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Article

Enhancing Quality of Service and Energy Efficiency in Wireless Sensor Networks through TDMA-Based Topology and Cross-Layer Approaches

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Abstract: It is necessary to continuously monitor the environment with the sensors in delay-sensitive wireless sensor network applications. The continuous monitoring operation results in higher energy consumption by the sensor nodes; wireless sensor networks are also subject to numerous difficulties, including latency, packet loss, and throughput. These are the most important constraints in wireless sensor networks (WSNs) and need to improve for better quality communication. In this research, quality of service is related to numerous systems that have very sensitive parameters such as end-to-end delay, packet loss, throughput, energy consumption, latency, and average delay. Therefore, it is necessary for the sensors to transmit reliable data within a reasonable timeframe. To find out better communication results, we have used the TDMA (Time Division Multiple Access) approaches in our paper to improve packet delivery ratio (PDR), latency, and throughput. The NS2 simulator is used to test communication between nodes. Latency, the packet delivery ratio (PDR) of transferring data packets, and throughput are measured. The TDMA approach is used in our proposed topology, and we can see a specific area where nodes are connected to communicate with one another. Each node is communicating with the other node using two different paths. Each node's bandwidth, latency, and PDR will be different. Hence, in one path, a TDMA approach is implemented, which results in improved node performance in terms of latency, packet delivery ratio, and bandwidth.

Keywords: Latency, Packet Delivery Ratio, Bandwidth, Time Division Multiple Access

1. Introduction

1.1. Background and Motivation

Ensuring the service quality in Wireless Sensor Networks (WSNs) remains exceptionally high, and we also want to use energy in a better way. To accomplish this, we are investigating cross-layer strategies and a novel method known as TDMA (Time Division Multiple Access). These aid in streamlining the communication between gadgets and sharing time slots, improving functionality, and preserving energy. We aim to enhance the performance of WSNs and reduce the amount of power they consume by adopting these techniques. As the use of Wireless Sensor Networks (WSN) grows in businesses and vital infrastructure, they need features that the current development tools don't offer. Before they are put into use, WSNs need to be tested in a scenario or in real life.

The on-site performance evaluation takes a lot of time and money and is not reliable with actual sensor nodes. It cannot readily account for the full range of predicted operational conditions. Resultantly, the only effective way to assess the efficiency of wireless networks is using simulations. The decline in Wireless Sensor Networks' latency, stability, and throughput quality reduces its usefulness in various applications. Increasing QoS is necessary because of the critical requirements of quick data transfer, data integrity, energy efficiency, and network scalability. Novel approaches to these issues, including as cross-layer methods and TDMA-based topology, may enhance the energy efficiency and quality of service of Wireless Sensor Networks, opening the door for their effective deployment in a range of real-world uses.

By dividing signals into time periods, various channels can be shared or used in time division multiple access (TDMA). This process is carried out independently. Different channels share the same frequency, yet each channel uses it to the best of its ability. With TDMA, many channels can share the same frequencies for mobile digital communication. In TDMA, the base station is not given access to the entire system's bandwidth for a set amount of time; instead, the frequency is split into smaller bands, and TDMA is utilized to access the frequencies in each band. The entire system that makes use of this form of technology is a multi-carrier system, and these frequency bands are known as carrier frequencies.

The wireless sensor network's performance is enhanced in this study using the TDMA technique. This method is being used in this research to reduce latency, improve packet delivery spd, and increase bandwidth. WSNs (wireless sensor networks) have recently received a lot of attention due to their diverse and wide range of applications. Scaling down innovations, particularly in MEMS (micro-electro-mechanical systems), has enabled the development of multi-purpose tiny smart sensors [1, 2]. The MTSE presently uses wireless sensor networks and is expected to totally replace its customary systems with wireless sensor networks. This will empower wireless sensor networks to touch a basic piece of human life. Using models of traffic generators, protocols like TCP/IP, devices, and channels like Wi-Fi, users of NS-2 can build simulations of computer networks and evaluate or visualize the results. Because of its capacity to scale huge networks, generate reproducible results (especially for wireless protocol design), and analyze systems that have not yet been deployed.

