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Assessing the Performance of Quality of Services in Wireless Sensor Networks

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ABSTRACT (11 PT, Bold, Center)

In wireless sensor networks, numerous sensor nodes are strategically deployed in specific regions to gather environmental information such as temperature, pressure, and humidity. These sensor nodes transmit data packets to a central sink node, and the quality of services in wireless sensor networks, including throughput, reliability, energy efficiency, and congestion control, play a crucial role in maintaining consistent and accurate results. This research paper focuses on evaluating the impact of reporting rate and packet size on the quality of services of a particular system. The evaluation is carried out by analyzing parameters such as packet delivery ratio and packet loss ratio concerning different packet sizes and reporting rates. Wireless sensor networks have emerged as a rapidly growing field of research due to their vast applications. Reliability, a significant quality of services parameter, ensures consistent and dependable results. This study specifically investigates how the reporting rate and packet size influence the reliability of the system, considering metrics such as packet delivery ratio and packet loss ratio.

KEYWORDS: Throughput, Energy efficiency, reliability, packet delivery ratio, congestion, packet size, reporting rate.

1. INTRODUCTION

Wireless sensor networks (WSNs) are comprised of numerous sensor nodes strategically placed in a given environment to gather data on humidity, pressure, temperature, and other parameters. These collected data are transmitted to the base station through gateways. Sensor nodes have limited energy resources, while the sink node has unlimited energy. Sensor nodes possess the ability to process data and communicate it to the sink node. During the data transmission process, the source node sends data packets to the sink node with the expectation that they will all be received successfully [1]. When the data packets are received at the sink node, an acknowledgment is sent back to the source node to indicate the successful transfer. However, due to congestion along the transmission path, there is a possibility of packet loss. In such cases, retransmission of the lost packet takes place [2].

There are various parameters that define the quality of service in WSNs, including reliability, congestion, throughput, and more. Reliability refers to the consistency in obtaining accurate results. A system is considered reliable when it consistently produces uniform results. High reliability is achieved when a high percentage of packets sent by the source node are received at the sink node. As the number of packets reaching the sink node increases, the reliability also improves. Congestion occurs when there is heavy traffic in front of sensor nodes during the data transmission process. Congestion can be classified as node-level or link-level congestion. Throughput is the measure of packet delivery from the source node to the sink node within specific time duration. WSNs offer several advantages over wired networks, such as reduced implementation cost and time, and the ease of replacing low-energy nodes with new sensor nodes. WSNs find applications in various sectors, including healthcare, environmental monitoring, home automation, and military applications [3].

In a WSN, multiple sensor nodes are distributed across a sensor field, and the source node sends data packets to the sink node. The figure depicted in Fig. 1 illustrates the path followed by the data transfer process, with arrows indicating the route taken. Fig. 2 depicts a wireless sensor network where sensor nodes

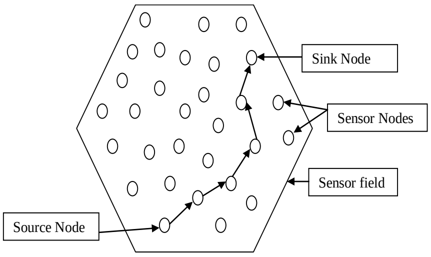

Fig. 1. Wireless Sensor Network

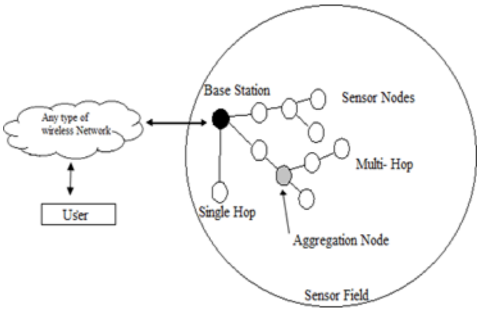

Fig. 2. Wireless Sensor Network working

are randomly distributed in the sensor field. In this network, the source node sends data packets to the sink node. The aggregation node is responsible for gathering all the data and data processing can be done through single-hop or multi-hop communication. Data transfer occurs via these routes, enabling the transmission of data or packets to the destination.

WSNs have various quality of service parameters, including reliability, congestion, throughput, and more. Reliability refers to the consistency in measuring the results obtained from the system. It is achieved when the system produces uniform results. Throughput is the measure of how much data can be transferred from one location to another within a given time. Reliability is considered high when the number of packets sent by the source node is completely received at the sink node. As the number of packets received at the sink node increases, the reliability also improves. Congestion occurs when there is heavy traffic in front of sensor nodes during the data transmission process [4]. Congestion can be categorized into node-level and link-level congestion. Energy consumption in the sensor network occurs due to data reception, data transmission, querying requests, and other factors. WSNs offer several advantages over wired networks, including reduced implementation cost and time, and the ease of replacing low-energy nodes with new sensor nodes. WSNs find applications in various sectors, including healthcare, environmental monitoring, home automation, and military applications.

