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QoS-aware protocol using priority packet scheduling scheme for wireless sensor networks

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Abstract— **Wireless Sensor Networks (WSNs) consists of several small sensor nodes; those are linked wirelessly to form a network. The data packets are transmitted from source to destination through several intermediate sensor nodes, which forward data packets to the neighboring sensor node. Conversely, each sensor node simultaneously participates in data transmission. This indicates that each sensor node handles several data packets, later they needs to be transmitted based on the availability of channel. Based on the application, data packets are either real time or non real time and hence, direct transmission of data packets may become critical. In this paper, a QoS-aware protocol (QAP) using priority packet scheduling scheme for WSNs is discussed. Using this approach, priority can be specified to each incoming data packet according to the delay, loss and other constraints. After analyzing and prioritizing the data packets, scheduling is done on the basis of packet priority. This scheme ensures the delivery of data packets as per their priority to enhance the QoS.**

Index Terms— **packet scheduling, QoS, Wireless sensor networks, FCFS, QoS-aware protocol (QAP).**

I. INTRODUCTION

A wireless sensor network is a self ordered network comprising of several sensor nodes. Each sensor node consists of sensing unit, a processing unit, power unit and transceiver unit. If they categorize and communicate among themselves, then it is an ad-hoc network. The wireless sensor network perceptive has been deployed in several applications such as health care systems, home automation and environment detection systems. All these applications require cost-effective facilities and little manual preservation. According to the application requirements, each node is allowed to use a low power microcontroller, RF module and a power source. WSNs include a large number of wireless sensor nodes that are deployed randomly. The sensor nodes are typically small, and furnished with low powered source. However in other wireless networks, it is generally not viable to charge or replace the drained sources. As energy usage is the indicator of network lifetime, prolonging lifetime of the sensor nodes is very important. Energy efficiency becomes the most important attribute of improving QoS for wireless sensor networks. Other attributes of QoS improvement are fairness, latency, delivery ratio, and bandwidth. Communication in between the sensor nodes is a key factor, Protocols and algorithms have to assure the issues associated such as increasing of lifetime, self configuration, robustness and fault tolerance. Energy consumption is the most important constraint of QoS in WSN [2]. Priority scheduling is the approach by which the system can decide the task to be executed with respect to time. However, it is used for effective distribution of load with desired QoS [5]. As per the working schedule, multiple data forwarding tasks must be prioritized so that the loads can be adjusted across the sensors. At present, most of the WSNs operate using First Come First Served (FCFS) scheduling algorithm that transfers the packets according to their arrival time and it needs more time to be transmitted to a Base Station (BS).

QoS-aware Protocol (QAP) using Priority Packet scheduling allots priorities to traffic flows with QoS concerns. Therefore, packets are queued and scheduled according to the assigned priorities, which are associated to the active periods of event reports. If a packet cannot be sent to the sink within the scheduled time, it will be discarded, causing in high packet drop rate. With the limited resource in sensors, the packets of the most capable event, which have the nearby deadline, should be marked with the highest priority. Conversely, the geographic distribution of sensors also has impact on the scheduling priorities [10]. The delay requirement of the packets from the remote sensors is tougher than that of close event report packets, so they should be marked with higher priority. For these concerns, packet scheduling must be distance-aware, lifetime-aware and that is QoS-aware [7]. Priority packet scheduling is a significant scheme to enhance the QoS in WSNs. In general, priority packet scheduling allots priorities to data packet movements with QoS considerations [1].

II. Related Work

Nidal Nasser et al [6] have projected a Dynamic Multilevel Priority (DMP) packet scheduling scheme. Where, each node, excluding those at the last level of the virtual hierarchy in the zone based topology of WSN, has three stages of priority queues. Highest priority queues hold the Real-time data packets and Non-realtime data packets are located into two other queues based on a threshold of their probable handling time. Leaf nodes may require separate queues for real-time and non-real-time data packets as they do not collect data from other nodes.

Lin Tang et al [9] have proposed a wireless differentiated queuing service (WDQS) algorithm to meet the diverse delay needs of multimedia transmission over WSNs. WDQS coveys the latest departure time (LDT) scheduling measures to analyze and forward by considering the lifetime of Packets. They also projected a useful approach to delay for remaining journey without adding any overhead by using the query technique of the sink. Further, they discussed that the lifetime of packet to meet the end-to-end release requirement.

