Resilient Disaster Communication

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January 11, 2024

Abstract

A. Background of the problem statement

Disaster response teams often face challenges when communicating in extreme weather conditions and remote locations, where traditional communication systems may not be reliable or available. This can result in delayed response times, miscommunication, and ultimately, reduced effectiveness in saving lives and property. Therefore, there is a need for a communication system that can operate in these challenging environments. [1–3]

B. Challenges and issues of the problem statement

The main challenges of the problem statement include optimizing the physical layer and data link layer for efficient and reliable data transmission in the WSN. Extreme weather conditions and remote locations can cause interference and noise, leading to poor signal quality, and unreliable communication. Moreover, the energy consumption of the nodes in the WSN is another challenge to be addressed. [4–6]

C. Existing approaches or methods and their issues

Existing approaches for communication in the WSN include routing protocols, MAC protocols, and data link protocols. However, most of these approaches have limitations and are not suitable for extreme weather conditions and remote locations. For instance, some routing protocols may lead to high energy consumption, while MAC protocols may not be efficient for large-scale networks. Existing ideas revolve around RRT(Reliable Routing Technique) the selection algorithm is that if not optimized, it can lead to delays or dropped packets in the network. Additionally, existing data link protocols may not provide sufficient reliability and may be prone to errors. One common drawback in all these approaches is the problem of energy consumption. [7–9]

D. Your problem statement

To design and simulate a communication system for disaster response teams that operates in extreme weather conditions and remote locations, using MATLAB/Python and comparing the existing CSMA/CA with the modified CSMA/CA approach. [10–12]

E. Objectives of the proposed work

The objective of our proposed work is to design and simulate a communication system required for remote locations and extreme weather conditions, by modifying parameters of CSMA/CA protocol to save energy.
Performance should be analyzed by evaluating range, data rate, modulation, and coding schemes. The communication system should be optimized to improve its performance while minimizing energy consumption. Finally, the proposed communication system should be compared with traditional communication systems and wireless sensor networks used in disaster response teams to determine its effectiveness. [13–15]

1. Introduction

1.1. Background of the problem statement

Disaster response teams play a critical role in saving lives and property during emergencies, natural disasters, and other crisis situations. However, they often face challenges in communicating effectively, particularly in extreme weather conditions and remote locations. In such situations, traditional communication systems, such as landlines and cellular networks, may be unavailable, unreliable, or overloaded, making it difficult or impossible for responders to coordinate their efforts and communicate critical information. This can lead to delays in response times, miscommunication, and ultimately, reduced effectiveness in saving lives and property. For instance, during a hurricane or other severe weather event, high winds and heavy rain can damage or destroy communication infrastructure, including cell towers and power lines, leaving responders without a reliable means of communication. Similarly, in remote areas or wilderness settings, responders may not have access to cellular networks or landlines, making it challenging to coordinate rescue efforts or provide updates on their progress. To overcome these challenges, there is a need for a communication system that can operate in these challenging environments. Such a system should be resilient, reliable, and able to function in extreme weather conditions and remote locations. Overall, the need for a communication system that can operate in extreme weather conditions and remote locations is critical to ensuring the effectiveness of disaster response efforts and saving lives and property. By investing in resilient and reliable communication systems, responders can improve their ability to coordinate their efforts, share critical information, and respond quickly and effectively to emergencies and other crisis situations. [1–3,5]

1.2. Challenges and issues of the problem statement

The problem statement refers to the challenges associated with the optimization of the physical layer and data link layer in Wireless Sensor Networks (WSN) for efficient and reliable data transmission. The physical layer is responsible for transmitting and receiving signals between the nodes in the network, while the data link layer provides the necessary protocols for error detection and correction.

One of the significant challenges of this problem statement is the optimization of the physical layer to ensure that the signals transmitted over the WSN are of high quality and can be reliably received by the nodes. Extreme weather conditions and remote locations can cause interference and noise, leading to poor signal quality and unreliable communication. As a result, there is a need to design and implement efficient techniques to mitigate the effects of these factors and ensure the reliability of the WSN.

Another significant challenge in WSNs is the energy consumption of the nodes. The nodes in a WSN are often powered by batteries, and the energy consumption of each node must be minimized to extend the lifespan of the network. Therefore, it is essential to develop energy-efficient protocols that can optimize the performance of the WSN while minimizing energy consumption. This requires the design and implementation of innovative energy management techniques and algorithms that can maximize the network's lifespan while ensuring reliable data transmission.

In summary, optimizing the physical layer and data link layer for efficient and reliable data transmission in WSNs is a significant challenge that requires addressing several factors, including interference and noise, energy consumption, and reliability. Meeting these challenges requires innovative techniques and algorithms that can improve the network's performance while minimizing energy consumption and maximizing its lifespan.

[4–6]

1.3. Existing approaches or methods and their issues

Wireless Sensor Networks (WSNs) are used to collect data from various environments, including remote and extreme weather conditions. Communication in WSNs is challenging due to the limited resources of the sensor nodes, including battery power, processing capabilities, and memory. Existing approaches for communication in WSNs, including routing protocols, MAC protocols, and data link protocols, have limitations and may not be suitable for extreme weather conditions and remote locations.

Routing protocols are used to find the best path for data transmission from the source node to the sink node. However, most of these protocols rely on flooding or multi-hopping techniques, which may lead to high energy consumption and network congestion. Moreover, these protocols may not be efficient for large-scale networks.

MAC protocols are responsible for coordinating the access of nodes to the shared wireless medium. However, these protocols may not be efficient in large-scale networks due to the limited bandwidth and high contention. Additionally, these protocols may not be suitable for extreme weather conditions, where the wireless channel is affected by fading and interference.

Data link protocols provide the reliability of data transmission by adding error control mechanisms, such as retransmission, acknowledgement, and checksums. However, these protocols may not be suitable for extreme weather conditions, where the wireless channel is prone to errors and interference. Moreover, these protocols may not provide sufficient reliability for critical applications, such as healthcare and military.

