With the emergence of various types of multimedia sensors, the popularity of video and camera sensors, as indicated by Google search trends, has been steadily on the rise. Conversely, there has been a declining trend in searches related to wireless sensors in recent years, as shown in Figure 1. This shift in search patterns highlights the increasing interest and focus on WMSN technology. Efficient routing withmultimedia capabilities has become a significant research priority within the realm of Wireless Multimedia Sensor Networks (WMSNs). In recent years, there has been a considerable amount of research dedicated to the development of routing algorithms, protocols, and techniques for traditional WSNs, tailored to the specific needs of various applications and network architectures. The goal of these solutions is to offer best-effort services aimed at maintaining the smooth operation of network systems, all while keeping energy conservation in mind as a primary concern. However, due to the diverse nature of media, the substantial volume of data, intricate data formats and operations, and the necessity for high-speed real-time transmission within WMSNs, their demands for processing, storage, and bandwidth far exceed the capabilities of standard WSN platforms like MICA (Hill and Culler, 2002). Achieving multimedia transmission within WMSNs relies on a routing protocol to establish a stable and resource- efficient path and to deliver varying levels of QoS/QoE in accordance with specific requirements. Resource efficiency encompasses not only the effective utilization of bandwidth but also the reduction of energy consumption. Consequently, routing design and development entail numerous specialized considerations.

2. RelatedWork

Wireless sensor networks find application in various fields, including monitoring, healthcare systems, and object tracking. While traditional WSNs primarily focus on monitoring and sensing applications, the following section provides a concise overview of diverse multimedia data transmission methods.

Wael Ali Hussein et al: Wireless sensor networks are utilized in various domains, such as monitoring, healthcare systems, and object tracking. Although conventional WSNs predominantly concentrate on monitoring and sensing applications, the subsequent section offers a succinct exploration of various techniques for transmitting multimedia data. The presented mechanism selects the most efficient paths for transmitting multimedia data from source to destination. In comparison to AGEM, TPGF, GPSR, and AODV, the SGFTEM algorithm has demonstrated superior performance in terms of both throughput and energy efficiency. However, it equally distributes energy and other resources among network nodes, leading to suboptimal resource utilization and potential wastage of network resources [1].

Jawwharlal R and L. Nirmala Devi: Authors have introduced a Quality Aware Multipath Routing (QAMR) approach, which determines multiple paths based on factors like transmission count, energy availability, and delay. QAMR creates a composite metric by combining these three parameters and selects nodes that establish non-overlapping multiple routes from the source tothe destination. The simulation outcomes indicate that the proposed QAMR outperformed in terms of energy efficiency, reduced delay, enhanced throughput, and improved packet delivery rate (PDR). This demonstrates the significant impact of MWSN in both research and industrial applications. However, despite its effective performance in terms of QoS metrics, QAMR still faces challenges in addressing common node failures within the system [6].

Murat Koyuncu et al: Presented a model that focuses on energy-efficient and precise object detection and classification in the context of WMSN. To conserve energy, WMSN nodes are transitioned into a sleep mode until multimedia content needs to be transferred. The enhancement in object recognition performance is achieved by fusing results obtained from both video and audio applications. Notably, auditory data demands fewer processing resources compared to visual data, and the overhead of processing auditory data contributes to extending the network's operational lifespan [7].

Tong Wang and colleagues: Presented the Simultaneous Wireless Information and PowerTransfer (SWIPT) technique designed for wireless-powered body area networks. These SWIPT networks effectively tackle the challenge of minimizing energy consumption while dealing with varying throughput levels. This problem is resolved by considering scenarios without battery reliance and implementing a time allocation scheme characterized by low complexity. Comparatively, the battery-assisted scenario exhibits a reduced likelihood of outages and lower energy consumption when compared to the battery-free scenario. Additionally, we examine a specific situation in which the feasible solutions for the ECM-TH problems mentioned earlier may be nonexistent, primarily due to the high throughput demands of the sensor nodes or adversechannel conditions [8].