XiaoHua Xu et al [8] have projected a family of efficient and helpful real-time scheduling protocols that can counter every job of each query task Ti belongs to T within a relative delay d(pi) under reserve constraints by addressing various tightly coupled tasks like routing, node activity scheduling, transmission plan creations and packet scheduling. Based on the design of protocol, they further planned schedulability test schemes to efficiently and successfully test whether, for a set of queries, each query job can be completed within a finite delay.

Joon-Woo Lee et al [11] have projected an ant colony-based scheduling algorithm to solve the Efficient-energy coverage (EEC) problem. Their algorithm is a simplified version of the conventional ant colony optimization algorithm for solving the EEC problem. They also used the probability sensor detection model and applied their proposed system to a mixed sensor set, which denotes a more realistic approach to solving the EEC problem.

Jandaeng et al [3] have presented the packet scheduling algorithm (PSA) in order to decrease the packet blocking in MAC layer which leads to reduce the overall packet conflict in the system. PSA is compared with simple CSMA/CA and other techniques using network topology standards in mathematical manner. The performances of their PSA are better than the standard CSMA/CA. The PSA yields better throughput than other algorithms. On other hand, the average delay of PSA is greater than prior works. However, the PSA uses the channel better than all algorithms.

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III. QoS-aware Protocol (QAP) using priority packet scheduling scheme

In this paper, we intend to develop a QoS-aware protocol (QAP) using Priority packet scheduling scheme for wireless sensor networks. During high priority data transmission, packet loss and delay at destination may affect the scheduling algorithm design. So the allotment of time slots must be assigned with the expected packet loss rate and anticipated delay [4]. The anticipated delay should not be more than the lifetime of packets. Hence, in this QAP scheme, packet loss and transmission delay are considered. The packet loss rate (PLR) and the effective maximum delay (EMD) at each sensor node is estimated.

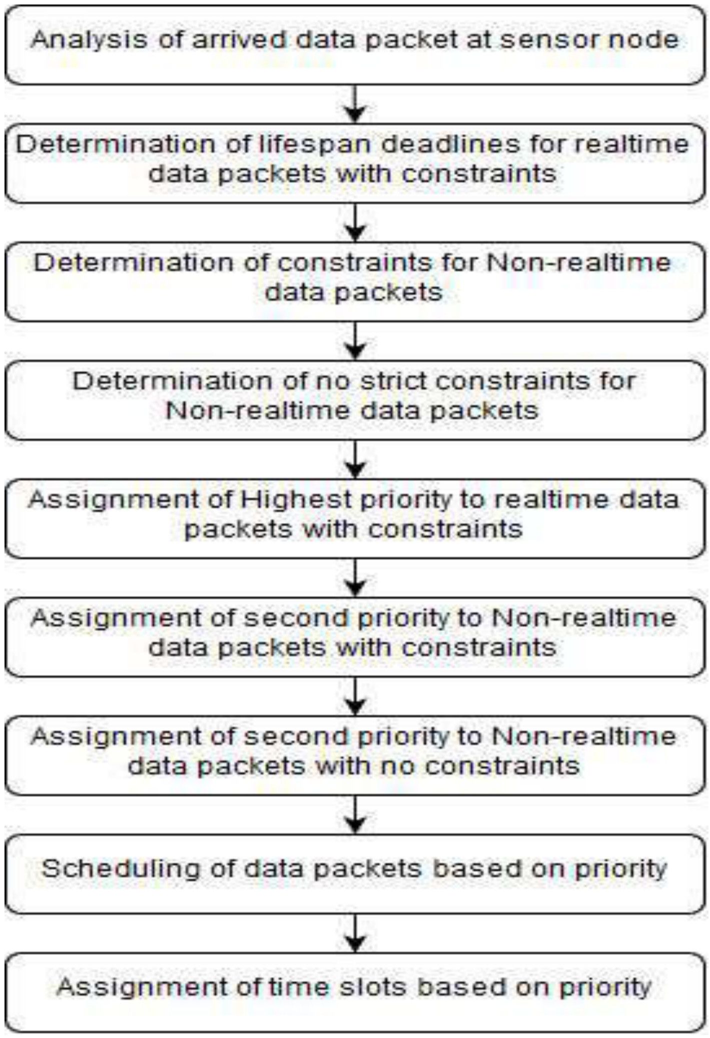

Fig. 1 Block Diagram

Fig. 1 depicts the block diagram of the proposed scheme. Initially, the firm lifespan deadline and reliability constraints for the real time (RT) packets and Non-real time (NRT) packets are determined. In the priority packet scheduling scheme, with strict deadlines and reliability constraints, highest priority-1 is assigned for real time packets, next priority-2 is assigned for non real-time packets and remaining packets are assigned the least priority-3. Later, the time slots are assigned according to priority of packets that is highest to the lowest. Therefore the real-time packets with priority-1 can be allotted time slots based on PLR and EMD values. Packets having priority-2 with can be allotted time slots based on PLR [6]. All reaming packets having priority-3 can be allotted time slots simply based on the sensing period and data transmission rate. Since the packet scheduling avoids losses and meets lifespan deadline, the energy consumption due to needless waiting and retransmission can be avoided.