Power control is a technique used to optimize the energy consumption of wireless devices in a communication network. In this approach, the power level of each wireless device is adjusted based on the distance to its intended receiver and the quality of the received signal. The goal of power control is to reduce unnecessary energy consumption while maintaining a desired level of signal quality. The main drawback of power control is that it can be computationally expensive and requires significant overhead to implement. Moreover, power control can lead to increased interference between wireless devices, which can further degrade the overall network performance. In conclusion, existing approaches for communication in WSNs have limitations and may not be suitable for extreme weather conditions and remote locations. To overcome these limitations, researchers have proposed various ideas, including RRT, but these ideas need to be optimized and evaluated for their performance in different environments. [7–9]

1.4. Problem statement

To optimize the communication system for disaster response teams that operates in extreme weather conditions and remote locations which solves the energy consumption problem using the modified CSMA/CA Protocol, and using MATLAB/Python and analyze the energy consumption of the previous approach and modified approach. [10–12]

1.5. Objectives of the proposed work

Develop a communication system that operates in extreme weather conditions and remote locations, using CSMA/CA protocol to minimize energy consumption. Design and implement the physical layer and data link layer of the communication system using MATLAB. Analyze the performance of the communication system by evaluating its range, data rate, modulation, and coding schemes. Optimize the design of the communication system to improve its performance while minimizing energy consumption. Compare the performance of the proposed communication system with existing approaches for communication in disaster response teams, including traditional communication systems and wireless sensor networks. [13–15]

2. Literature Review

Wireless Sensor Networks (WSN) are a critical component of disaster response systems. They can provide valuable information about the environment and help in disaster response efforts. However, WSNs face significant challenges when operating in extreme weather conditions and remote locations. Traditional communication systems may not be reliable or available in such environments, leading to delayed response times, miscommunication, and reduced effectiveness in saving lives and property

2.1 Existing approaches and their issues

2.1.1. Routing protocols

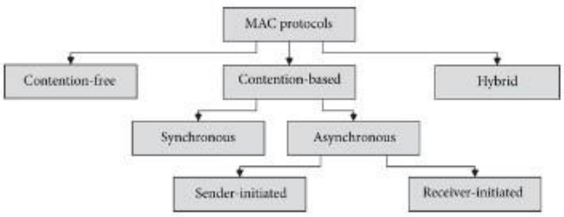
Routing protocols, MAC protocols, and data link protocols are commonly used approaches for communication in wireless sensor networks (WSNs). However, these approaches have several limitations when it comes to operating in extreme weather conditions and remote locations. Routing protocols are used to determine the best path for data transmission between the source and the destination nodes in the network. There are various types of routing protocols such as proactive, reactive, and hybrid protocols. Proactive protocols maintain a complete routing table, whereas reactive protocols establish a route on-demand. Hybrid protocols combine the best features of proactive and reactive protocols. However, these protocols do not consider the energy consumption of the nodes. This can result in premature node failure and network partitioning, especially in remote and harsh environments.

	Proactive	Reactive	Hybrid
Main Features	Maintain outing information on all nodes in the network at all times.	Maintain routing information for the nodes which are needed and only for the time when they are needed	Proactive for short distances and reactive for long distances
Pros	Low route setup	Low routing overhead	No route setup required
Cons	High routing overhead	Larger route setup	More complex

[16]

2.1.2 MAC protocols

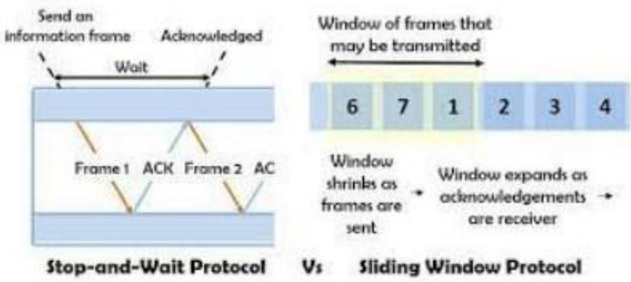
MAC protocols control the access of nodes to the shared wireless medium in the network. There are various types of MAC protocols such as contention-based, contention-free, and hybrid protocols. Contention-based protocols allow nodes to access the medium whenever it is free. Contention-free protocols reserve the medium for a specific node or a group of nodes. Hybrid protocols combine the best features of both contention-based and contention-free protocols. However, MAC protocols may lead to high energy consumption and interference, making them inefficient for large-scale networks.

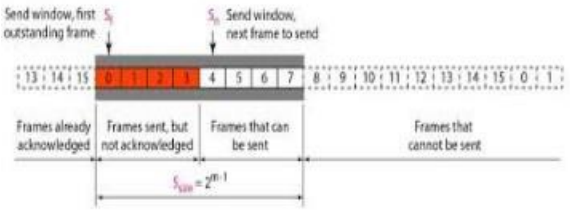


[17]

2.1.3 Data link protocols

Data link protocols are responsible for the transmission of data between adjacent nodes in the network. There are various types of data link protocols such as the stop-and-wait protocol, sliding window protocol, and selective repeat protocol. The stop-and-wait protocol transmits one packet at a time, and the receiver sends an acknowledgment back to the sender before transmitting the next packet. The sliding window protocol allows the sender to transmit multiple packets before receiving an acknowledgment. The selective repeat protocol retransmits only the lost packets instead of the entire sequence. However, data link protocols may not provide sufficient reliability and may be prone to errors, especially in harsh environments. In conclusion, routing protocols, MAC protocols, and data link protocols are commonly used approaches for communication in WSNs. However, these protocols have several limitations and may not be suitable for extreme weather conditions and remote locations. The limitations include high energy consumption, interference, reduced network lifetime, and unreliable communication.





