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A Review of Packet Scheduling Schemes in Wireless Sensor Networks

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Abstract: Many wireless sensor network (WSN) applications heavily rely on information being transmitted in a timely manner. In such sensor networks, packet scheduling plays a vital role in reducing end-to-end data transmission delays. It also helps in reducing sensors energy consumptions, thus increasing the lifetime of the wireless sensor network. The simplest packet scheduling scheme is FCFS (First Come First Serve). Many more packet scheduling schemes have been proposed for wireless sensor networks such as EDF(Earliest Deadline First) and those based on priority with single and multiple queues. This paper discusses different packet scheduling techniques that have been proposed for wireless sensor networks and the various concepts related to them.

Keywords: Packet scheduling, wireless sensor networks, real-time data, pre-emptive, priority.

I. INTRODUCTION

Wireless sensor network (WSN) is a network of a large number of self-organizing nodes distributed in some region. It is a rapidly developing area with a wide range of potential applications like environmental monitoring, medical systems, battle fields, biometrics, industrial control, smart spaces etc. Each node in a WSN is equipped with one or more sensors, a processor, some memory and low-power radio. They are small in size, light weight and low cost. The sensors sense the surroundings and send the information to the base station (or sink) either directly or through intermediate nodes as shown in Fig. 1. The end user can get the information from the base station.

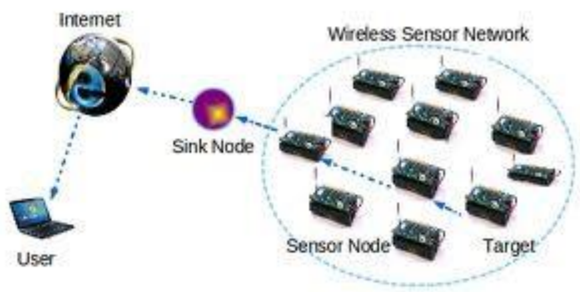

Fig.1. Example of a wireless sensor network

Timing constraints are very important in many wireless sensor networks applications and should be taken into consideration while designing packet scheduling schemes for such applications. Some examples are WSN-based disaster warning system and surveillance system. Such systems must immediately notify the authorities on occurrence of an event. If the data could not reach the sink within a specified real-time deadline, it becomes invalid and need not be transmitted further. First Come First Serve (FCFS) scheduler is the most traditional and simplest packet scheduling scheme which process packets as they arrive. As a result, many packets may have to wait for a long time and this might lead to their expiration. Earliest Deadline First (EDF) scheduling scheme finds a solution to this by scheduling packets based on their deadline. But EDF treats all packets equally and does not differentiate between real-time and non-real time data. This lead to priority based scheduling schemes where the delivery order of data packets in their ready queue are changed by the intermediate nodes based on their importance. It can be implemented using single or multiple queues. Real-time priority scheduler ensures delivery of real-time emergency data with shortest possible end-to-end delay. The above discussed packet scheduling schemes in WSNs are not dynamic to changing requirements of WSN applications due to their pre deterministic and static nature. A Dynamic Multilevel Packet (DMP) scheduling scheme brings in dynamism by virtually organizing sensor nodes into hierarchical structure based on distance to base station. This scheme maintains separate queues for real-time data, non-real-time remote data and non-real-time local data.

The rest of the paper is organized as follows. In section II we discuss the various concepts related to packet scheduling in WSNs. The existing packet scheduling schemes in WSNs are explained in section III. The paper ends with conclusions and acknowledgment.

II. GENERAL CONCEPTS

This section mentions certain important concepts used in scheduling schemes.

A. Pre-emptive & Non-pre-emptive Scheduling

Pre-emptive and non-pre-emptive packet scheduling is based on the concept of priority. Tasks are usually assigned with priority. At times, it is required that a higher priority task must be done immediately. Then, the currently executing task is interrupted and its execution is resumed after completing the higher priority task, i.e., the higher priority task pre-empt the execution of a lower

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priority task. Packet scheduling scheme in which processing of a lower priority packet is pre-empted for a higher priority packet is called pre-emptive priority scheduling.

In non-pre-emptive priority scheduling, once a process is started, it is not interrupted until it is finished. i.e., the processing of a higher priority packet is done only after the current packet.

Pre-emptive priority packet scheduling is used in wireless sensor networks for immediate processing of real time and emergency data. But, an issue with pre-emption is that continuous arrival of high priority data may lead to starvation of non-real-time data.

B. *Real-time & Non-real-time Data*

Real-time data denotes information that is delivered immediately after collection. There is no delay in the timeliness of the information provided. It is valid only for a short time period and is no more useful on expiration of that time period. In case of non real-time data, time constraint is not so strict. So, in packet scheduling schemes, real-time data packets are given higher priority. An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it.

Wireless sensor networks interact directly with environment and often have timing constraints in the form of end-to-end deadlines. In order to support real-time communication, sensor network protocols should be designed so as to minimize packet deadline miss ratio, i.e., the percentage of packets that meet their end-to-end deadlines.