In wireless networks, data is transmitted continuously from the source to the destination, resulting in energy consumption within multi-hop wireless networks. The challenge of energy harvesting arises from the ongoing interaction and random movement of nodes. **Xiang Tian** and colleagues addressed these issues by introducing the concept of Throughput-Optimal Broadcast for Time-Varying Directed Acyclic Wireless Multi-hop Networks. The network introduced an online max-weight broadcast algorithm that considers the time-varying nature of linktransmission rates, influenced by energy-harvesting dynamics when scheduling transmission slots. Through simulation experiments, the algorithm's throughput and latency performance wereempirically evaluated, and the results align with our theoretical analysis [9].

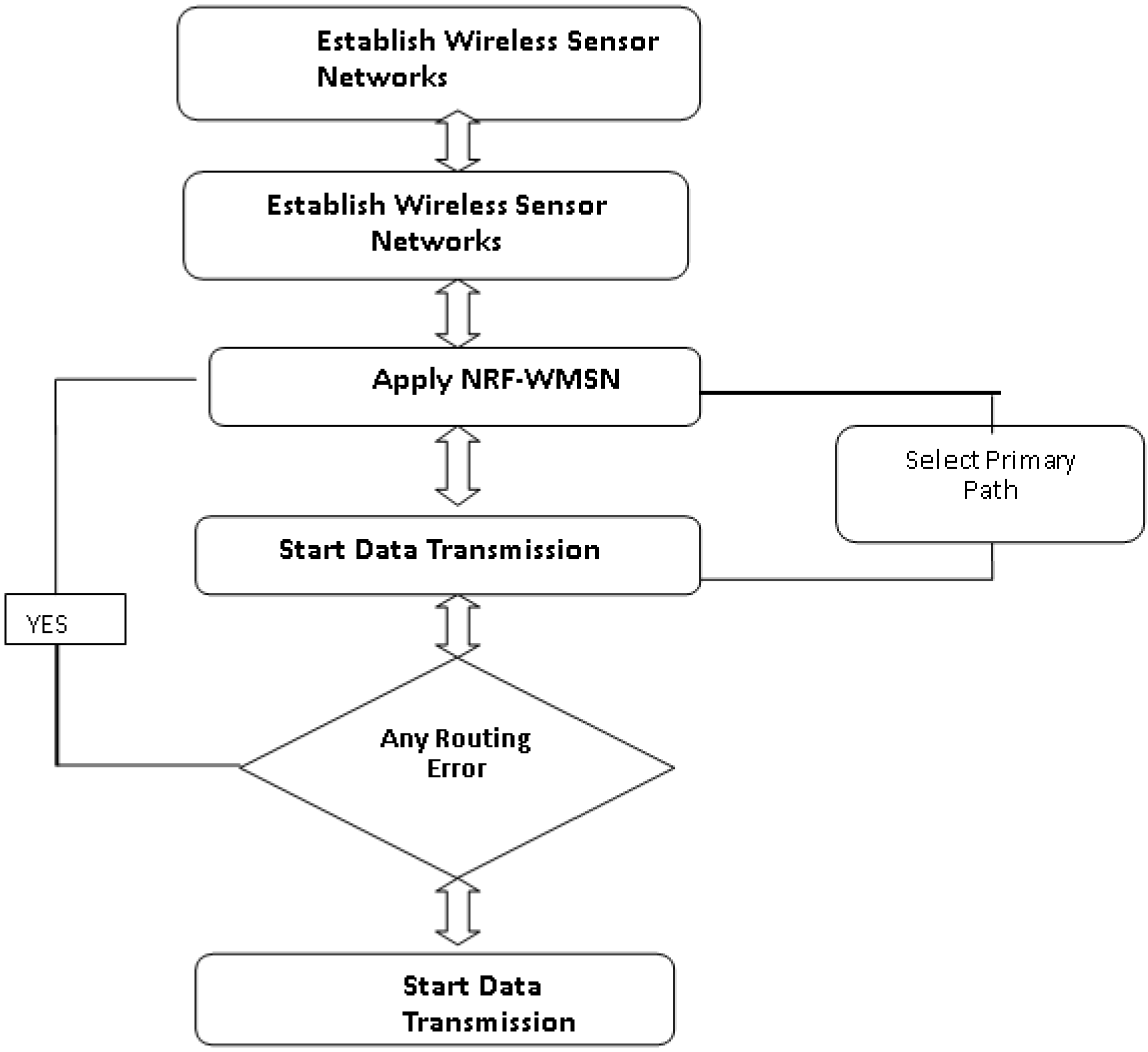
3. Proposed Methodology

Problem Definition

WSNs consist of sensor nodes that communicate with one another to collect data from their surrounding environments. These sensor nodes operate in a decentralized manner, utilizing low energy resources within the WSN. Such networks find deployment in a wide array of emerging applications, including healthcare systems, industrial operations, environmental