During data transmission in WSNs, the data packets pass several sensor nodes prior reaching its destination. In order to prioritize the data packets and develop QAP, the delay and loss parameters of packet transmission are necessary. In our proposed technique, the transmission delay and packet loss rate are determined to serve as a basis for the data prioritization process. The packet loss rate (PLR) and the effective maximum delay (EMD) are estimated at each sensor node. After the estimation of required constraints, sensor node begins prioritization and scheduling of the data packets. Based on the priority, data packets are grouped as priority group-1, priority group-2 and priority group-3 [6]. The prioritization order will be followed to schedule the transmission of data packets. The process of determining the packet transmission details and Priority scheduling are described in the following algorithms: Algorithm-1 and Algorithm-2 respectively

TABLE I TERMINOLOGIES AND NOTATIONS

Terminologies & Notations	
N_k	: Node k
RT	: Real Time
NRT	: Non Real Time
EMD_k	: effective maximum delay at node k
τ_p	: packet lifetime
k,l,m	: node names (integer)
d_l	: delay experienced by packet at node l
DLD(k)	: departure lifespan deadline time for packet at node k
Tx_{dep}	: packet's departure time at the source
PLR	: Packet loss rate
Rx_k	: packets received rate at node k
Tx_k	: packets transmitted rate by source
T_r	: data transmission rate
TxN_p	: number of packets transmitted
TxT	: transmission time
P-1	: Priority-1
P-2	: Priority-2
P-3	: Priority-3
Q-1	: Queue-1
Q-2	: Queue-2
Q-3	: Queue-3
τ_s	: Sensing Time

Algorithm-1:

1. When a RT data packet arrives at a node, N_k; it estimates the EMD_K value according to equation-1.

$$EMD_k = \tau_p - \left[\sum_{l=1}^{k-1} d_l + \sum_{l=1+1}^{m} d_l\right] \quad (1)$$

2. After the sensor node determines the delay caused by it during data transmission, it estimates DLD(k) according to equation (2).

$$\mathrm{DLD(k)} = \tau_p + \mathrm{Txdep} - \sum_{l=k+1}^{m} \mathrm{dl} \tag{2}$$

3. If the DLD(k) is a smaller value, then the data packet has strict lifespan deadlines and needs to be transmitted to its destination at the earliest.

4. The sensor node will estimate the PLR at N_k according to equation (3).

$$PLR = \frac{\mathrm{R_x k}}{\mathrm{T_x k}} \tag{3}$$

5. For the NRT data packets, the PLR value can be estimated by equation (3).

6. If the PLR value is smaller, then the data packets may have strict reliability constraints, else they does not have any reliability constraints.

7. For the data packets which have no reliability constraints, the N_k estimates the T_r value according to equation (4).

$$\mathrm{T_r} = \frac{\mathrm{TxN}_p}{TxT} \tag{4}$$

In this way, based on the type of data packet, the sensor node estimates the related constraints required for the prioritization of data packets.

TABLE II SIMULATION CONFIGURATION AND PARAMETERS

Number of Nodes	:100
Area	: 500 m^2
Simulation Time	:50s
MAC	:IEEE 802.11
Rate (KB)	:150,250,350,450,550
Traffic Source	:Constant Bit Rate(CBR)
Antenna	:Omni-directional
Initial Energy	:21.1J
Transmission	:0.5
Received Power	:0.4

Algorithm-2:

1. The RT data packets with strict deadline and reliability constraints are given with highest priority i.e., P-1.
2. The N_k assigns the P-1 data packets to the Q-1, which will be transmitted first as soon as N_k begins transmitting.
3. The data packets are provided with shorter time slots in Q-1.
4. In Q-1, the P-1 packet with higher PLR and EMD_k value is placed in primary timeslots and other P-1 packets are placed in diminishing order of its values.
5. The NRT data packets with strict reliability constraints and no lifespan deadline constraints are given second priority level i.e., P-2.