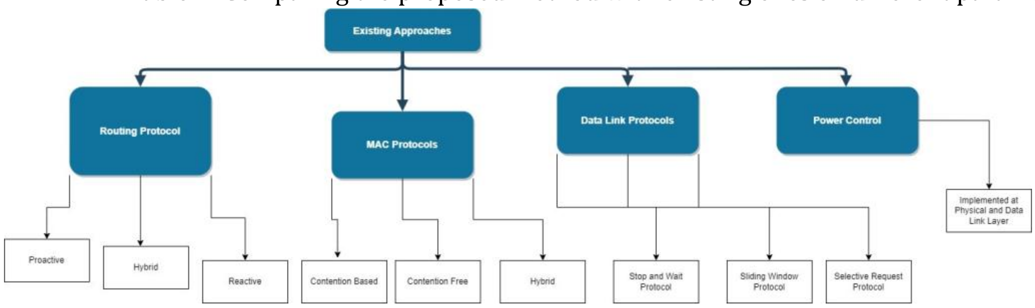
[18]

2.1.4 Power control

Power control is a technique used in wireless communication systems to optimize network performance and reduce the energy consumption of nodes. It can be implemented at different layers, including the physical, MAC, and network layers. At the physical layer, power control adjusts transmission power based on the quality of the wireless channel, while at the MAC layer, it adjusts power based on network congestion. At the network layer, power control optimizes routing paths between nodes. However, power control can lead to a trade-off between energy consumption and network performance, and the optimal transmission power must be carefully chosen based on application requirements and network topology. [15]

Parameter	Routing/MAC/Power Control Approach
Energy efficiency	Routing and power control approaches are more energy-efficient than MAC approach
Scalability	Power control approach is more scalable than routing and MAC approaches
Robustness	Routing approach is more robust than MAC and power control approaches
Complexity	MAC approach is simpler to implement than routing and power control approaches
Adaptability	Power control approach is more adaptable to changing network conditions than routing and MAC approaches
Cost	MAC approach is the least expensive to implement compared to routing and power control approaches
Latency	MAC approach typically has lower latency than routing and power control approaches due to centralized control
Interference	Power control approach can mitigate interference more effectively than routing and MAC approaches by adjusting transmission power

Table 1: Comparing the proposed method with existing ones on different parameters



3. Proposed Methodology

3.1 CSMA/CA Protocol

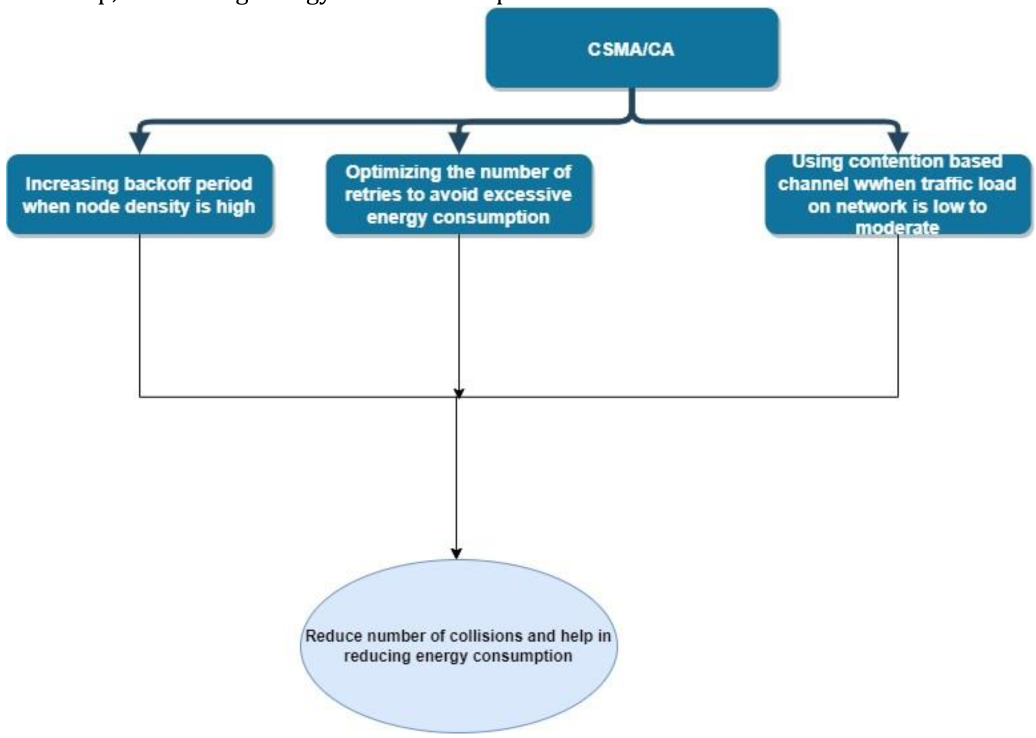
The common problem identified in the existing approaches was that of energy consumption. This can be resolved using the CSMA/CA protocol. Wireless Sensor Networks (WSNs) consist of a large number of small, battery-powered nodes that can sense and transmit data wirelessly. The nodes in WSNs are typically deployed in an area of interest, and they are responsible for sensing physical phenomena such as temperature, humidity, or motion. The nodes then communicate with each other to relay the sensed data to a central node, known as a sink, for further processing.

One of the primary concerns in WSNs is energy consumption. Since most nodes in WSNs operate on battery power, energy conservation is essential to prolong the network's lifetime. The CSMA-CA protocol is a solution that addresses this challenge by reducing energy consumption in WSNs at the physical layer.

The CSMA-CA protocol is based on the Carrier Sense Multiple Access (CSMA) protocol, which is used in Ethernet networks. CSMA is a protocol that requires nodes to listen to the medium before transmitting data. If the medium is found to be busy, the node waits for a random period before attempting to transmit again. CSMA helps to avoid collisions by spreading out the transmission times of nodes. However, it is not energy-efficient in WSNs since nodes have to be active continuously to sense the medium.