Using models of traffic generators, protocols like TCP/IP, devices, and channels like Wi-Fi, users of NS-2 can build simulations of computer networks and evaluate or visualize the results. Because of its capacity to scale to huge networks, generate reproducible results (especially for wireless protocol design), and analyze systems that have not yet been deployed, simulation plays a crucial role in research and education [3, 4]. We believe that researchers need to be able to transition more easily between simulation, test beds, and live experiments, and NS-2 is designed to help with that. A particular focus of NS-2 is the high level of realism in the models (including frameworks for real applications and kernel code) and integration of the tool with virtual machine environments and test buds. The studies that are related to this work are covered in Section 2. In Section 3, we discuss our methodology. Results and discussion are presented in Section 4 along with the information we discovered. Finally, Section 5 draws everything to a close and provides a conclusion.

1.2. Literature Review

The partial bundle recuperation is outstanding for expanding system throughput and lessening outline retransmissions. However, the fractional bundle recuperation strategies in the writing are not power-conscious, and thus are incompatible with battery-powered remote sensor bits. They proposed GF (Green-Frag), a novel and versatile incomplete parcel recuperation component that is energy friendly. It can help delay the battery life of remote sensor bits that are typically asset compelled.

Hoc networks and Vehicular networks are both networks that are being designed and improved for energy efficiency and safety in order to manage vehicular traffic. Packet losses are very common in this kind of network from origin to destination, and most of them are due to the high mobility of the network nodes, such as vehicles. Different layers are being mitigated to impact the problems. In their work, they explained how the network acknowledges media access control. They worked on the duplicate generation of unexpected packets and proposed two filters for different layers of packet routing carried out geographically and topologically. And both techniques showed the results that involved avoiding collisions. The statistical analysis showed the effects of reducing the load of traffic in every routing protocol. They also expected and observed the geographical degradation of packets [5].

In [6, 7] The author investigated the congestion of quality of service and wireless sensor networks (WSN), which reduces organized execution by lowering throughput and increasing delay in transmitting bundles. Numerous wireless sensor network applications depend on convenient transmission of data to the target. In such systems, clog control instruments assume an essential job to extend the organization's lifetime, enhance reasonableness, or QoS, regarding throughput, and bundle conveyance proportionally to every node delay. In this research, it was proposed that parcels need an insinuation-based clog control instrument. Researchers presented a network strategy called PPI and its bits in every parcel to mirror its significance. The principal goal of this system is to send higher-need bundles with the least amount of postponement. The proposed network strategy instrument is sent in the current Ad Hoc on Demand Vector steering convention to switch over to a mindful directing convention. The execution of the proposed methodology is mimicked in a simulator called NS2 programming, and its effectiveness is checked. The reproduction results are contrasted with those of the current methodology. The suggested statistical analysis demonstrated how the QoS metric improves the network's performance in terms of latency, bandwidth, energy, and reliability [8].

In [9] author explains that in our daily life practice, wireless sensor networks have taken their own place, such as those that are being used in smart houses, buildings, urban resilience, animal farming, smart agricultural forms and in many other fields of life. They further said that Wireless Sensor Networks (WSNs) can also be used for capturing images, audio, and video as multimedia sensors. They said WSNs have two main goals: the first is to monitor everything being done to save energy, and the second is to deliver packets successfully to sink them [10]. In their research, they investigated different categories of low data density and analyzed their effects on some other networks. They used MAC addresses for synchronization of MAC protocols on every node. They compared energy consumption in four scenarios of environmental monitoring applications [11, 12].

In [13, 14] author said that WSNs (wireless sensor networks) are single-channel constructed and primarily focused with respect to energy productivity and versatility. During this research, they may promptly experience the ill effects of issues such as transmission capacity deficiency, impedance, sticking, et cetera. The previously mentioned issues have been exacerbated by the introduction of thick sensor systems and the beginning of sight and sound innovation. To address those difficulties, scientists have utilized multichannel innovation in wireless sensor networks that center around expanding transfer speed and throughput while diminishing impact, blocking, postponement, and energy utilization. Discovering a complete investigation of multichannel innovation in wireless sensor networks In [15] Simulated analyses have been performed and reported for the SGFTEM technique. Its performance has been compared to that of AGEM, TPGF, GPSR, and AODV in a variety of network density situations using a simple network design with 35, 55, and 75 nodes, and afterwards with the addition of two voids. The method was also simulated under various network densities, simulated with expanded coverage, and simulated with energy management to examine its effectiveness at load balancing and consuming energy.

