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Priority based Multi-Queue Packet Scheduling Scheme for Wireless Sensor Network

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Abstract

Wireless sensor networks have recently come into prominence because they hold the potential to revolutionize many segments of our economy and life, from environmental monitoring and conservation, to manufacturing and business asset management, to automation in the transportation and health-care industries. Scheduling different types of packets, such as real-time and non-real-time data packets, at sensor nodes with resource constraints in Wireless Sensor Networks (WSN) is of vital importance to reduce sensors energy consumptions and end-to-end data transmission delays. Most of the existing packet-scheduling mechanisms of WSN use First Come First Served (FCFS), non-preemptive priority and preemptive priority scheduling algorithms. These algorithms incur a high processing overhead and long end-to-end data transmission delay due to the FCFS concept, and improper allocation of data packets to queues in multilevel queue scheduling algorithms. In the proposed scheme, Efficient Dynamic Multi-Queue Packet (EMP) Scheduling Scheme for Wireless Sensor Network for Wireless Sensor Network each node, except those at the last level of the virtual hierarchy in the zone based topology of WSN, has three levels of priority queues. Real-time packets are placed into the highest-priority queue and can preempt data packets in other queues. Non-real-time packets are placed into two other queues based on a certain threshold of their estimated processing time. Leaf nodes have two queues for real-time and non-real-time data packets since they do not receive data from other nodes and thus, reduce end-to-end delay. Data packets sensed by nodes at different levels are processed using a TDMA scheme.

Keywords

Wireless sensor network, packet scheduling, preemptive priority scheduling, non-preemptive priority scheduling, real-time, non-real-time.

I. Introduction

In order to emphasis the ultimate requirement for the WSNs applications, energy consumption and transmission delay is the main concern. Real time data packets need to be sent with minimum delay to the corresponding base station, it is proposed to be placed in first priority queue. Applications related to the emergency events needs to be delivered before the expiry of the deadline, so that an application could be successful. Existing scheduling mechanisms like preemptive, non-preemptive priority algorithms possess high processing overhead and results in starvation of real time as well as non- real time packets in both the mechanisms. First Come First Served (FCFS) schedules the data packets according to the order of their arrival time leads to increased delay for reaching the base station .In FCFS many data packets arrive late experiencing long waiting times. Real time packets are given higher priority and processed with minimum possible delay. Real time packets can preempt lower priority non real time packets while processing. Since non real time packets are given lower priority it can be processed using FCFS. The main aim of choosing three queues are (i) for enhancing the transmission of real time packets (ii) non real time packets are larger than real time packets, so they are provided with two queues.

II. Literature Survey

Scheduling data packets at sensor nodes are important to prioritize applications of wireless sensor nodes. Scheduling data packets as real-time and non-real time at wireless sensor nodes decreases the processing over-head, reduces the end-to-end data transmission delay and saves energy consumptions of packets [9]. Data sensed as real time application are given high priority than non-real time data. There exist wide range of study and research on scheduling the sleep-wake times of sensor nodes have been performed [1]–[18], but only a small number of studies subsist in the literature on the packet scheduling of sensor nodes that schedule the dealing out of data packets presented at a sensor node and also reduces energy consumptions[19]–[22]. But, most commonly used task scheduling algorithm in wireless sensor networks is First Come First Served (FCFS) scheduler algorithm in which the progression of data packets takes place based on arrival time and thus it takes more amount of time to be delivered to a appropriate base station (BS). However, to be clearer, the sensed data should reach the base station within exact time period or before the expiration of a deadline. In Addition to that, real-time emergency data should be delivered to base station with the minimum possible end-to-end delay. Hence, the intermediate nodes call for changing the delivery order of data packets in their ready queue based on their significance such as real or non-real time data packet and delivery deadline of packet. But First Come First serve algorithm is inefficient with regard to end-to-end delay and sensors energy consumptions. In existing wireless sensor networks task scheduling algorithms do not accept traffic dynamics since intermediate nodes need data order delivery change in their ready queue based on priorities and delivery deadlines.

