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# A Study on Dynamic Multilevel Priority Packet Scheduling Scheme for WSNs

Shantveer and Dr Jagadish S Kallimani

*Department of Computer Science and Engineering, M S Ramaiah Institute of Technology, Bangalore, India*

***Abstract*- Wireless Sensor Networks (WSNs) consists of densely distributed self-organizing wireless nodes with a tiny amount of CPU memory, low processing power and a very low battery capacity. These wireless nodes sense the environmental situations and generate different types of data packets, such as real-time and non-real-time data packets. Scheduling these different types of data packets in the network is a challenging task. Many sensor applications rely on information being delivered in a timely manner, so it is important to reduce the total end-to-end delay. Many of the existing packet-scheduling algorithms in WSNs use, First Come First Serve (FCFS), Earliest Deadline First (EDF), Shortest Job First (SJF), Preemptive priority, non-preemptive priority. FCFS, EDF and SJF algorithms don't provide any priority to real-time data packets this leads to starvation of real-time data packets when non-real-time packets arrive with a higher Burst time. In priority based algorithms, non-real-time data packets starve because of continuous arrival of higher priority real-time data packets. Some scheduling algorithms are based on number of queues in the sensor node. Existing algorithms incur a high processing overhead and large end-to-end delay. These algorithms are not dynamic in nature to adapt the changing requirements of the Wireless Sensor Networks**.

**A Dynamic Multilevel Priority (DMP) Packet Scheduling scheme is proposed to overcome the starvation problem, to reduce processing overhead and end-to-end delay. This scheduling algorithm divides the ready queue into three individual priority queues. Real-time data packets are allotted the highest priority and are placed in the priority 1 queue, non-real-time remote data packets are allocated to priority 2 queue and local non-real-time data to the priority queue 3. This algorithm uses a zone-based technology and visualizes the whole network as a hierarchical structure. The sensor nodes that are adjacent to the Base Station are considered to be present at level 0, nodes which are at one hop distance are said to be at level 1. Each level in the hierarchy is allocated with a time slot of varying time quantum using a TDMA scheme.**

***Keywords*-- Wireless Sensor Networks, FCFS, EDF, preemptive priority, non-preemptive priority, end-to-end delay, non-real-time packets, real-time data packets, DMP, zone-based, TDMA scheme.**

## I. INTRODUCTION

Wireless Sensor Networks (WSNs) consist of densely distributed self-organizing wireless motes with a tiny amount of CPU memory, low processing power and very low battery capacity which support sensing, signal processing, embedded computing and connectivity. Sensor nodes are smart, small in size light weight, inexpensive nodes that monitor physical and environmental situations. These nodes collect the environmental data like temperature, humidity, light intensity and ultrasonic sounds etc. Wireless sensor networks have wide range of applications in military and border security. the data sensed at the Wireless Nodes (WNs) is to be sent to a Base Station node via a LAN connection that connects all the nodes of the Wireless Sensor Network that uses very less Bandwidth Base Station collect the data from various nodes using a single- hop transmission and sometimes multi-hop transmission, in some cases cluster technique [1] used for data collection, cluster collect data from wireless nodes and all cluster heads collectively send data to the Base Station. A Base Station is the gateway between end user and Sensor Nodes.

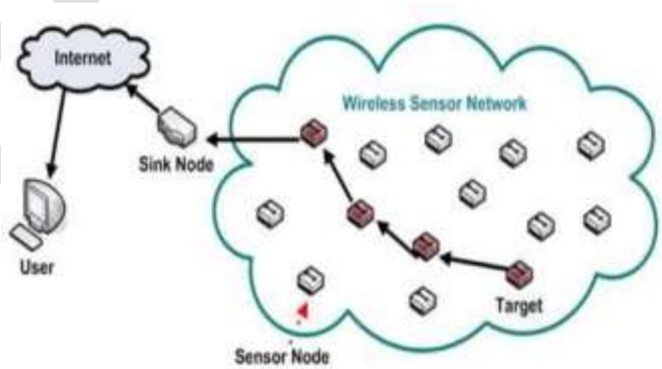


Figure 1: Network model of Wireless Sensor Network [2]

The major traffic in the medium is the data which is reported from each sensor Node to the Base Station. The Base Station is overloaded with different types of data packets and the processing overhead of the node increases. The data propagation technique between the hops of the network can be routing or flooding. Data packets sent to a Base Station (BS) are categorized into 2 types namely Real-time data and Non-real time data. Real time data packets are of the highest priority among all the other data packets and need to be delivered to the BS without any transmission and processing delay with a minimum end-to-end delay otherwise the data may not be useful if it is sent after its significance. Non-real-time data packets have lower priority when compared to real time data packets. And there is no urgency for these packets to be sent to the BS immediately. A scheduler runs a scheduling algorithm upon which the packets arriving at a node are scheduled for further processing. Algorithms currently used in the WSNs are 1) First Come First Serve (FCFS) 2) Shortest Job First (SJF) 3) Earliest Deadline First (EDF) 4) Priority Scheduling 5) Preemptive Scheduling 6) Non-preemptive Scheduling [3]. All these algorithms are pre-defined and are not dynamic [4] in nature and these algorithms result in starvation of one or the other types of data packets.