To solve the congestion issue, [16] suggested an adaptive routing technique with three steps. Multistage fuzzy logic (MFL) is utilized in the first stage to select the ideal alert level for queue control, and in the second step, the congestion notification is modified to increase the effectiveness of route finding. In the final phase, a unique navigation method based on angular and linear distances is used to build the routing modification and control mechanisms.

It has been suggested to use a novel rate aware network bandwidth (RACC) technique that categories congestion into three tiers depending on data rate, throughput, overhead, and delay. RACC at the transport layer reduces congestion by regulating source rates in the designated hotspot zones. In [17] author offers a classification and comparison based on a newly developed taxonomy that divides protocols into nine different categories, including next-hop selection, network architecture, and originator of communications, network topology, protocol operation, delivery method, path establishment, application type. In our proposed method we examine every class, talk about its representative routing protocols, and contrast them according to various factors under the relevant class.

In order to improve network performance, the suggested protocol concentrated on trust score safe data communication with effective clustering and optimal path discovery using optimization algorithms. The proposed system employs the MSFO proposed algorithm with more secure data transfer by utilizing the Elgamal digital signature algorithm to differentiate between malicious nodes and regular nodes.

2. Material and Methods

Physical objects or processes may be felt, and information about them acquired, by recognizing changes in their states. It lets you know when important external factors like temperature, pressure, or others change or happen. The main things that receive and send this kind of data in wireless sensor networks (WSNs) are sensors, which are special devices made for this job.

WSN design is mostly plagued by the restricted energy supply of sensor nodes. Eventually the batteries that power these nodes run out of juice and need to be changed or refilled. Still, battery replacement or rechargeability varies according to the deployment conditions. Sometimes changing batteries is hard or even impossible, especially in remote or inaccessible areas. Energy savings turn into a critical component to extend the lifetime and efficiency of the sensor network.

With programs like NS2, an energy model is utilized to simulate energy use. Many features are included into this model, which also shows the power that each sensor node has at the beginning of the experiment. Fundamental elements of an energy model are the starting power, which shows the energy level of a node at the beginning of the simulation; the TX (transmit) power; and the AX (receive) power, which represent the energy used during packet transmission and reception, respectively [18]. Including these elements allows the simulation to evaluate and maximize the energy consumption of the sensor nodes.

The topology of a sensor network defines the connections and structure among its nodes. The goal of intricate TDMA schedules is to provide temporal or time-based division multiple access, which allows several nodes to share the same channel by allocating non-overlapping intervals. The challenging aspect is finding the optimal schedules with graph coloring methods. The shortest duration of time frames that can maximize spatial reuse and satisfy the communication needs of the network is sought for by these algorithms. Conversely, pure mesh topologies could provide benefits in some circumstances, such ad hoc networks. In a mesh design, decentralized connections between nodes permit random data flow between them without the requirement for a central base station.

It is crucial to understand that although a sensor network's logical structure often resembles a tree, with the base station serving as the root and the sensor nodes as leaves, the actual distances between nodes may vary. Nodes on distinct pathways may not be direct neighbors in the routing tree, although they may be situated near one another on the real network. As a result, interference and collisions may happen between nodes that are not in the routing tree but encounter proximity-based issues as a result of their geographic positions.

Energy management is a major aspect of wireless sensor network design. Understanding and optimising energy use with energy models and simulation tools like NS2 is essential [19]. Whether the network is built with complex TDMA schedules or only mesh configurations, the best topology should be selected according to its particular requirements and characteristics. Considerations of node proximity and interference potential in sensor networks contribute to reliable and efficient data transmission.

- E (N, M) = ln>0 (lm = nETack+lm! = nERack) +m>0 (lm = nETpck+ lm! = nERpck1
- Energy expended at node *N* as a result of node *M* = *E* (*N*, *M*)
- ETack is the amount of energy used to send a single acknowledgement packet.
- ETpck is the unit of energy used to transmit one data packet.