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6. The N_k assigns the P-2 data packets into Q-2, which is queued to transmit after Q-1 transmission.
7. Within Q-2, the P-2 data packets are allocated time slots a little larger than the P-1 timeslots.
8. In Q-2, the P-2 data packets with higher PLR are placed foremost in the queue and the rest of data packets are followed in the diminishing order of PLR value.
9. The NRT data packets with no strict constraints and all remaining data packets are considered as least priority traffic i.e., P-3.
10. The N_k assigns P-3 data packets into Q-3.
11. The Q-3 is allowed to transmit its packets after Q-1 and Q-2 completes its transmission.
12. In Q-3, the P-3 data packets are allotted larger time slots.
13. Within Q-3, the P-3 packets are arranged after considering the T_r and τ_s.
14. The P-3 packets with higher T_r and τ_s are placed leading in the Q-3 and then the other P-3 packets are placed in the diminishing order of their values.
15. Once, the N_k starts transmitting, the P-1 data packets in Q-1 are transmitted initially to its destination, followed by the P-2 data packets in Q-2 and then finally the P-3 data packets in Q-3.

Consequently, all the data packets are scheduled based on its priority and placed in respective queues. Then all the scheduled packets are transmitted to their destinations. In this way, this technique ensures that the critical data packets are delivered at the destination with highest priority.

IV. SIMULATION AND RESULTS

A. Simulation configuration parameters: We used NS2 software to simulate our proposed Priority Packet Scheduling scheme with QoS-aware protocol. We used IEEE 802.11 for wireless sensor networks as the MAC layer protocol, because it can report the network layer about link cracking. During our simulation process, the data transmission rate is varied as 150,250,350,450 and 550KB. The area size is 500 m^2 for 50 seconds simulation time. The simulation configuration parameters are summarized in Table-1

B. Performance metrics: We evaluated the performance of the QoS-aware protocol according to the following parameters. We compare the FCFS protocol with our proposed QoS-aware protocol (QAP).

- **Average Packet Delivery Ratio**: It is the ratio of the number of packets received successfully and the total number of packets transmitted.
- **Delay:** It is the amount of time taken by the packets to reach the respective destination.
- **Energy Consumption:** It is the amount of energy consumed by the sensor nodes to the data transmission.
- **Packet Drop:** It is the numbers of packets throw down or lost during the data transmission.

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C. Results and Result analysis: The delay, packet drop and energy consumption are estimated by varying the data transmission rates (i.e., 150, 250, 350, 450 and 550KB).