The problems with the existing algorithms are high end -to-end delay, high processing overhead and congestion at the Base Station. In deadline based algorithms the higher priority packets are never allowed unless their arrival time is up, they should wait till their turn and there is a chance that these packets will experience a huge delay and it may lead to starvation of Real-time data packets. In priority based scheduling algorithms, lower priority packets will starve because of continuous arrival of higher priority packets to the sensor nodes. Because of this, the number of packets in the queue increases with different types of data packets in it. This in turn increases processing time and end-to-end delivery time. More number of resources are consumed at a node when the congestion in the network increases. The energy of node gets depleted completely; this reduces the life time [5] of the whole network.

To avoid this problem there is a need to develop a new packet scheduling algorithm which is dynamic in nature, priority based and has a multiple queuing systems. To avoid the processing overhead, total end-to -end delay of packet delivery and starvation of both Real-time and Non-real time data packets at the Base Station.

A Dynamic Multilevel Priority (DMP) packets scheduling technique uses multiple queue system and uses a zone based technology. The nodes in the wireless sensor network are assumed to be virtually organized into a hierarchical structure. The distance between a wireless node and the Base Station is calculated in terms of hop distances [6]. The Sensor nodes which are at equal hop distances from a base station are said to be in the same level, i.e. nodes that are adjacent to the base station are at level 0, nodes that are at 1 hop distance from the BS are said to be at level 1, nodes which are at 2 hop distance from base station are at level 2 and so on. Data packets that are to be sent from a sensor node is allocated with a time slot using a Time Division Multiple Access (TDMA) scheme. For instance nodes that are adjacent to the Base Station are allocated with the first slot of TDMA scheme; nodes that are 1 hop distance are allocated with the second time slot of the access and so on. The data packets from the sensor nodes can be forwarded to the Base Station either directly or through intermediate nodes called hand-shaking.

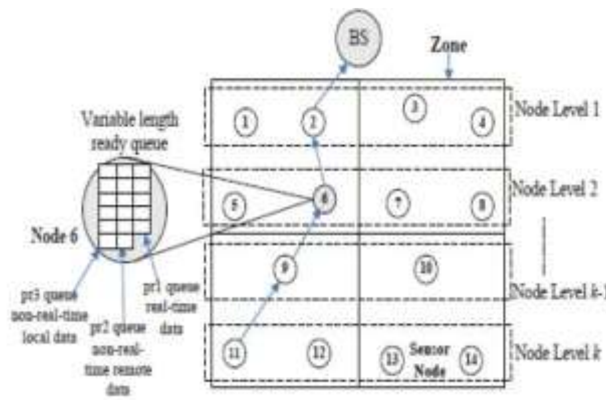


Figure 2: DMP packet scheduling scheme for WSNs [7]

## II. RELATED WORKS

In this section we study about the existing packets scheduling algorithms that are currently being used in WSN. These algorithms are categorized into different classes based on the various factors.

The following tree representation of the classification can be illustrated as follows:

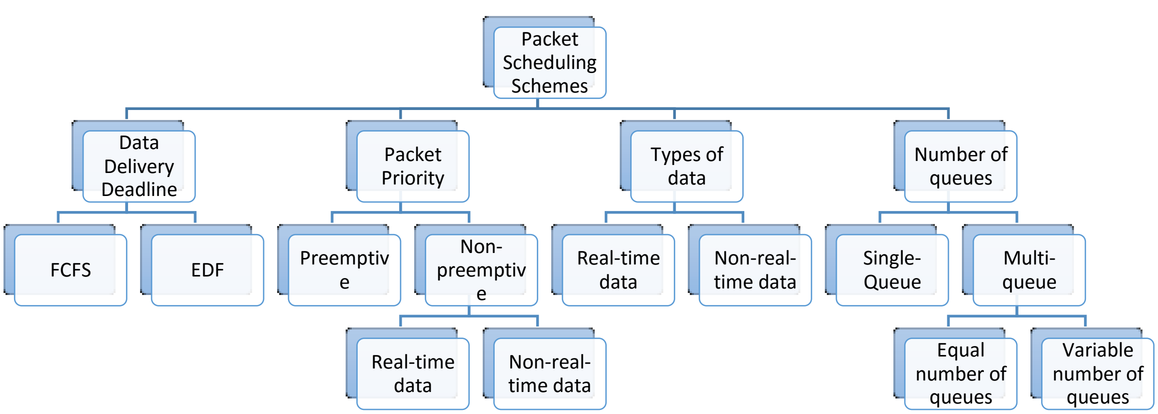


Figure 3: Classification of packet Scheduling Schemes in WSNs

*Classification of packet scheduling schemes*

*2.1 Data delivery deadline*

In this class of scheduling algorithms the factor under consideration is arrival time of a packet in the ready queue (FCFS) or completion time of a packet processing (EDF).

Real time data delivery in WSNs is a challenging task, so scheduling and managing them is a major issue. Various opersting systems in current wireless sensor networks make use of deadline based algorithms like FIFO and EDF.

*Earliest Deadline First (EDF)*

For some real time applications in WSNs, a realtime scheduler such as Earliest Deadline First (EDF) or its variants are used. Some of the Operating Systems in existing Wireless Sensor Networks using EDF scheduling techniques are, EYES OS and EMERALDS.

Disadvantages of this scheduling algorithm are if a new packet arrives with a shorter deadline, that packet will be allowed to prosess first hence starvation of the processes with higher burst time and larger end-to-end delay.

*First Come First Serve (FCFS)*

Some of the operating systems in current WSNs use a FCFS [8] algorithm. This is a very simple and easy to implement approach in scheduling Real-time data packets. This scheduling technique use arrival times of a packet as a factor of consideration. This algorithm has a very poor performance and the average waiting time of this algorithm is high. Some of the operating systems using FCFS scheduling algorithm are TinyOS, EYES OS and SenOS.

The major problems with data delivery deadline based scheduling algorithm are: All the packets that arrive to the schedules are arranged in a ready queue irrespective of the type of data packet, so no priority for the Real-time data packets. And it leads to starvation of higher prioriy Real-time data packets when Non-real-time data packets with a huge burst times are present in the ready queue.

*2.2 Packet priority based scheduling*

Each packet that arrives to the ready queue is assigned a priority. Process with highest priority is to be executed first and then the lower priority packets and so on. Priority can be assigned based on memory or any other resourse requirement. Processes with same priority are executed using a FCFS or SJF for tie breaking. Operating systems in current technology of WSNs using priority scheduling are MANTIS, EYES OS.

*Preemptive*

In this scheduling approach, the packets with a higher priority are allowed to execute prior to the lower priority packets in the queue. Suppose a packet is already being processed with a priority p2, if a new packet arrives with a priority p1, then the current processing of the packet p2 is preempted and p1 is executed until the end of p1, later the process p2 resumed from the point interruption.

*Non-preemptive*

In Non-preemptive packet scheduling scheme arrival of a higher priority packet in the sensor node doesn't affect the execution of the current lower priority packet processing. The higher priority packet must wait till the current processing of the lower priority packet is completed. If a packet is with a priority p2 is being processed, then arrival of a new packet with priority p1 then the execution of p2 is not preempted.so the packet p1 has to wait till the completion of p2's processing. The major problem with the priority packet scheduling technique is, starvation of lower priority packets because of continuous arrival of higher priority data packets in the sensor node.

*2.3 Scheduling based on the type of packet*

Data packets generated at the sensor nodes are classified into two types namely real-time and non-real-time data packets. The schedulers at the sensor nodes identify the types of data packets and schedule them accordingly.

*Real-time data packet scheduling*

These type of data packets are of highest priority and need to be delivered very quickly , Real-time data packets are processed and delivered to the Base Station with a minimum possible end-to-end delay, Otherwise if the delivery of these data packets take a longer time then the data will be of no use .So in-time delivery of the Real-time [9] data packets is very important.

*Non-real-time data packet scheduling*

Non real-time data packets are of lower priority than real-time data packets. These packets are usually the data packets from the lower level nodes which have been sent to the Base Station through hand-shaking. The Real-time data generated at the senser nodes locally is of least priority. These data packets need not be processed quickly and also should not be kept to waiting forever in ready queue, to achieve fairness property. So these packets are scheduled using a FCFS/SJF algorithm among all the Non-real-time data packets are present in ready queue. The processing of these packets will be interrupted by arrival of real-time data packets.