2. METHDOLOGY

Robert J. Hall et al [5], proposed a method called "Center distance with priority (CD-P)" to improve the scalability and reliability of the system. The authors pointed out two existing approaches: the flooding approach and the scalable approach. The flooding approach involves indiscriminately retransmitting packets, which can lead to high network load and make it unscalable. On the other hand, the scalable approach lacks the necessary intelligence to provide effective directionality for packet movement [8].

The authors recommended the CD-P method to address these limitations. It is based on three key concepts:

- **Center proximity:** A node retransmits a packet if it is closer to the center of the geocast region than all other duplicate packets it has received.
- **Sequential attention:** A node pays attention to all other retransmissions before initiating its own retransmission. If it detects that another node closer to the center has already transmitted, it withdraws its own retransmission.
- **Packet prioritization:** Scalability is improved by having each node prioritize its send queue, sending packets that bring it closer to the center of the geocast region first.

By implementing these concepts, the CD-P method aims to enhance the scalability and reliability of the system using geographic addressing of packets.

In the paper by Ming-Fei Guo et al. [6], the authors explore the use of multi-packet reception (MPR) to improve the throughput of wireless sensor networks (WSNs) while maintaining fairness among the sensors. MPR is made feasible due to recent advances in the physical layer of wireless communication. The authors formulate the joint routing and scheduling problem in MPR-based WSNs as an optimization problem. They propose a feasible heuristic scheme to address this problem. To formulate the optimization problem, the authors first derive the necessary and sufficient conditions for interference-free link scheduling. These conditions are also used in the design of the heuristic scheme. The optimization problem is solved in three steps:

- **Routing step:** This step is completed using linear programming, which determines the routes for the packets in the network.
- **Link scheduling step:** A greedy algorithm is employed to find a link schedule, which determines the time slots for each link to transmit packets. Another linear program is then formulated to assign time fractions to the link schedule.
- **Performance evaluation:** The authors analyze the throughput gap between the upper bound obtained from the optimization and the performance of the heuristic scheme. They also adjust various network parameters to evaluate the performance of the heuristic scheme. The results indicate that MPR can significantly improve the throughput of wireless sensor networks, and the paper provides some network design implications based on these findings.

Overall, the paper presents a feasible heuristic scheme that utilizes MPR to enhance the throughput of wireless sensor networks while considering fairness requirements among the sensors. The authors formulate the joint routing and scheduling problem and provide an optimization-based approach to address it, demonstrating notable throughput gains in their performance evaluation.

In DWEHC, clusters are formed within the network using a hierarchical structure. Each node in the network identifies its next logically connected node and calculates a weight for that node based on its energy level and the distance to the next node. The node with the highest weight is selected as the cluster head. This process helps distribute the energy load among the nodes in the network.

Within each cluster, the nodes gather information and transmit it to their respective parent nodes. This information is then forwarded to subsequent parent nodes until it reaches the cluster head. The cluster head performs data aggregation and modification on the incoming data from all cluster nodes. The modified data is then sent to the base station, reducing energy consumption throughout the network.

The DWEHC protocol ensures that each node in the network executes the protocol individually, resulting in the formation of a hierarchical structure of clusters. [7] Within each cluster, there are two types of nodes: cluster heads and sensor nodes. Time-Division Multiple Access (TDMA) is employed for the functioning of the nodes within the clusters. Based on the allocated time slots, sensor nodes sense the data and forward it to their parent nodes, continuing until it reaches the cluster head. Finally, the cluster heads transmit the data to the base station. By following this process, the DWEHC protocol achieves significant energy savings in the network. It also maintains the reliability, throughput, delay, and congestion, which are essential parameters for a Wireless Sensor Network.

3. RESULTS AND DISCUSSION

NS2 is a discrete event simulator commonly used for modeling and analyzing the performance of various network protocols and applications. In this scenario, we employed 30 sensor nodes, each with a packet size of 50 bytes. The sensor field area was set to 1000 * 1000 square meters. For the Medium Access Control (MAC) protocol, you utilized IEEE 802.11, which is a widely used standard for wireless local area networks (WLANs). This MAC protocol governs the access to the wireless medium and facilitates communication between the sensor nodes. Regarding the routing protocol, you chose the Ad-hoc On-Demand Distance Vector (AODV) routing protocol. AODV is a reactive routing protocol commonly used in ad-hoc networks, where routes are established on-demand as needed. It enables the sensor nodes to dynamically discover and maintain routes to other nodes in the network.

By configuring NS2 with these specifications and protocols, you were able to simulate the behavior and performance of your wireless network scenario, allowing you to analyze factors such as network throughput, latency, energy consumption, and other performance metrics.

In Fig. 3, the graph depicts the packet delivery ratio (PDR) as a percentage (%) in relation to the packet size in bytes. Initially, when the packet size is 50 bytes, the PDR is high, indicating a high rate of successful packet delivery in the network. However, as the packet size increases, the PDR starts to decrease. This decline in PDR can be attributed to congestion within the network. When the packet size becomes larger, it occupies more network resources, leading to potential congestion. As a result, packets may struggle to find an optimal path to reach their destination. In addition to congestion, the increase in packet size may also lead to nodes in the network entering a starvation mode. These nodes neither transmit nor receive data packets effectively, further contributing to the decrease in PDR. The combined effect of congestion and node starvation results in a lower PDR rate for the given network as the packet size increases. This observation highlights the importance of managing packet size and addressing congestion issues to maintain a higher delivery ratio in the network.