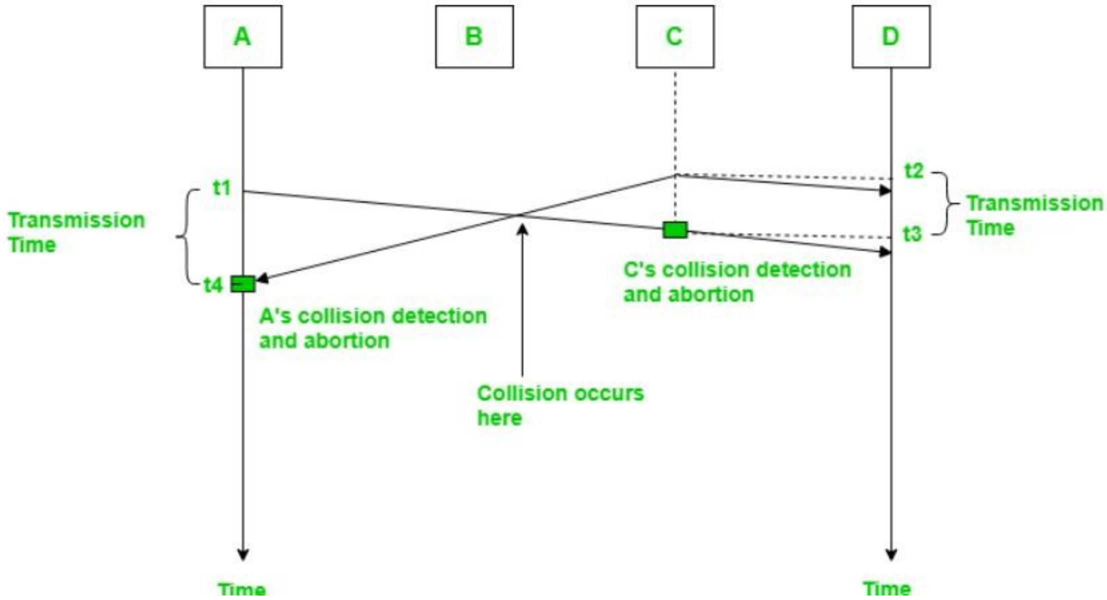
To address this issue, the CSMA-CA protocol was introduced. The CSMA-CA protocol adds a Collision Avoidance (CA) mechanism to the CSMA protocol. The CA mechanism requires nodes to back off for a random time if they detect the medium to be busy. The random backoff time helps to avoid collisions between nodes and conserves energy by allowing nodes to sleep when there is no incoming packet.

Furthermore, the CSMA-CA protocol uses an energy-efficient preamble structure that allows nodes to detect the start of a packet without decoding the entire packet. This is achieved by using a synchronization header, which contains a unique bit pattern that nodes can detect. Once the synchronization header is detected, the node can go back to sleep, conserving energy until the next packet arrives.



The CSMA-CA protocol can be customized by adjusting the protocol parameters to suit the specific network requirements. The backoff period, the number of retries, and the channel access mode are some of the key parameters that can be adjusted. For example, if the network is dense, the backoff period should be longer to reduce the likelihood of collisions. If the network is sparsely populated, the backoff period can be shorter to improve network performance.

In conclusion, the CSMA-CA protocol is an effective solution for reducing energy consumption in WSNs at the physical layer. It helps to avoid collisions, conserve energy, and improve network performance by using a random backoff mechanism, an energy-efficient preamble structure, and by adjusting the protocol parameters to suit the specific network requirements



Reduce number of collisions and help in reducing energy consumption using CSMA/CA [19,20]

3.2 Idea of Implementation

Wireless sensor networks are composed of small, low-power devices with limited computational resources and battery life. These devices are often deployed in remote and harsh environments to monitor various physical and environmental conditions, and transmit data to a central processing unit or gateway.Due to the limited resources of the nodes and the shared nature of the wireless medium, it is crucial to use efficient medium access control protocols to avoid collisions and improve network performance.

CSMA/CA is a contention-based protocol where nodes listen to the wireless medium before transmitting data. If the medium is idle, the node can start transmitting. If the medium is busy, the node waits for a random amount of time before retrying. This random backoff time helps avoid collisions and allows nodes to share the medium fairly.

The backoff time is a critical parameter in CSMA/CA, as it determines how long a node waits before attempting to transmit data after sensing the medium is busy. If the backoff time is too short, collisions may occur, and data may be lost. If the backoff time is too long, the network may experience low throughput and latency.

To determine the appropriate backoff time, it is necessary to measure the node density in the network. This can be done using various methods, including randomly selecting nodes and counting neighbouring nodes within a certain distance or using a grid-based approach to divide the area into equal-sized cells and counting nodes in each cell.

Implementing a mechanism for dynamically adjusting the backoff period based on changing node density can help improve network performance. This can be done by multiplying the current backoff period by a factor of the current node density divided by the previous node density. By adjusting the backoff period dynamically, nodes have more time to sense the medium and avoid collisions, reducing the number of retransmissions and energy consumption.

Another important parameter in WSNs is the contention-free channel. The contention-free channel is a reserved channel where nodes can transmit data without contention. However, the existing contention-free channel access method requires a centralized scheduling entity or coordinator, which can become a single point of failure in the network.

To address this issue, a round-robin algorithm can be used to distribute the scheduling responsibility among the nodes themselves. Each node can maintain its own local schedule and transmit data only during its allocated time slots, reducing the need for a centralized coordinator and improving the fault tolerance of the network. This algorithm ensures that all nodes have an equal opportunity to transmit their packets, and that no node monopolizes the channel for an extended period of time.

In addition to these parameters, other techniques such as power control, duty cycling, and data aggregation can also be used to improve the performance of wireless sensor networks. These techniques help reduce energy consumption, increase network lifetime, and improve data reliability.

3.3 Justification for the above proposed approach

- The CSMA-CA protocol is a well-established approach for reducing energy consumption in WSNs. This protocol helps to avoid collisions and conserve energy by requiring nodes to listen to the wireless medium before transmitting data and by using an energy-efficient preamble structure.

- The backoff period in CSMA-CA is a random delay between a minimum and maximum value that a node must wait before attempting to transmit data. This delay is calculated by the node's MAC layer using a binary exponential backoff algorithm. To adjust the backoff period for a specific WSN, we can modify the minimum and maximum values used in the backoff algorithm. For example, an increase in the maximum value to provide a longer backoff period, will allow nodes to wait longer before attempting to transmit again. This can be particularly useful in networks with a higher node density or heavier traffic load, where the probability of multiple nodes attempting to transmit at the same time is higher. By increasing the backoff period, nodes will have more time to detect the medium as busy and avoid collisions, improving overall network performance and reducing energy consumption.