monitoring, and military applications. In traditional WSNs, the operation involves three distinct levels: the base station, cluster heads, and sensor nodes. Sensor nodes are responsible for gathering data from their surroundings and forwarding it to the cluster head node. However, the cluster head nodes receive multimedia data for a fixed duration, and this behavior rotates periodically. These rotational changes in cluster head roles contribute to increased energy consumption and data transmission delays. To overcome these limitations and enhance the current state of WSNs, this research paper introduces a novel routing protocol based on nearest path selection.

Novel Routing optimization Algorithm

The proposed MWSN incorporates a two-phase optimized path selection mechanism. In the initial phase, it utilizes an optimized path selection algorithm to start the transmission of an RREQ (Route Request) packet from the source node to the destination node. This RREQ packet undergoes a broadcast process by intermediate nodes until it successfully reaches its intended destination.



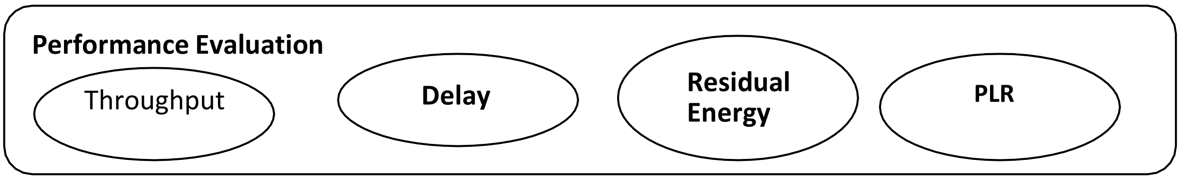


Figure 1: Proposed Novel Routing Protocol for Multimedia Transmission in Wireless Multimedia Sensor Network Architecture