Management of bandwidth is also important and necessary to avoid network congestion and poor performance. Packet scheduling technique maximizes bandwidth utilization. The Scheduler for packet scheduling ensures that packets are transmitted from the queue buffer. There are wide ranges of scheduling techniques which include random scheduling, round robin scheduling, priority scheduling and weighted fair queuing scheduling. It emphasizes rules in link-bandwidth sharing. Wireless sensor networks use fair queuing scheduling algorithms for a share of link capacity to guarantee multiple packet flow [5].

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III. Terminologies

(i) Levels

In a particular zone several levels are available indicating certain number of nodes. Nodes which are at the same hop distance from the base station are said to be located at the same level. Nodes which are placed at the lowest as well as highest level will be allocated with separate time slots.

(ii) Priority

To achieve the overall goal of WSNs real time packets is being regarded as vital elements and given first priority. Based on the remotely sensed data and local data, non-real time data packets are assigned. By assigning priority to the packets, real time data packet's transmission delay is minimized to appreciable level. To avoid starvation of non-real time packets from local nodes, packets from remote nodes can be preempted for a certain period which leads to the assurance for fairness.

(iii) Queue

Each node has a ready queue in which different types of tasks are placed. Scheduling among various tasks takes place with the assistance of schedulers. Number of queues in a particular node will be relying on the level of the node in the network. It can be understood that nodes that are available in lowest level will not receive packets from remote location and hence does not need more number of queues. Mostly, multi-level queue can able to avoid delay since it has several working phases like aligning the tasks among different queues and scheduling.

IV. Priority Based Multi-Queue Packet (PMP) Scheduling Scheme

As discussed earlier, in non-preemptive packet scheduling schemes (interchangeably use as task scheduling in this paper), real-time data packets have to wait for completing the transmissions of other non-real-time data packets. On the other hand, in preemptive priority scheduling, lower-priority data packets can be placed into starvation for continuous arrival of higher-priority data. In the multilevel queue scheduling algorithm, each node at the lowest level has a single task queue considering that it has only local data to process. However, local data can also be real-time or non-real time and should be thus processed according to their priorities. Otherwise, emergency real-time data traffic may experience long queuing delays till they could be processed. Thus, we propose Priority based Multi-Queue packet scheduling scheme that ensures a tradeoff between priority and fairness. In this section, we present the working principle of Priority based Multi-Queue packet scheduling scheme with its pseudo-code.

1. Working Principle

Scheduling data packets among several queues of a sensor node is presented in Figure 1. Data packets that are sensed at a node are scheduled among a number of levels in the ready queue. Then, a number of data packets in each level of the ready queue are scheduled. For instance, Figure 1 demonstrates that the data packet, *Data*1 is scheduled to be placed in the first level, Queue1. Then, *Data*1 and *Data*3 of Queue1 are scheduled to be transmitted based of different criteria. The general working principle of the proposed PMP scheduling scheme is illustrated in Figure 1.

The proposed scheduling scheme assumes that nodes are virtually organized following a hierarchical structure. Nodes that are at the same hop distance from the base station (BS) are considered to be located at the same level. Data packets of nodes at different levels are processed using the Time-Division Multiplexing Access (TDMA) scheme. For instance, nodes that are located at the lowest level and the second lowest level can be allocated timeslots 1 and 2, respectively. We consider three-level of queues, that is, the maximum number of levels in the ready queue of a node is three: priority 1 ($pr1$), priority 2 ($pr2$), and priority 3 ($pr3$) queues.