- The number of retries in CSMA-CA refers to the number of times a node will retransmit a packet before giving up. This parameter can be adjusted to balance the need for successful transmission with energy consumption. In networks with a high reliability requirement, where successful delivery of packets is critical, the number of retries can be increased. This ensures that packets are transmitted multiple times until they are successfully received, thereby improving the overall reliability of the network. On the other hand, in networks where energy conservation is a higher priority, the number of retries can be decreased to avoid excessive energy consumption. By reducing the number of retries, nodes can conserve energy by avoiding unnecessary retransmissions and conserving their battery power.

- Contention-based channel access is used when the traffic load on the network is low to moderate. In this mode, nodes contend for the channel by sensing the wireless medium and transmitting data when the channel is idle. However, in networks with a higher traffic load, the probability of collisions increases, leading to packet loss and retransmissions.

- To address this issue, contention-free channel access can be used. In this mode, a schedule is predetermined, and each node is assigned a specific time slot for transmitting data. This ensures that nodes do not contend for the channel, reducing the likelihood of collisions and improving the reliability of the network. The implementation of contention-free channel access requires a central coordinator or scheduling entity that generates the schedule and distributes it to the nodes. The coordinator assigns each node a specific time slot during which it can transmit data, ensuring that there are no overlapping transmissions. The nodes then follow the schedule and transmit data only during their allocated time slots, reducing the likelihood of collisions and improving the efficiency of the network.

  In summary, the CSMA-CA Protocol can help reduce energy consumption in WSNs by avoiding collisions between nodes during data transmission. By optimizing the protocol parameters to suit specific network requirements, the performance of the network can be further improved. [21]

4. Implementation

1. Dynamic Backoff Period Adjustment: To adapt the backoff period in response to changing node densities, adynamic adjustment mechanism is implemented. The backoff period is multiplied by a factor calculated as the ratio of the current node density to the previous node density. This dynamic adjustment ensures that nodes allocate more time for medium sensing and collision avoidance. As a result, the number of retransmissions decreases, leading to reduced energy consumption in the network.
2. Round-Robin Scheduling: To overcome the limitations of a centralized coordinator in contention-freechannel access, a round-robin scheduling algorithm is employed. Each node maintains its local schedule and transmits data only during its allocated time slots. This approach distributes the scheduling responsibility among the nodes, improving fault tolerance and reducing the reliance on a centralized entity. The roundrobin scheduling algorithm ensures fair access to the channel for all nodes and prevents any single node from monopolizing the channel for an extended period.

Experimental Setup: To evaluate the effectiveness of the proposed approach, experiments are conducted in a simulated WSN environment. The experiments consider various parameters such as node density and network size. The count of nodes or node density can be taken into consideration using the following algorithm: • Define a sensing radius: Set a radius that represents the maximum distance within which neighboring nodes are considered.

- Select a reference node: Choose a node at the desired location for density estimation.
- Initialize a counter: Set the counter to zero.

- Iterate through all nodes in the network:

  1: Calculate the Euclidean distance between the reference node and each neighboring node.

  2: If the distance is less than or equal to the sensing radius, increment the counter.

- Calculate the node density: Divide the counter by the sensing radius to obtain an estimate of the node density at the specific location.

- Repeat the process periodically: To account for changes in the network, periodically update the node density estimation by repeating steps 2-5.

Dynamic Adaptive Backoff Algorithm

Performance metrics such as energy consumption, backoff period and collision count are analyzed to assess the impact of the dynamic backoff period adjustment. Explanation of the algorithm:

- The new algorithm calculates the backoff time for each set of nodes based on the number of retransmissions (n) and a fixed slot time (slot time). It incorporates a modification factor that adjusts the backoff time depending on the number of nodes.

- For the first node (i = 0), the backoff time is the same as the old algorithm, calculated using the csma ca backoff function.

- For subsequent nodes, the backoff time is calculated by multiplying the backoff time of the current node (i) with a modification factor. This modification factor is defined as (i+1) / (i). The purpose of this modification is to increase the backoff time for each additional node, thus reducing the likelihood of collisions.

- By adjusting the backoff time for each node based on the number of nodes present in the network, the new algorithm aims to improve the efficiency of the CSMA/CA protocol by reducing collisions and optimizing the utilization of the communication medium.

We calculate the energy consumption based on the backoff times generated by the CSMA/CA protocol for both the traditional and proposed algorithms.

For the traditional algorithm:

- We directly use the backoff times generated by the CSMA/CA protocol.

- Each backoff time is multiplied by a constant power value to obtain the energy consumption for each node.

- The energy consumption of all nodes in the network is then summed up to obtain the total energy consumed using the traditional algorithm.

For the proposed algorithm:

- We modify the backoff times before calculating the energy consumption.

- We apply a formula that adjusts the backoff time based on the number of nodes in the network.

- The adjusted backoff times are multiplied by the same constant power value used in the old algorithm to obtain the energy consumption for each node.

- The energy consumption of all nodes in the network is then summed up to obtain the total energy consumed using the proposed algorithm.

By comparing the total energy consumption of the old and new algorithms, we can observe the relative difference in energy efficiency.

The new algorithm aims to reduce energy consumption by adjusting the backoff times based on the number of nodes. This adjustment allows for better utilization of the shared medium and reduces unnecessary waiting times, leading to lower energy consumption. Here we have assumed that the energy consumption calculation assumes a fixed power value and does not consider factors such as idle power consumption or transmission power variations.

The calculation provides a comparative measure to evaluate the relative energy efficiency between the old and new algorithms.

Round Robin Traversal

Performance metrics such as throughput and average waiting time are assessed. Waiting Time Calculation in the Traditional Algorithm:

In the traditional algorithm, the waiting time for a node is calculated as the sum of the transmission times of all preceding nodes in the queue.

- The waiting time for the first node in the queue is always zero since there are no preceding nodes.
- For subsequent nodes, their waiting time is determined by the sum of the transmission times of all preceding nodes
- This means that nodes that arrive earlier have a lower waiting time compared to nodes that arrive later.
- The waiting time represents the time a node has to wait in the queue before it can access the channel for transmission
- By calculating the waiting time for each node in the traditional algorithm, we can analyze the efficiency and fairness of the traversal scheme.