- ERack is the energy required to receive one acknowledgment packet.
- ERpck is the acronym for "energy expended for a single data packet."
- If value is 1, then lp = p is true. Otherwise, 0

The methodology could be understood with the help of topology.

The connection, communication, and data sharing mechanisms of the nodes in a wireless sensor network (WSN) are controlled by its design. Each sensor node in this case has a unique address that allows it to connect and identify with other network nodes. The topology explains the configuration and connections of the WSN that allow efficient data flow and inter-sensor communication. It describes the relationships and connections between the nodes in order to show how they are related. The topology allows us to ascertain the routes and channels that data will follow when moving throughout the network.

Every node in the network is linked to every other node according to the fundamental architecture shown. This demonstrates that there is no need for intermediate nodes when direct communication is allowed between any two sensor nodes. Efficient information exchange and network communication are promoted by this level of connectivity, sometimes known as a fully linked topology. In addition, every node in this system is eventually linked to a data sink, which is a base station or other sizable structure. Gathering and processing data from the sensor nodes, the base station acts as a central hub. After then, the data might be processed furthermore, looked over, or sent to a higher-level system for storage or decision-making.

Many important parameters, including bandwidth, latency, and packet loss ratio, need to be considered in order to assess and enhance network performance. The proportion of data packets lost during network transit is computed using the packet loss ratio. We call this "latency" the delay in data transmission between the source and the destination node. How much or how fast data can move over a network is expressed as bandwidth.

This work uses TDMA technology to improve the network's throughput, latency, and packet delivery ratio (PDR). Time Division Multiple Access, or TDMA, is a method that sets up particular time windows or frames from the available time for each node to transmit data. Through careful choice of these time intervals, the researchers want to optimize the use of network resources and raise the performance indicators. The use of TDMA technique inside the suggested architecture is intended to boost throughput, reduce delay, and raise packet delivery ratio. By enabling each node to transmit data inside its designated time slot, this method reduces congestion and enhances network performance generally. Additionally eliminated are collisions and interference.

Determining the connectivity, interaction, and data sharing of the nodes in a wireless sensor network (WSN) depends critically on its architecture. Given distinct addresses, each sensor node in this scenario can be recognized and connected to other network nodes.

Encouraging effective data flow and communication between the sensor nodes, the topology describes the structure and connections of the WSN. To illustrate the links between nodes, it explains them. Studying the topology allows us to determine the channels and paths that data will take to go throughout the network. All the network's nodes are linked to one another in the primary topology that is presented. This indicates that there are no intermediary nodes necessary for direct communication between any two sensor nodes. This level of connectedness, also known as a fully linked topology, promotes effective data interchange and communication within the network.

In addition, every node in this architecture is eventually linked to a base station or other major structure that serves as a data sink. Data from the sensor nodes is collected and processed by the base station, which acts as a central hub. The gathered information may then be further processed, examined, or sent to a higher-level system for storage or decision-making.

In Fig.1 and Fig. 2, we have calculated the bandwidth, latency, and packet delay in a specific department, and we generated results using NS2 to find these terms. Specific department nodes are exchanging data with each other through their addresses. Node 2 is connected to nodes 4, 5, and 7, while node 3 is connected to node 7. In this area, every node is connected to each other via two paths. Throughput, latency, and packet loss ratio will be different in each path between these nodes. Hence, we calculated the packet delivery ratio (PDR), latency, and throughput by connecting these nodes and improved all these parameters by applying the TDMA approach.

Several crucial measures, including packet loss ratio, latency, and bandwidth, must be considered in order to assess and enhance the network's performance. The packet loss ratio indicates how much of a fraction of data packets are lost in the network. Data transmission lag between the source and destination nodes is referred to as "latency". Broadband is the capacity or rate at which data may be moved over a network.