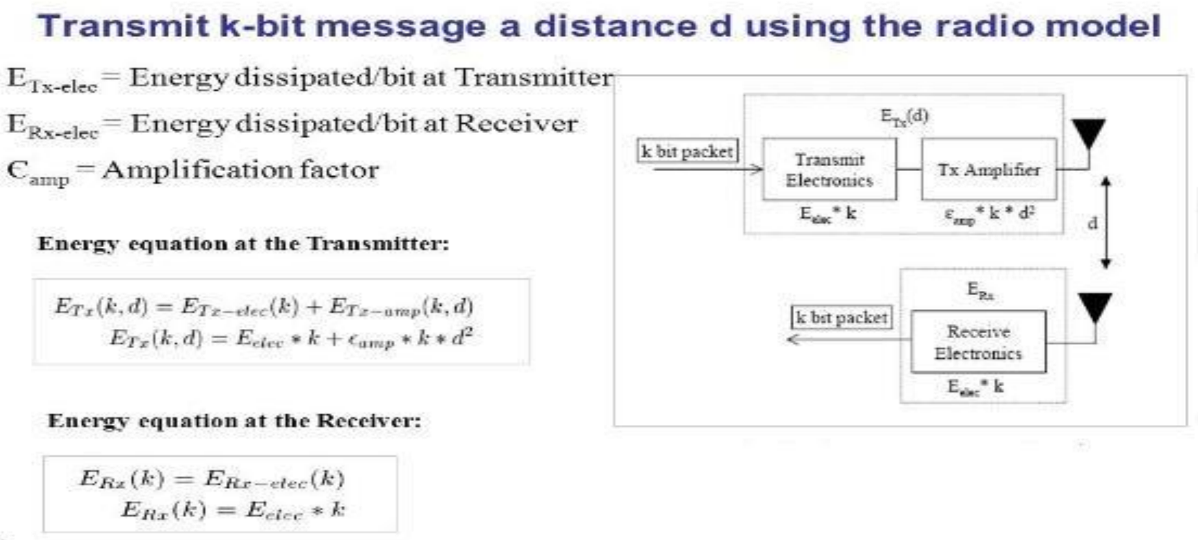


Figure 2: First order radio model

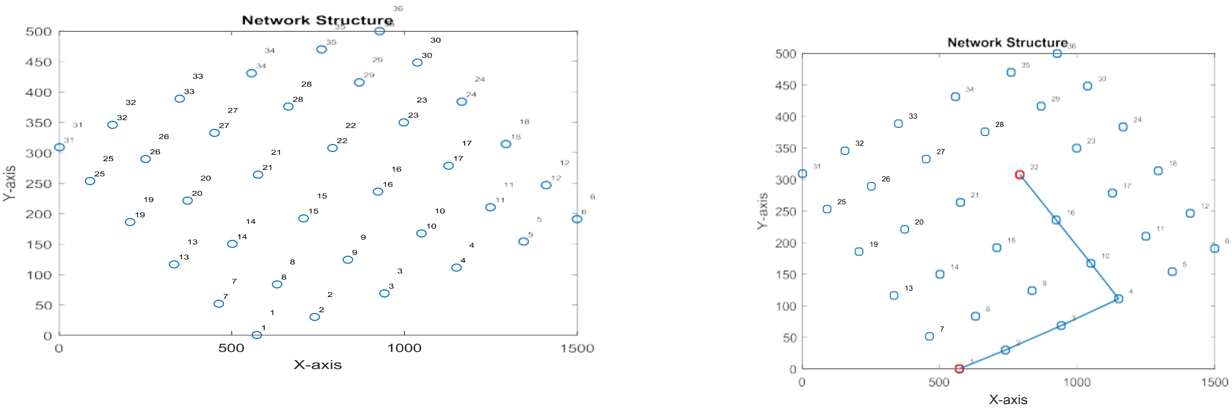


Figure 3: Network Structure

Algorithm Name: **pseudo Code of POA**

Start POA.
1. Input the optimization problem information.
2. Determine the POA population size (*N*) and the number of iterations (*T*).
3. Initialization of the position of pelicans and calculate the objective function.
4. For *t* = 1:*T*
5. Generate the position of the prey at random.
6. For *I* = 1:*N*
7. Phase 1: Moving towards prey (exploration phase).

8. For *j* = 1:*m*
9. Calculate new status of the *j*th dimension using Equation .
10. End.
11. Update the *i*th population member using Equation .
12. Phase 2: Winging on the water surface (exploitation phase).
13. For *j* = 1:*m*.
14. Calculate new status of the *j*th dimension using Equation .
15. End.
16. Update the *i*th population member using Equation .
17. End.
18. Update best candidate solution.
19. End.
20. Output best candidate solution obtained by POA.
End POA.

The summation of node distance values is computed, resulting in the ordering of all optimized paths. The destination node employs the primary optimized path to transmit an RREP packet back to the source node. Additionally, the network provides access to optimized alternate paths. In the event of a link or node failure within the network, these alternate paths are utilized for data transmission. Detailed implementation steps for the path selection algorithm in WSN are also provided to optimize the process.

4. Implementation

1. Firstly we define the network parameter like number of node energy area
2. Secondly we calculate the parameter which used to make the shortest route
3. Route parameter like we calculate the trust for the security reason calculate the PDR delay and packet

   loss and some other parameters for the route selection
4. Parameter calculation we design modified optimization algorithm for the find the optimum route
5. Introduce mobile wireless charging node in the network which provides power to other node having

   less energy with define threshold
6. Generate route for mobile wireless charging node in WSN using POA optimization algorithm
7. Calculate performance parameter

It appears that you are proposing a network optimization algorithm for route selection in a network with energy constraints. Here are some potential parameters that could be used for route selection:

Shortest route: The shortest route between the source and destination nodes could be calculated using distance or hop count as a parameter. Shorter routes could potentially result in lower energy consumption and reduced latency.

Node Residual Energy: The residual energy of nodes, which represents the remaining energy after accounting for energy consumption, could be used as a parameter for route selection. Nodes with higher residual energy levels could be preferred to ensure longer network lifetime and reliable data transmission.

Node Mobility: If nodes in the network are mobile, their mobility characteristics, such as speed and direction, could be considered as a parameter for route selection. Routes that involve more stable or less mobile nodes could be preferred to minimize disruptions in the network caused by node movements.