Waiting Time Calculation in the Round Robin Algorithm:

- In the Round Robin algorithm, the waiting time for a node is calculated based on its position in the queue and the time quantum assigned to each node.
- Each node is given a fixed time quantum during which it can transmit its data.
- The waiting time for the first node in the queue is zero since there are no preceding nodes.
- For subsequent nodes, their waiting time is determined by the sum of the transmission times of all preceding nodes, taking into account the time quantum assigned to each node.
- When a node exceeds its time quantum, it is preempted and moved to the end of the queue, allowing the next node in the queue to transmit.
- This preemptive behavior ensures fairness among nodes by providing equal opportunities for transmission.

Using the formula, we can calculate the throughput : Throughput = (Total Data Packets Transmitted) / (Total Transmission Time)

Total Data Packets Transmitted:

- In Round Robin scheduling, due to the fair distribution of the channel among nodes, each node gets an equal opportunity to transmit its data packets within the assigned time quantum.
- This fair distribution ensures that all nodes have a chance to transmit their data packets, resulting in a higher total number of data packets transmitted.

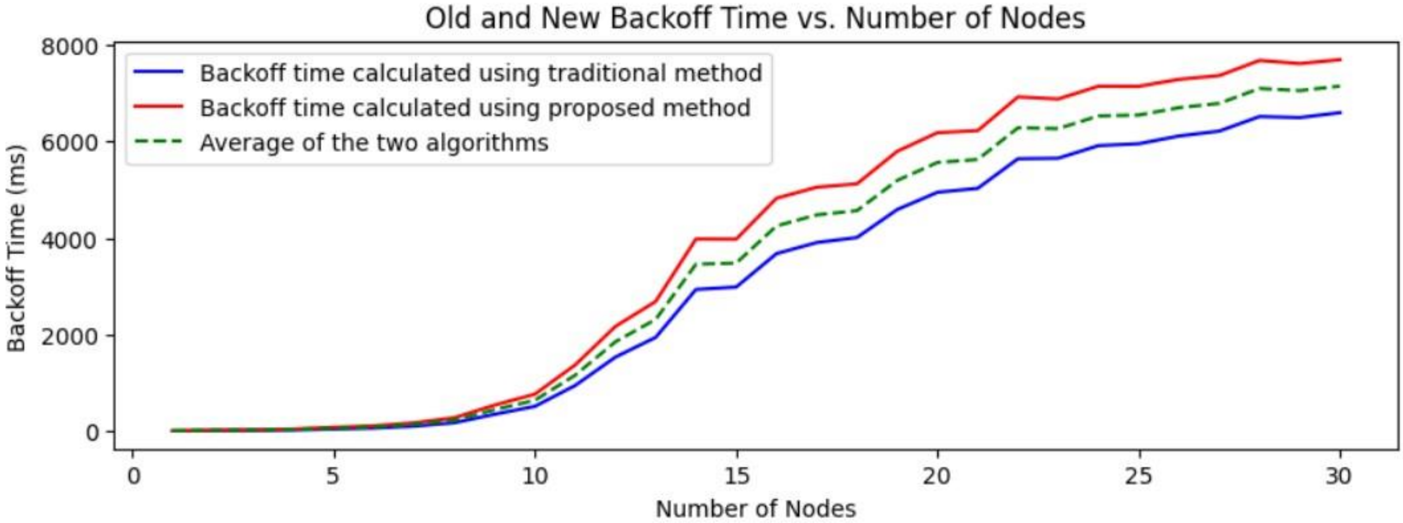
Total Transmission Time:

- The total transmission time includes the actual transmission time of each node, as well as the waiting time of nodes in the queue.
- In Round Robin scheduling, the waiting time is reduced due to the fixed time quantum allocated to each node.
- As a result, the idle time decreases, and the overall transmission time is more efficient compared to the traditional algorithm.

5. Result and Analysis

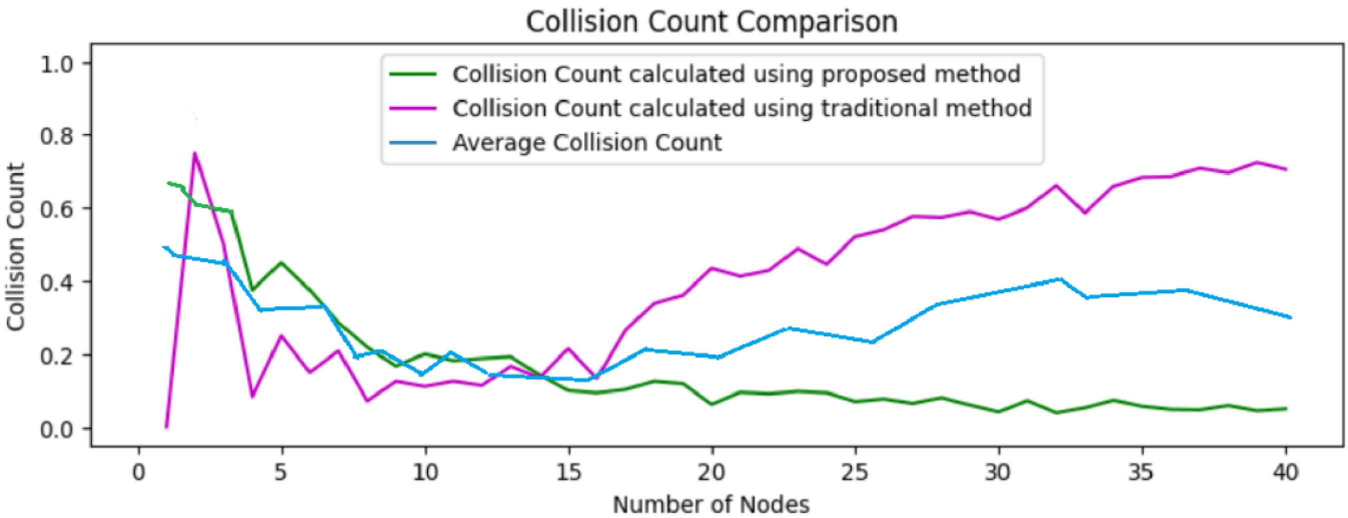
The implementation of the dynamic backoff period adjustment and round-robin scheduling algorithm offers several advantages in the WSN:

- Enhanced Performance: The dynamic adjustment of the backoff period based on node density allows the network to adapt to changing conditions. This results in improved network performance, including reduced packet loss and improved throughput.
- Energy Efficiency: By allocating more time for medium sensing and reducing collisions, the proposed approach reduces the number of retransmissions. Consequently, the energy consumption of the nodes is minimized, prolonging the network's operational lifetime.
- Fault Tolerance: The round-robin scheduling algorithm eliminates the need for a centralized coordinator, enhancing the network's fault tolerance. In the event of a failure in the scheduling entity, the network can continue operating without interruptions, ensuring continuous communication between nodes.