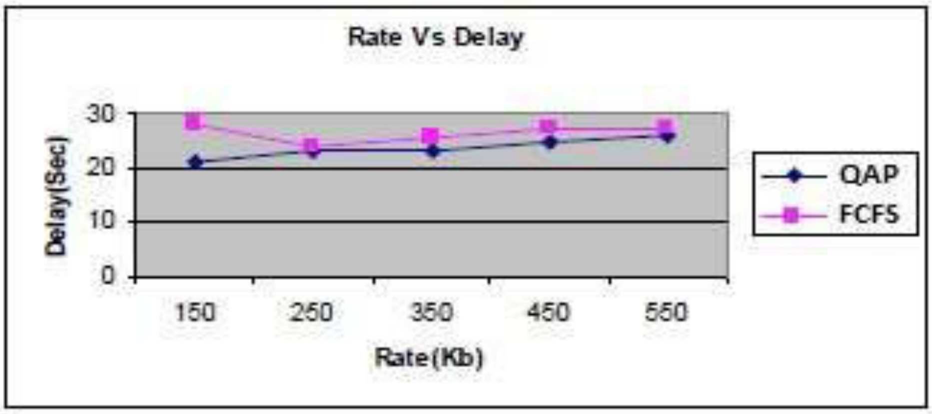

Fig. 2 Rate Vs Delay

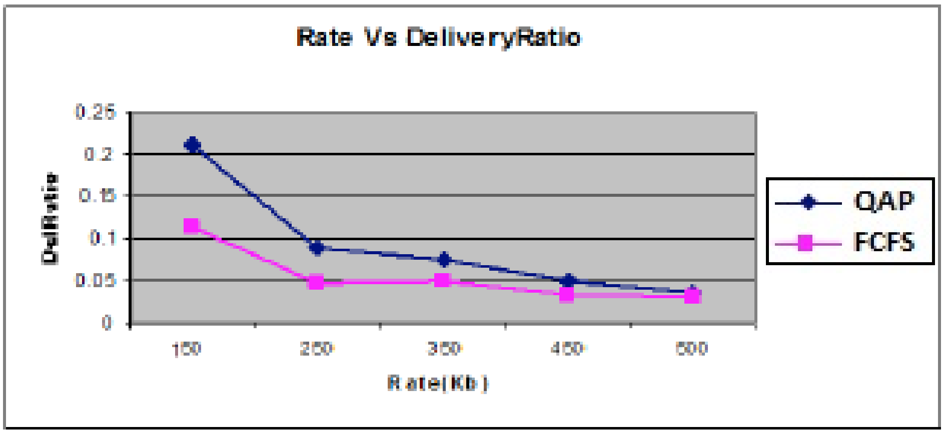

Fig. 3 Rate Vs Delivery Ratio

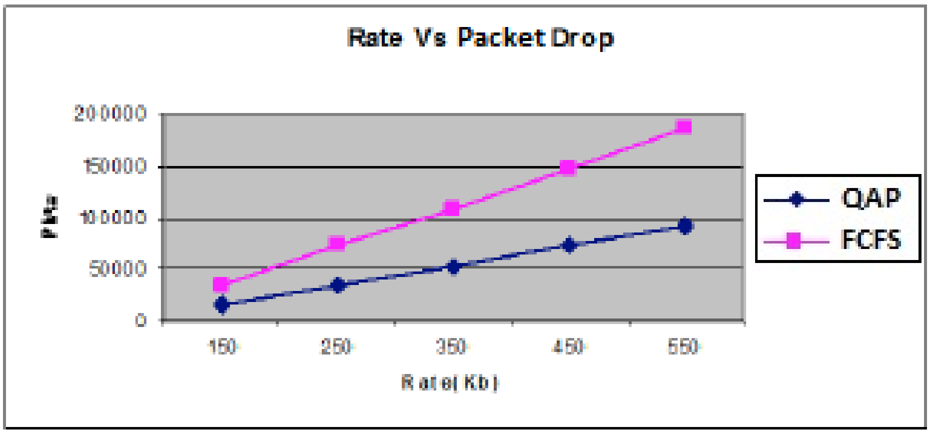

Fig. 4 Rate Vs Packet Drop

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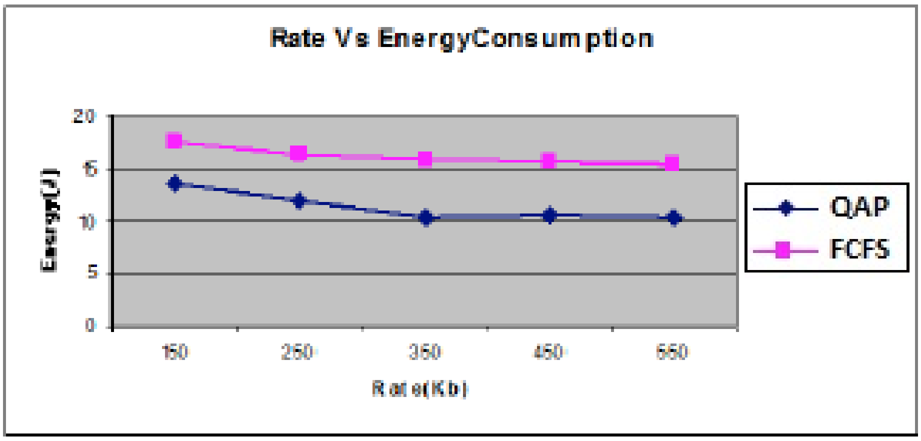

Fig. 5 Rate Vs Energy Consumption

Figures 2 to 5 show the results of Delay, Delivery Ratio, Packet Drop and Energy Consumption by varying the transmission rate from 150Kb to 550Kb for Constant Bit Rate traffic in QAP and FCFS protocols. When compared the performance of the two protocols, we conclude that QAP outperforms FCFS by 14% in terms of Delay, 42% in terms of Delivery ratio, 62% in terms of Packet Drop, and 29% in terms of Energy Consumption.

V. CONCLUSION

In this paper, we have projected efficient QoS Protocol using Priority Packet Scheduling scheme for Wireless Sensor Networks. When data packet arrives, the sensor node analyzes the received data packet before forwarding it to the destination or next sensor node. Initially, the sensor node estimates the delay implicated in data transmission and the packet drop rate. Based on the estimated constraint's value, the priority of each data packet is assigned. Next, based on the different priority, the node schedules every data packet and accordingly allots time slots. The data packets are arranged in the order from highest priority to the lowest priority at the node. When the sensor node begins transmitting, the highest priority data packets are transmitted first followed by the lower priority data packets. This ensures that critical data packets are delivered at the destination before the lifespan deadline, and thus guarantees efficient network performance.

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