Node Congestion: The congestion level of nodes or links in the network, which represents the amount of traffic or data being transmitted, could be considered as a parameter. Less congested nodes or links could be preferred to avoid network bottlenecks and improve data transmission efficiency.

Node Reliability: The reliability or stability of nodes, which reflects their ability to consistently operate without failures or disruptions, could be used as a parameter. More reliable nodes could be given higher priority in route selection to ensure robust and dependable network performance.

Network Load Balancing: Load balancing, which aims to distribute network traffic or data evenly across nodes or links, could be considered as a parameter. Routes that achieve better load balancing could be preferred to prevent nodes or links from becoming overloaded and ensure efficient resource utilization.

Trust: Trustworthiness of nodes along the route could be considered as a parameter. Nodes with higher trust levels, based on factors such as reputation or historical behavior, could be given higher priority in route selection to ensure security and reliability of data transmission.

Quality of Service (QoS): If your network has specific QoS requirements, such as PDR, delay, or Packet Loss, these parameters could be considered in route selection. Routes that meet or exceed the desired QoS levels could be preferred to ensure satisfactory performance for network applications.

Let's denote the parameters as follows: Shortest route: SR
Trust: T
Node Residual Energy: RE Node Mobility: M
Node Congestion: C Node Reliability: R
Network Load Balancing: LB

Quality of Service (QoS): Q
Then, the combined equation for route selection could be formulated as:
Score = w1*(SR+Q+RE)+w2*(T+C+R)+w3*(LB+M)

Honey Badger Optimization is a nature-inspired optimization algorithm that mimics the foraging behavior of honey badgers in nature. It is known for its ability to handle multi-objective optimization problems and is commonly used in various fields, including computer networks and communications.

To use Honey Badger Optimization to determine the weight values in your combined equation for route
selection, you can follow these steps:

Initialize the weight values (w1, w2, w3) with random values or an initial guess.

Generate a population of honey badgers, each representing a potential solution with different weight values.

Evaluate the fitness of each honey badger solution by calculating the performance score using the combined equation for route selection with the current weight values.

Update the weight values of the honey badgers using the Honey Badger Optimization Algorithm's search mechanisms, such as random exploration, local search, and global search, to find better weight values.

Repeat steps 3 and 4 for a certain number of iterations or until a convergence criterion is met.

Select the honey badger solution with the highest fitness (i.e., the best performance score) as the optimized weight values for your route selection formula.

You can adjust the parameters of the Honey Badger Optimization Algorithm, such as the population size, search mechanisms, and convergence criteria, based on your specific needs and requirements. The algorithm will iteratively update the weight values to find the best weights that would result in optimal route selection in your specific network scenario

In Wireless Sensor Networks (WSN), energy management plays a crucial role in prolonging the sensor nodes' lifetime. Solar charging is a viable solution to extend the battery life; however, it can lead to increased network costs. To address this issue, this research introduces a Mobile Wireless Charging Node (MWCN) to the network, which selectively provides power to nodes with lower energy levels, based on a predefined threshold. To optimize the energy routing process, the Pelican Optimization Algorithm (POA) is applied to generate efficient routes for the MWCN, ensuring maximum energy transfer to needy nodes. The proposed approach achieves both extended sensor node lifetime and cost-effectiveness, making it a promising solution for sustainable and resilient WSN applications.

5. Results Analysis

The novel routing algorithm designed for WMSN is executed using Matlab R2018. The empirical simulation results are presented to evaluate the performance of MWSN in handling multimedia data transmission. Detailed comparative results are further elaborated in the subsequent subsections

5.1 Simulation Environment

Sno	Network parameter	Network value
1	Type of Channel	Wireless Channel
2	Radio-Propagation	Propagation/Two Ray Ground
3	Network Interface	Wireless Phy
4	Interface Queue Type	Drop Tail
5	Model of Antenna	Omni Antenna
6	Length of Queue	60
7	Routing Protocol	Proposed

8	Number of Nodes	100
9	Data Rate	3MB
10	Basic Rate	1MB
11	Total Simulation Time	40

Table 1: Simulation Environment

Table 1 provides an exhaustive list of network parameters employed in the configuration of the WMSN simulation. The deployment of the WSN utilizes the two-ray ground radio propagation model. Various performance metrics are scrutinized to assess the effectiveness of the proposed mechanisms, with a particular focus on improvements in terms of delay, throughput, and packet delivery ratio. Table 1 provides an exhaustive list of network parameters employed in the configuration of the WMSN simulation. The deployment of the WSN utilizes the two-ray ground radio propagation model. Various performance metrics are scrutinized to assess the effectiveness of the proposed mechanisms, with a particular focus on improvements in terms of delay, throughput, and packet delivery ratio.