The major problem with the scheduling algorithm that are based on the type of data packets are: These algorithms are dynamic in nature and multiple queue are not introduced in them.

*2.4 Scheduling techniques based on no of queues*

Number of queues in a sensor node contributes a lot towards the performance of the scheduling process. Number queues in the sensor node better is the performance of the scheduling process. These algorithms are divided into two catagories namely Single queue and multiple queue scheduling algorithms.

*Single queue scheduling algorithm*

Each and every sensor node in the network has only one queue known as ready queue. Any packet that enters will be forwarded to the same queue irrespective of the size, type and priority of the packet, after they enter the ready queue they are then scheduled based on their size, type or priority.The starvation of process in a single queue system is very high, as all types  priority level packets compete in the same queue.

*Multiple queue scheduling algorithm*

A ready queue is partitioned into several separate queue. Data packets are scheduled as per their category and are assigned to only one queue based on some property permanently. Each queue can have its own scheduling algorithm. Interqueue scheduling is also possible using fixed-priority scheduling (each of the queue has priority, process in queue with higher priority are scheduled before other queues) and time slice (each queue gets certain partition of processor time).

Multiple queue scheduling has two phases: scheduling among different queues and scheduling within the queue.

The number of queues in a sensor node maybe equal for all levels or can be different for each level. The number of queue in a sensor node depends on in which level the node is present from the Base Station. For instance, a node at the boundary (a leaf node) has a minimum number of queues when compared to the nodes at the upper level or (a node which is closer to the base station). This is because of two reasons: the nodes near to the base station have to deal with a huge number of packets when compared to the sensor nodes at the boundary and to reduce end –to-end data transmission delay [10] and balance network energy consumption.

A multiple queue scheduling in a sensor node can be visualized as:

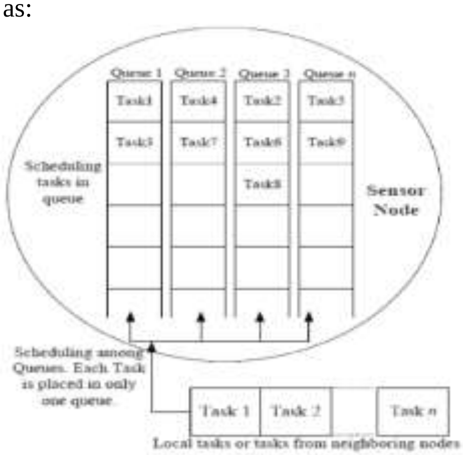


Figure 4: Scheduling among multiple queues [6]

III. PRELEMINARIES

In this section we study about some of the general assumptions and terminologies that are used in designing the Dynamic Multilevel Priority (DMP) packet scheduling scheme are defined.

*3.1  Assumption made in DMP design [6]*

- Only real-time data packets and non-real time data packets are present in the data traffic medium.
- Both real time data packets and non-real time data packets are of same size.
- All sensor nodes in the network are time synchronized.
- No data aggregation is done at intermediate node for real-time data, but it is done for non-real time data.
- Nodes located at different levels are allocated with variable time slots using TDMA scheme.
- Ready queue of each sensor node is divided into three individual queues only (i.e. pr1 for real-time data, pr2 for non-real-time data from other nodes, pr3 for non-real time data generated at node locally).
- Length of data queues in a sensor node is variable for instance; pr1 length is smaller than pr2 and pr3 queue and length of pr2 and pr3 are same.

*3.2  Factors considered in DMP design.*

*3.2.1  Hierarchical structure*

Where network is virtually organized into a hierarchical structure, considering the base station as the root node, and the sensor nodes that are adjacent to the base station are considered to be at level 0 and nodes with a hop distance of 1 from the base node are said to be at level 1 and so on, nodes at the boundary are called as leaf nodes.

*3.2.2  TDMA scheme*

Each level in the hierarchical structure is allocated with a time slot. The time slots are variable (i.e. the time slot allocated for node, at level1 may be different from the time slot allocated for the nodes at the boundary). In the design of DMP scheduling variable time slots are used because nodes at lower level or nodes which are nearer to the base station have more number of packets to process than compared to the nodes which are far from the base station, considering this observation the length of time slots at the upper level node is set to higher time value compared with time slot length of lower level sensor nodes.

*3.2.3  Data aggregation*

Data aggregation at each sensor nodes is a process in the data sensed at multiple sensor nodes are grouped together as input on certain criteria to form a single data of more significant meaning. Non-real-time data which is produced as the sensor nodes are allowed for data aggregation because a little delay in the end-to-end delivery of non-real-time data packets does not affect much, and on other hand the energy efficiency of the nodes in improved as there is no redundant data packet transfer. Whereas , real-time data which is produced by time-critical emergency application should not be subjected to data aggregation at the intermediate nodes as they should be delivered to the base station with a minimum possible delay, Hence the time slots with real-time data packets at all levels is almost equal and short.