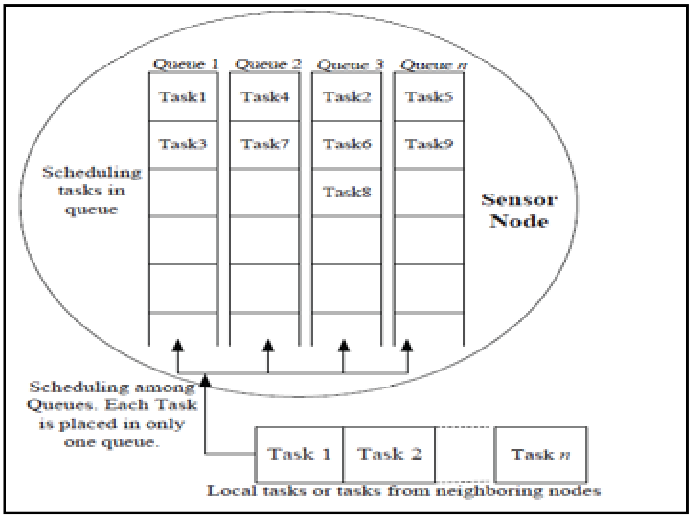

Fig. 1 : Scheduling data among multiple queues

2. Algorithm

In our proposed Priority based Multi-Queue packet scheduling scheme, nodes at the lowest level, l_k, sense, process and transmit data during their allocated timeslots, whereas nodes at level l_{k-1} and upper levels receive data in addition to sensing, processing and transmitting data. Now, we present the pseudo-code of proposed PMP packet scheduling scheme. We consider only two levels in the ready queue of sensor nodes that are located at the lowest level since these nodes do not receive packets from any lower level nodes. Other nodes have three levels in the ready queue and place non real time local tasks into pr_3 queue. We also consider that each node requires time to sense data packets and also process local and/or remote data packets. For instance, $t_1(k)$ in the pseudo-code represents the real-time data sensing time at a $node_i$. If the processing time of real-time data at *nodei* is less than $t1(k)$ then $node_i$ will have time remaining to process non-real-time pr_2 data packets. Similarly, if $node_i$ still has some remaining time, it can process non-real-time pr_3 data packets. The pseudo-code also shows that if the pr_1 queue is empty and pr_2 packets are processed α consecutive timeslots, the processing of pr_2 data packets will be preempted for j timeslots.

while $task_{k,i}$ is received by $node_i$ at level k, i.e., l_k **do**
  if $Type(task_{k,i}) = real - time$ **then**
    put $task_{k,i}$ into pr_1 queue
  else if $node_i$ is not at lowest levels **then**
    if $task_{k,i}$ is not local **then**
put $task_{k,i}$ into pr_2 queue
    else
put $task_{k,i}$ into pr_3 queue
    end if
  else
    put $task_{k,i}$ into pr_2 queue
  end if
Assume, the duration of a timeslot at $l_k \leftarrow t(k)$

Data sensing time of $node_i$ at $l_k \leftarrow senseTime_k(t)$
Remaining time after data sensing, $t_1(k) = t(k) - senseTime_k(t)$
Let total real-time tasks for $node_i$ at $l_k \leftarrow n_k(pr_1)$

$$procTimepr_1(k) \leftarrow \sum_{j=1}^{n_k(pr1)} procTime(j)$$

if $procTimepr_1(k) < t1(k)$ **then**
All pr1 tasks of $node_i$ at l_k are processed as FCFS
Remaining time $t2(k) \leftarrow t1(k) - procTimepr_1(k)$
Let, total pr_2 tasks for $node_i$ at $l_k \leftarrow n_k(pr_2)$

$$procTimepr_2(k) \leftarrow \sum_{j=1}^{n_k(pr2)} procTime(j)$$

if $procTimepr_2(k) < t_2(k)$ **then**
All pr_2 tasks are processed as first distant packet & then SJF
pr_3 tasks are processed as FCFS for the remaining time,
$t_3(k) \leftarrow t_2(k) - procTimepr_2(k)$
else
pr_2 tasks are processed for $t_2(k)$ time
no pr_3 tasks are processed
end if
else
only pr_1 tasks are processed for $t_1(k)$ time
no pr_2 and pr_3 tasks are processed
end if
if pr_1 queue empty & pr_2 tasks are processed α consecutive timeslots since $t(k) \leq procTimepr_2(k)$ **then**
pr_2 tasks are preempted at α +1,...,α+ j timeslots by pr_3 tasks
if pr_1 task arrives during any of α+1,α+2,...,α+j timeslots then
pr_3 tasks are preempted and pr1 tasks are processed context are transferred again
for processing pr_3 tasks
end if
end if
end while