5.2 Metric Comparative Analysis

We compare the Proposed NRP-WMSN with various previous mechanisms that have been developed to enhance performance in WSNs, including the Smart Greedy Forwarding algorithm based on Throughput and Energy-Awareness (SGFTEM), the Adaptive Greedy Compass Energy-Aware using Multi-path (AGEM) approach, and the Two-Phase Greedy Forwarding (TPGF) method. Detailed definitions of performance metrics can be found in the following section.

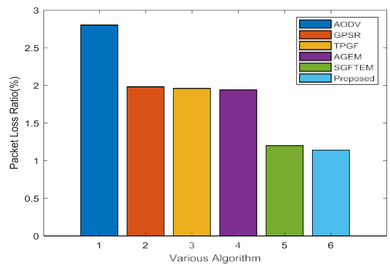
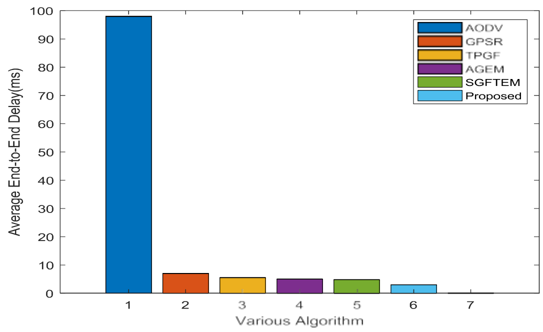
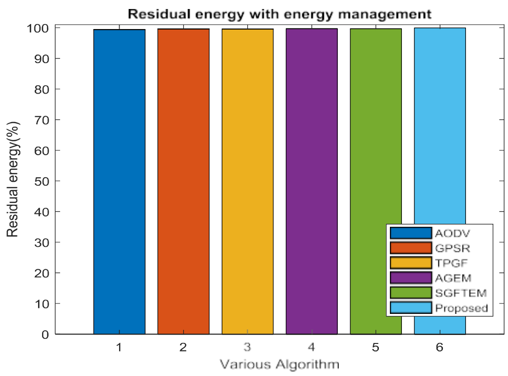


Figure 4: Packet loss ratio comparision





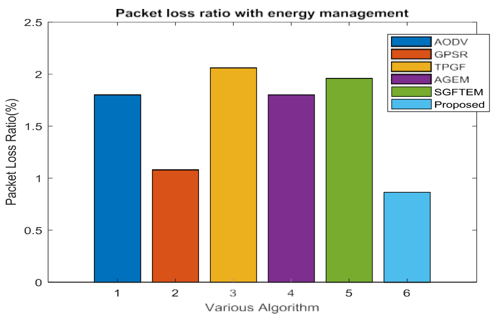


Figure 5: Average end-to-end delay

Figure 6: Packet energy with energy management management

Figure 7: Packet loss with energy

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5. Conclusion

Advancements in WSNs have found applications in various real-time fields such as military, healthcare, agriculture, and smart cities. WSNs are particularly efficient for data transmission, with sensor node operations tailored to real-time environments. Given the resource-constrained nature of sensor nodes in WSNs, addressing the network's challenges is crucial. This research paper focuses on proposing a novel WMSN routing algorithm to tackle these issues, with a primary emphasis on enhancing network performance and reducing network delay. The role of the proposed routing algorithm is pivotal in facilitating multimedia data transmission and the optimal path selection process between source and destination nodes within the network. This routing algorithm not only keeps track of node distance status but also establishes alternate paths that can be employed in case of primary path failures, be it due to link or node issues. The implementation of this routing algorithm has resulted in improved network performance, particularly in terms of reduced delay, increased throughput, and enhanced Packet Delivery Ratio (PDR). In contrast, the NRP-WMSN demonstrates superior performance when compared to various throughput-focused WSN approaches. In essence, the optimization of WMSN is geared towards improving the transmission of multimedia data within WSNs.

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