### 3.2.4 *Priority*

Real-time data packets and emergency data should be given the might priority and should be delivered with least delay. The priority of non-real-time data packet is assigned based on the sensed location (local or local) and the size of data. Data packets received by a sensor node n from the lower level nodes (nodes that are far from the base station) are given in a higher priority ($pr_2$) when compared to non-real time packets generated at the node n itself, because data at the node nearer to base station as the aggregated data which makes more sense and is grouped data from many other sensor nodes. Processing of a priority3 ($pr_3$) packet can be interrupted by arrival of a higher priority2 ($pr_2$) packet, and arrival of a priority1 ($pr_1$) packet can interrupt processing both $pr_2$ and $pr_3$ packets.

### 3.2.5 *Round-robin scheduling within the queue*

Real time and non-real time data packets are scheduled among the multiple queues based on the DMP scheduling. Once these packets are distributed and are enqueued in a specific queue then, there is need for a scheduling them with in the queue. Existing scheduling techniques are SJF are FCFS scheduling with in the queue of these scheduling techniques of starvation free, so we propose a round robin scheduling neither round robin approach is like pre-emptive FCFS algorithm, in these approach the ready queue is operated as a circular queue. Data packets in the ready queue are kept in FIFO order. CPU time is shared among the requesting data packets in round robin sequence. The scheduler picks first packet from the ready queue at the same time, sets a timer to the interrupt at the end of the time slice and dispatches the packet. When the timer goes off, either the data packet processing completes and releases the CPU or get preempted

Observations of round robin:

- It is a preemptive algorithm by default.
- It allocates CPU to a packet for processing only once in a row.
- Given n process in read queue and time quantum q, each process get 1/*n* of the CPU time in quantum of q time units. So each process wait no more than *(n-1)*q*.
- It depends directly on the size of time quantum.

Advantages:

- No packets starve.
- This algorithm lets every active packet in the ready queue to get processed so that no packets waits forever
- This scheduling process is work-conserving. If one flow is out of the packets. Next data will take its place ,thus to avoid link resource go unused
- Round robin scheduling results in max-min fairness if data packets are equally sized

### 3.2.6 *Fairness*

Fairness metric ensures that the non-real time data with different priorities are processed with a minimum waiting time at ready queue based on the priority of the packets. For instance if lower priority packet is waiting in ready queue because of continuous arrival of higher priority non-real time data packets, fairness defines a constraint that allows lower priority packet to get processed after a certain time.

- *Fairness in SJF by aging*

In the existing algorithms SJF algorithm is used for scheduling data packets within the queue SJF algorithm process shortest job in prior to the jobs with large burst time. So starvation of jobs with higher burst time. To avoid this, aging concept is used in SJF algorithm. Aging gradually increases the priority of low priority process. The higher priority non real time packets can preempt lower priority packets for a certain time. After that waiting period of lower priority packets can preempt the execution of higher priority process in ready queue. The Round-robin preemptive scheduling algorithm is easy to implement, starvation free and makes use of varying time quantum.

- *Fairness in Round-Robin*

In order to schedule data packets fairly, a Round –robin scheduler generally employs time-sharing i.e. Giving each job a time quantum and interrupting the job if it is not completed within the given time quantum.

### 3.2.7 *Routing protocol*

To avoid complete depletion of energy of a sensor node, a zone-based routing protocol [11] is used. In a zone based routing protocol each zone is identified by a zone head. Nodes in a zone fallow a hierarchical structure, based on hop distance. Each zone in the hierarchy is divided in to a number of squares in such a way that if a node exists in a square it covers all of its neighboring nodes; this protocol avoids the presence of sensing hole [12] in the network.

## IV. CONCLUSION

In this paper, we successfully studied about the existing algorithms that are being used in Wireless Sensor Networks. The factors on which the existing algorithms are developed and their disadvantages in terms of starvation, processing overhead and end-to-end delay. We also studied about a Dynamic Multilevel Priority (DMP) packet scheduling scheme, its prerequisites and the factors that are being considered in the algorithm. This paper deals with issues such as - how the starvation of both types of data packets is avoided, how the processing overhead, average end-to-end delay is reduced for the delivery of both real-time and non-real-time data packets. We studied the DMP packet scheduling scheme that improves the overall performance of scheduling in a WSN.

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