Comparison of the Backoff times of Random traversal of nodes and Proposed traversal of nodes

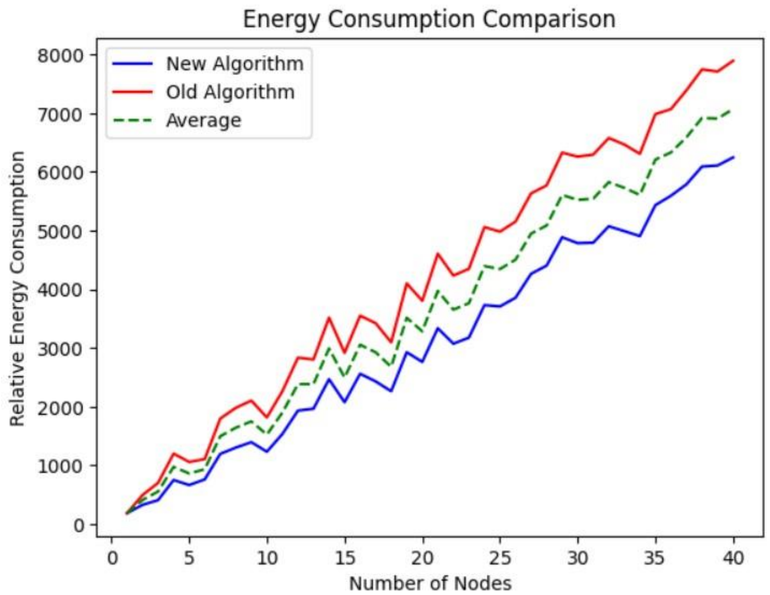
The backoff time comparison plot showcases the backoff time experienced in a network using both the traditional and proposed algorithms. As the number of nodes increases, we observe that the backoff time increases for both the traditional and proposed approach, but the rate of increase for the proposed algorithm is lesser as compaerd



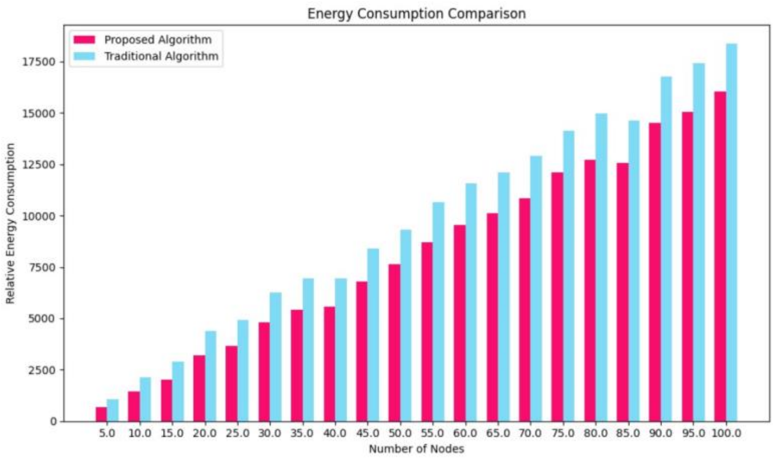
to that of the traditional one.

Comparison of the Collision Counts using the Traditional algorithm and Proposed algorithm

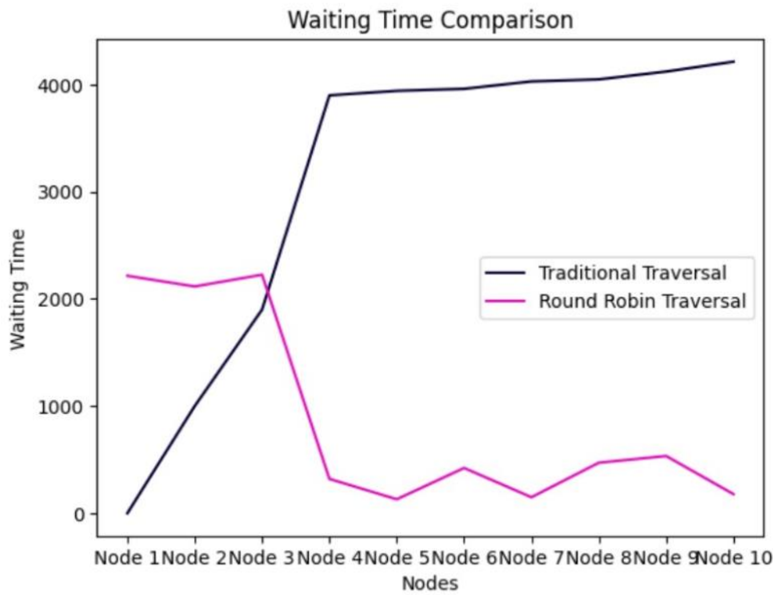
The collision count comparison plot illustrates the number of collisions that occur in a network using both the traditional and proposed algorithms. The average collision count line provides an overall perspective by calculating the average of the collision count values from both algorithms for each number of nodes. This line serves as a reference point for evaluating the relative performance of the Traditional and Proposed algorithms in terms of collision count.