This work enhanced packet delivery ratio (PDR), latency, and throughput of the network using the TDMA technology. Time Division Multiple Access, or TDMA, is a technique that divides available time into time slots, or frames, therefore allocating time periods for each node to transmit data. In this effort, we planned time periods deliberately to maximize the use of network resources and improve performance indicators. It was expected that putting the Time Division Multiple Access (TDMA) technique into the suggested architecture would boost throughput, lower latency, and improve packet delivery ratio [20]. By allocating specific time slots to each node for data transmission, this approach effectively mitigates congestion and elevates overall network performance by eliminating collisions and interference.

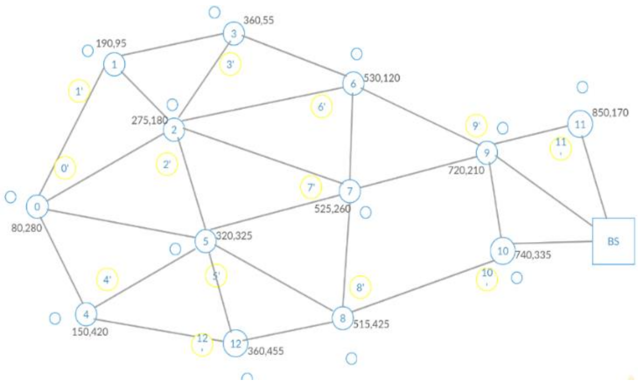

Figure 1.WSN topology.

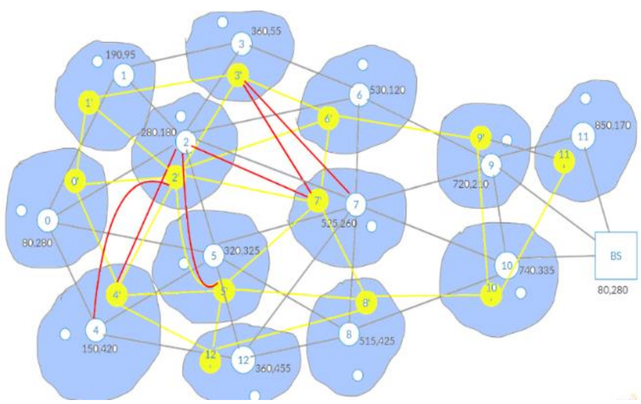

Figure 2.WSN NS-2 topology.

3. Results and Discussion

Our proposed network topology improves the quality-of-service factor in terms of packet delivery ratio (PDR), latency, and throughput. We use graphs to understand performance improvement. We have separate graphs for PDR, latency, and throughput, through which we can estimate performance evaluation.

The latency findings are shown in Fig. 1, The average absolute difference in AL between both tracking and no tracking modes is 2.4 percent. Lightly loaded, substantially loaded, and saturated are the three various states that the system that is not in tracking mode experiences. Both modalities have the same tendency to modify latency. This shows that delivery of data packets is delayed from source nodes to sink nodes for a period of time during data transfer. It demonstrates that when we transmit data from one node to another or to a sink node, the delay in packet delivery varies as the time interval of data transmission changes. The flow control of the data also shows the delay in packet delivery from one node to another. As it shows on node 3, the delay is increased, and in the next node, the delay again decreases.

The packet delivery ratio is depicted in Fig. 3, Delivery performance, which is translated into a network lifetime metric, is of utmost significance in energy-constrained networks. WSNs are the ideal monitoring system for a variety of situations, including occasionally hostile and inaccessible ones that will demonstrate the significant multi-path communication possibility of a wireless connection. The environment, the coding scheme selected, and the unique properties of a transceiver circuit all have a role in packet delivery performance.

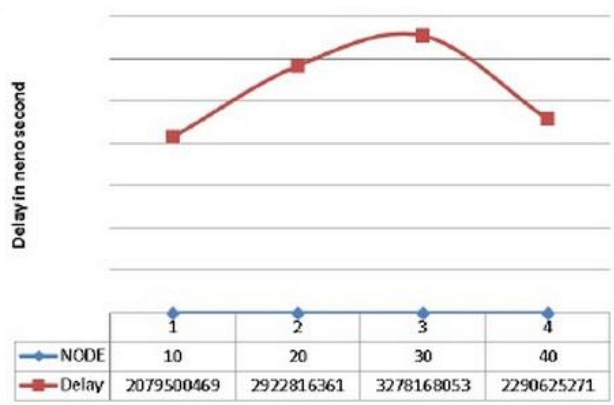

Figure 3. Flows monitor result of factor control.