3. Performance Analysis

The simulative comparison of different scheduling techniques with proposed technique is shown in this section. The simulation model is implemented using Java. It is used to evaluate the performance of the proposed Priority based Multi-Queue Packet (PMP) scheduling Scheme packet scheduling scheme, comparing it against the PMP, and FCFS scheduling schemes. The comparison is made in terms of average packet waiting time, and end-to-end data transmission delay. The number of simulated zones varies from 1 to 4 zones. Nodes are distributed uniformly over the zones. The ready queue of each node can hold a maximum of 50 packets. Each packet has a Type ID that identifies its type. For instance, type 0 is considered to be a real-time task. Moreover, each packet has a hop count number that is assigned randomly, and the packet with the highest hop count number is placed into the highest-priority queue. We run the simulation both for a specific number of zones, and levels in the network until data from a node in each zone or level reach BS. Simulation results are presented for both real-time data and all types of data traffic.

Figures 4.1 and 4.2 demonstrate the end-to-end delay of all types of data traffic over a number of levels and zones, respectively. From these results, we find that the Priority based Multi-Queue Packet (PMP) sceduling Scheme task scheduling scheme outperforms FCFS, and PMP scheduler in terms of end-to-end data transmission delay. This is because in the proposed scheme, the tasks that arrive from the lower level nodes are given higher priority than the tasks at the current node. Thus, the average data transmission delay is shortened.

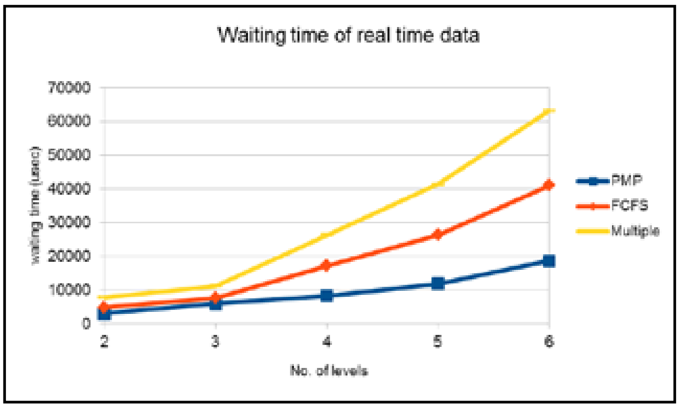

Fig. 4.1 waiting time of real time data over no. of levels

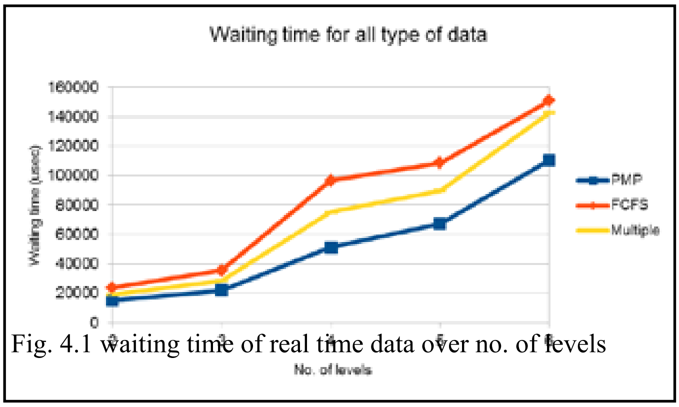

Fig. 4.2 Waiting time of all type of data over no. of levels

V. Conclusion

This dissertation work minimizes end-to-end data transmission delay & average packet waiting time. Proposed Priority based Multi-Queue Packet (PMP) scheduling scheme for Wireless Sensor Networks (WSNs) uses three-level of priority queues to schedule data packets based on their types and priorities. It ensures minimum end-to-end data transmission for the highest priority data while exhibiting acceptable fairness towards lowest-priority data. Experimental results show that the proposed PMP packet scheduling scheme has better performance than the existing FCFS and DMP Scheduler in terms of the average task waiting time.

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