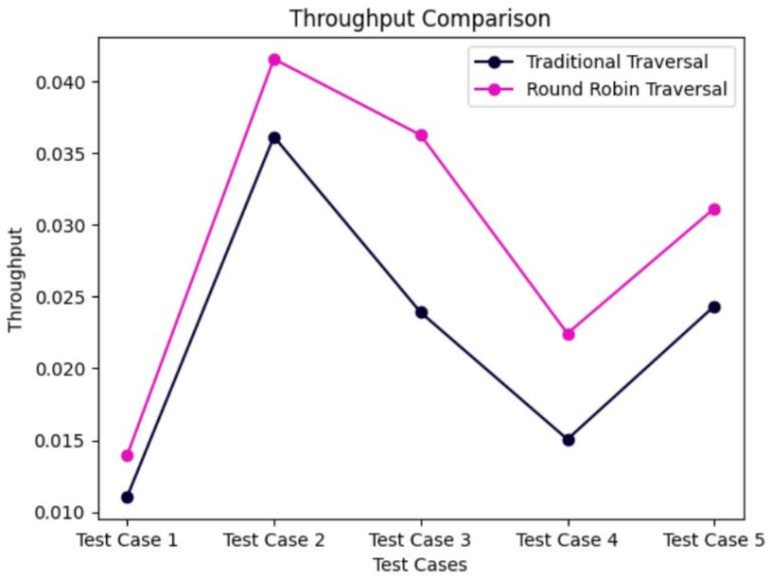
Comparison of the Relative Energy Consumption using the Traditional algorithm and Proposed algorithm



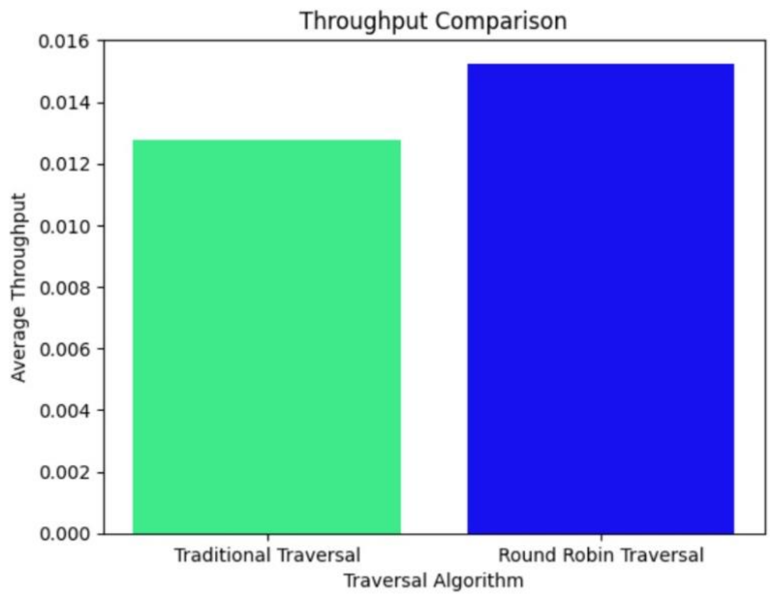
The energy consumption comparison plot visualizes the energy consumed by the network using both the traditional and proposed algorithms. It also includes an additional line representing the average energy consumption, which is calculated by taking the average of the energy values from the traditional and proposed algorithms for each number of nodes.



Comparison of the Waiting Time for each node using Random traversal and Round Robin traversal of nodes. We observe that as the the number of nodes increases, the waiting time for round robin traversal decreases as for the traditional approach, starvation takes place for nodes with lesser transmission time, which increases the waiting time for them, thereby leading to uneven access of the transmission medium.



Comparison of the Throughput by taking test cases using Random traversal and Round Robbin traversal of nodes. We observe that the throughput is more in case of round robin traversal as compared to the traditional traversal as in case of round robin, each node gets to access the transmission medium evenly, so there is no case of starvation, since the medium is actively involved, the throughput increases.



Comparison of the Average Throughput using Traditional traversal and Round Robbin traversal of nodes

6. Conclusion

Implementing a round-robin traversal of nodes instead of a random traversal in the CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) protocol offers a promising approach for reducing energy consumption. By adopting a systematic and deterministic order of node access, the round-robin traversal optimizes resource utilization and minimizes collisions, resulting in more efficient network operation and energy conservation. This deterministic approach enables nodes to transmit data in a synchronized manner, reducing the overall contention and contention resolution overhead.

Compared to random traversal, where nodes access the network in an unpredictable manner, the roundrobin method brings several advantages. First, it eliminates the occurrence of back-off collisions that can lead to unnecessary retransmissions and wasted energy. With round-robin traversal, nodes take turns accessing the channel, reducing the chances of simultaneous transmission attempts and consequent collisions.

Second, the systematic order of node access facilitates better scheduling and planning of network resources. By assigning time slots or priorities based on the round-robin sequence, the protocol can allocate bandwidth more effectively, ensuring fair and efficient utilization among all participating nodes. This balanced resource allocation minimizes idle time and maximizes throughput, resulting in reduced energy consumption.

Furthermore, the deterministic nature of round-robin traversal simplifies the coordination and synchronization of nodes. With each node knowing its turn to access the channel, unnecessary listening periods and idle times are reduced, leading to optimized energy usage. This predictability also enables nodes to enter low-power states during their idle periods, further conserving energy and prolonging battery life.

Overall, the adoption of round-robin traversal in CSMA/CA protocol introduces a structured and organized approach to accessing the network. By minimizing collisions, optimizing resource allocation, and enabling efficient power management, this method effectively reduces energy consumption, making it a valuable enhancement to the protocol’s energy efficiency.

7. Future Work

Further scope of the implementation may include the following features:

- Adaptive Round-Robin Scheduling: Develop an adaptive round-robin scheduling scheme that dynamically adjusts the node access order based on network conditions and node priorities.

- Explore algorithms that take into account the node density in a given area. By considering the number of nodes in proximity, these algorithms can optimize resource allocation and energy consumption, especially in areas with varying node densities.

- Continuously optimize the round-robin algorithm to enhance performance metrics such as throughput, latency, and fairness in resource access. This will ensure that the system operates efficiently and delivers optimal performance in different network scenarios.
- Develop intelligent power management strategies that allow nodes to enter low-power states during idle periods.

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