Figure 4. Packet delivery ratio of packet loss with latency.

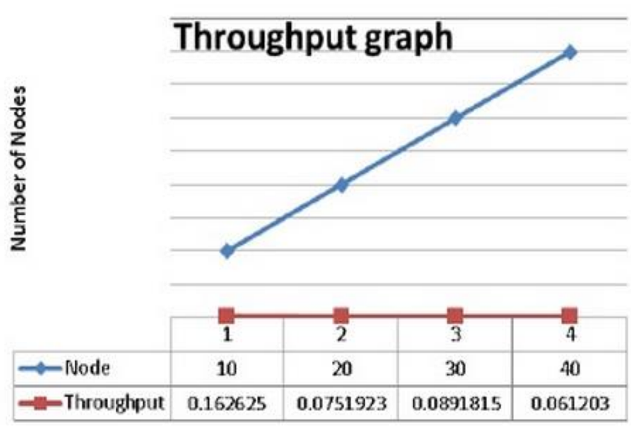

Figure 5. Throughput of high bandwidth.

It shows the number of packets received at the sink node and transmitted from the sensor node in each time interval. The packet transmission ratio can be calculated. Basically, the received and created packets as captured in the trace file are used to calculate the Packet Delivery Ratio (PDR). PDR is typically described as the ratio of packets generated by the source to packets generated by the destination. The trace file is processed by the awk script, which generates the result and calculates the packet delivery ratio. Fig. 4, depicts the evaluation of throughput. Data rate requirements depend on the kind of information that you want to send, how often you will send it, and how many nodes are using the same channel for transmission. For instance, variables such as temperature, humidity, and vibrations require only a few bytes to be transmitted. Other types of information, such as sound or video, will require higher data rates. Fig. 5, illustrates how throughput increases in megabits per second depending on node transmission rate, with each node transmitting data at a distinct rate. In this figure, we calculate the throughput, which can be defined as the Throughput is the number of successfully received packets in a unit of time, and it is represented in bps. Throughput is calculated using an awk script that processes the trace file and produces the result. Its works on a 45-degree angle. If the throughput is at the same Mbps, then all the packets will be received successfully.

3.1. Multiple Access of Carrier Sensor

The primary distinction between carrier sensor multiple access and ALOHA-net is that, in carrier sensor multiple access, hubs first sense the medium before they start a transmission. This reduces the number of crashes. In non-determined carrier sensor multiple access, a remote hub is permitted to instantly transmit information once it finds the medium inactive. If the medium is full, the hub performs a back-off task, which means it waits for a specific amount of time before attempting to transmit again. Interestingly, a hub wishing to transmit information persistently faculties the medium for action in determined carrier sensor multiple access. When the medium is discovered to be inactive, the hub transmits its information promptly. On the off chance that a crash happens, the hub sits tight for an arbitrary timeframe before endeavoring to transmit once more. In carrier sensor networks, multiple access hubs sense the medium, yet don't instantly get to the channel when it is discovered as inert.

By using NS-2 for the determination of multi-hop and single-hop delays in cross-layer and CSMA/CA protocols, respectively, end-to-end display in delay distribution has been used for evaluation. The system that was used was equipped with an Intel Core i3 processor and Windows 7 as its operating system. Along with it, WSN test-based simulations have been conducted where the system's memory was 4 GB. The simulation was carried out in the same system.

The distribution rate was determined by the packet size that was passed from node to node and local traffic that was sent to the sink. In this experiment, it was suggested by the NS-2 simulator that the average time required to transfer every single packet from the sender node to the receiver node is about 1.8 milliseconds. The power that was used to transfer packets was 16 dBm from start to finish for each testing experiment. End-to-end hop and single-hop measurements were made; at the generation of source node packets, it sends an electric pulse through a twisted-paired wire simultaneously from the start node to the end node. When a pulse is triggered, the destination node starts its timer and waits for the packet after receiving it.