In Fig. 4, the graph represents the average energy consumption as a function of the reporting rate. Initially, as the reporting rate increases, the average energy consumption also increases. This relationship is expected, as a higher reporting rate requires more frequent transmission of data, leading to increased energy consumption by the network nodes. However, beyond a specific threshold, the graph shows that as the reporting rate continues to increase, the average consumed energy starts to decrease. This phenomenon can be attributed to congestion in the network. As the reporting rate becomes excessively high, the network experiences congestion, causing delays and packet losses. Consequently, nodes may reduce their transmission activities, resulting in a decrease in average energy consumption.

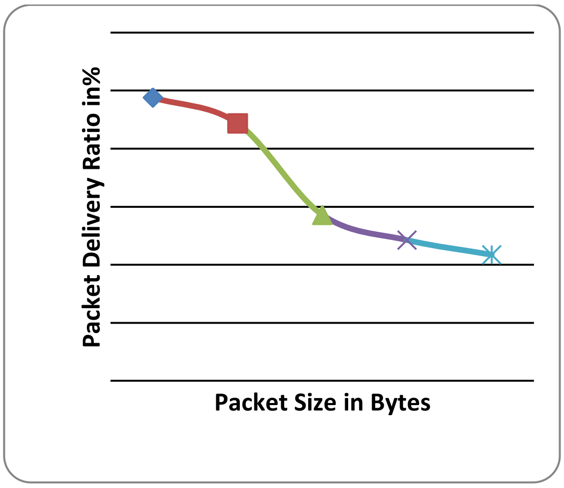

Fig. 3- PDR in % as a function of Packet Size in bytes

Fig. 5 shows Consumed energy (in joules) as a function of Packet size in bytes. It demonstrates the consumed energy by the network against different packet sizes. The graph indicates that the consumed energy remains relatively constant across various packet sizes. This observation suggests that packet size does not have a significant impact on the average consumed energy in the network. Overall, these findings suggest that while the reporting rate can influence the average energy consumption in the network, packet size does not have a substantial effect on energy consumption. It is essential to consider the trade-off between reporting rate and energy consumption to optimize the network's performance and energy efficiency.

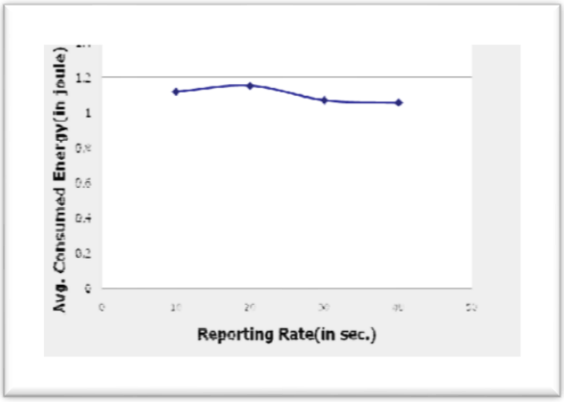

Fig. 4. Consumed energy (in joules) as a function of reporting rate in packets per seconds and Packet size in bytes.

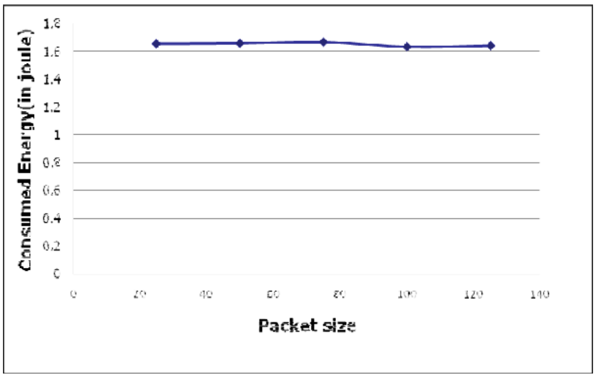

Fig. 5. Consumed energy (in joules) as a function of Packet size in bytes.

4. CONCLUSION

In this paper, through the analysis of six different graphs in the performance analysis, several notable changes were observed during the data transmission process. Specifically, when examining the graph of the number of packets sent and received as a function of the reporting rate (in packets per second), it was observed that both the number of packets sent and received increased as the reporting rate increased. Based on these findings, future work will focus on implementing more suitable techniques and algorithms to improve different quality of service capabilities in the network, while considering other relevant parameters. The aim is to enhance the overall performance and efficiency of the network.Additionally. It displayed a reduction in average energy consumption, leading to improved results for the users. These findings collectively suggest that packet size has an impact on the number of packets received at the destination during the data transmission process. The study highlights the importance of considering packet size when analyzing the performance and effectiveness of the network.

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