In Fig. 6, the recreations with Network Sensor-2 for Cross-Layer Protocol indicate wireless sensor networks for carrier sensor multiple access conventions executed for ascertaining normal deferral between two sensor hubs and end-to-end delay between systems. It was decided to implement End-to-End deferred dispersion in WSN to overcome its impediments and gradually utilize it.

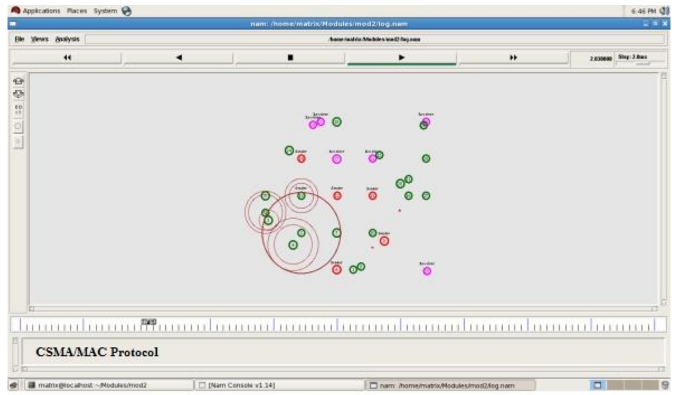

Figure 6. CSMA/MAC protocol output.

Table 1.Packets passed delay count in NS-2 Simulator

Sr. No.	Parameters Passed	Packets Passed	Cross layer	CSMA/MAC
1	Average Delay Millisecond	90	0.513	0.9833
2	E2E (End to End) Delay Millisecond	90	0.2977	0.462
3	Average Delay Millisecond	45	0.072	0.268
4	E2E (End to End) Delay Millisecond	45	0.12008	0.5122

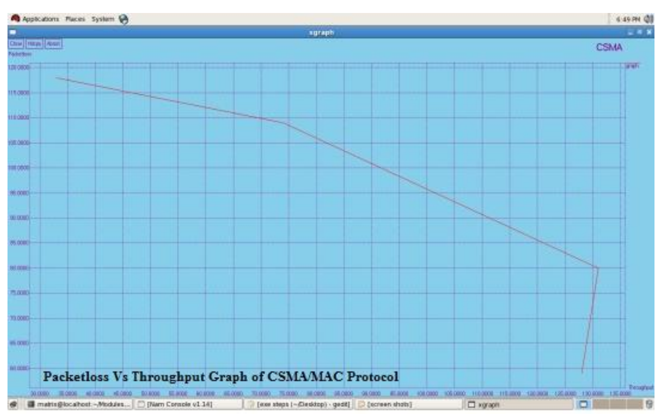

Figure 7. Packet loss vs. throughput graph of CSMA/MAC.

It was decided that through data analysis, the framework would profit from lower add-ons to in-store printing costs, a lower add-on to the cost of proprietorship, decreased labor, a higher rate of profitability, and increased consumer loyalty. Wireless Sensor Networks for Cross-Layer Convention is used to calculate normal deferral between two sensor hubs and end-to-end system delay. The reproduction results for cross-layer give the base endwise delay when contrasted with carrier sensor multiple access. Table 1 that follows compares the existing framework and cross-layer.

The packet loss strength in the CSMA/MAC strategy is depicted in Fig. 7. The simulation was carried out in the same system. The distribution rate was determined by the packet size that was passed from node to node and local traffic that was sent to the sink. In this experiment, it was suggested by the NS-2 simulator that the average time required to transfer every single packet from the sender node to the receiver node is about 1.8 milliseconds.

3.2. Ad Hoc on Demand Distance Vector Router

The case of an on-request or receptive convention (AODV convention) Contrasted with proactive directing conventions, responsive conventions don't keep up nodes until the point when they are asked for and utilized. A source hub, knowing the character or address of the goal hub, starts the node revelation process inside the system, which finishes when somewhere around one node is found or when every single conceivable node has been analyzed. A node is then kept up until the point when it either breaks or is never again required by the source. The Ad Hoc on Demand Distance Vector Router is based on a communicated node disclosure component, which is used to powerfully build up course table passages at highway hubs. The way the revelation procedure of an Ad Hoc on Demand Distance Vector Router is started when a source hub needs to transmit information to another hub.

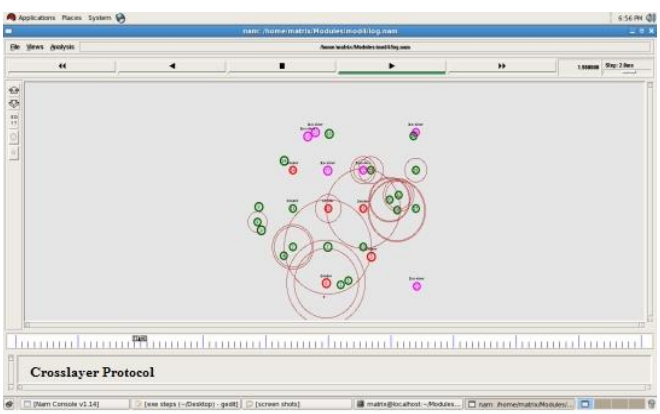

Figure 8. Cross layer approach graph in cross layer.

In Fig. 7 and Fig. 8, we examine packet loss and throughput using a cross-layer approach. A source hub, knowing the character or address of the goal hub, starts the node revelation process inside the system, which finishes when somewhere around one node is found or when every single conceivable node has been analyzed. A node is then kept up until the point when it either breaks or is never again required by the source. The Ad Hoc on Demand Distance Vector Router is based on a communicated node disclosure component, which is used to powerfully build up course table passages at highway hubs.

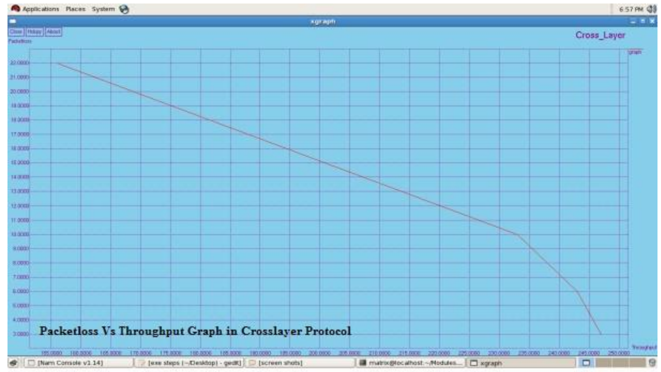

Figure 9. Packet loss vs throughput.

The overall comparison of throughput and packet loss between the CSMA/MAC and cross-layer approaches is depicted in Fig. 9. We can see that by using a cross-layer approach, data packet performance is good compared to the CSMA/MAC approach.

Progressively, an extensive number of wireless sensor network applications require ongoing quality of service. Such quality-of-service prerequisites as a rule rely upon two regular parameters: timing and unwavering quality. The asset limitations of wireless sensor networks, be that as it may, confine the degree to which these necessities can be ensured. Furthermore, in these multi-hop systems, the arbitrary impact of the remote channel precludes the improvement of the determined quality of service.

4. Conclusion

To facilitate efficient group preparation inside the network architecture, this research's main goal is to meet the need for essential conservation in large-scale wireless sensor networks (WSNs). The study looks at WSNs that run iterative applications and are made up of clusters of evenly distributed sensors. The ideas set out in this study are designed to achieve essentiality sufficient from a variety of angles, acknowledging it as one of the most important factors in any WSN game strategy. One important factor taken into consideration is the imperativeness consumption capability, or the effective use of resources. The goals of the framework include a wide range of WSN redesign and optimization-related topics. The researchers focused their first efforts on rethinking the information flow inside the network. This requires the creation of efficient routing strategies, data aggregation techniques, and communication protocols to ensure the reliable and fast information flow among the sensor nodes. The most important WSNs are to be prepared with special attention. This means figuring out where the critical network nodes are or where specific events or occurrences must be monitored and recognized. By purposefully clustering more sensors in these centers, the network is better equipped to collect and assess relevant data, which leads to improved situational awareness and event detection. The work aims to expand the approach by considering the scalability and long-term viability of the WSN.

Part of this is looking at ways to increase the network's operational life, utilize less energy, and enhance the general performance and dependability of the system.

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Conflicts of interest: The authors declare no conflict of interest.

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