C. *Single & Multiple Queues*

In single queue based packet scheduling scheme each sensor node has a single ready queue. All packets enter this queue and from there they are scheduling according to the packet scheduling scheme used in the network. Even though using single queue is simple to handle it has a high starvation rate.

In multi-level queue schemes, each node has two or more queues, depending upon the location of node in the network. Usually, nodes at the lowest level have minimum number of queues and nodes at higher level (closer to the base station) have more number, so as to balance network energy consumption and reduce end-to-end data transmission delay.

III. PACKET SCHEDULING SCHEMES IN WSNS

The following are some of the packet scheduling schemes proposed for wireless sensor networks:

A. *FCFS*

The first come, first served scheduling algorithm is the simplest packet scheduling algorithm in which packets are processed as they come. . It is the traditional method that was used to support real-time communication. But, if many sensor nodes generate data at the same time, , data packets from nodes far away from base station need more time to reach the base station than those from nearby nodes. Therefore we should consider scheduling delivery order of data packet in immediate nodes within a deadline.

Wireless sensor networks are usually deployed over a wide area and consist of a large number of randomly deployed nodes. This makes scheduling a major concern. Each node has to decide which packet is urgent for real time data communication. If there is deadline for data delivery of data packet, that should also be taken into consideration while scheduling the delivery order so that the meaning of the data is not lost when it reaches the base station.

B. *EDF*

Earliest deadline first (EDF) is a dynamic packet scheduling algorithm used for real time applications. In this scheme, the packets are scheduled based on their deadline. Whenever a scheduling event occurs the queue will be searched for the packet closest to its deadline. This packet is the next to be scheduled for processing. This results in faster forwarding of emergency data, thus minimizing expiration of data packet.

C. *Priority Based Scheduler*

C. Lu et al., in RAP [2] suggests Velocity Monotonic Scheduling (VMS) policy suitable for packet scheduling in sensor networks. It is based on a different concept of packet requested velocity. It is expected that each packet meets its end-to-end deadline if it can move toward the destination at its requested velocity, which reflects its local urgency.

In comparison with non- prioritized packet scheduling, VMS improves the dead- line miss ratios of sensor networks by giving higher priority to packets with higher requested velocities. Local urgency of a packet is more accurately reflected by requested velocity when packets with the same deadline have different distances to their destinations and hence VMS is better than deadline-based packet scheduling. In this scheme it is assumed that each sensor knows its own location (using GPS or other location services), from which it determines the requested velocity locally. This property helps VMS to scale well in large-scale sensor networks.

D. RACE

K. Mizanian et al. proposed RACE algorithm in [5], a real time scheduling policy for large scale wireless sensor networks. The main goal of RACE algorithm is to support a soft real-time communication service through the path with minimum delay. Thus the end-to-end delay in the sensor network becomes proportional to congestion of nodes between source and destination.

The Bellman Ford algorithm is used to find the path with minimum traffic load between source and destination. Weight of algorithm is the sum of propagation delay, queuing delay and contention delay. Earliest Deadline First (EDF) scheduling algorithm is used in each node to send the packet with earliest deadline before other packets in the nodes queue.

The miss ratio and end-to-end deadline in sensor networks are greatly reduced by the RACE algorithm. It will also balance load and energy consumption of network, thus increasing the life time of the sensor network.

E. Adaptive Task Balancing

In this scheme, scheduling is done based on the topology of the sensor network. In WSNs nodes close to the base station have to forward data packets from other sensor nodes to the base station. At the same time, they also have to process their own sensing packets. These nodes get overloaded in high rate applications. The overloading problem in FCFS scheduling can be reduced by using priority schemes. But still, these nodes may not get fair chance to process their local sensing packets if the forwarding operations are given higher priority than sensing operations. Such nodes have always their queues full with tasks most of them being forwarding tasks. As a result they may not be able to successfully sense or interact with the environment as they are busy with communication activities.

F. Tirkawi et al. proposed an adaptive task balancing scheme in [4] which enhances the fairness of distributed sensing by switching priority between sensing and network tasks. The sensing tasks are compression, encoding and signal processing activities, while the network tasks include sending, receiving and forwarding of packets. The priority is based on the nods depth (number of hops to the base station) in the network topology and changes as nodes change their position.

In this scheme, every sensor node, monitors its current depth in the network and if it moves close to base station (i.e. to depth two or one), then its sensing tasks are switched to higher priority for just X% of its duty cycle. Within this time, nodes can complete sensing and processing their local tasks and pass local data to base station. On completion of X% of duty cycle, priority is switched back to critical tasks which are in the network stack. The value of X depends on many factors such as amount of local activity, network size and network density.

F. Multi-Queue Scheduler

E. M. Lee et al. suggested a method in [3] to reduce the amount of exceeded deadline packet by changing delivery order among packets in the ready queue of intermediate nodes and thus reduce the packet miss ratio.. They proposed a Multi-Level-Queue scheduler scheme which use different number of queue according to location of node in the network. They consider two methods to change the packet delivery order in intermediate nodes : (1)SP(Simple Priority), and (2) Multi-FIFO-Queue

In the first method, when a node inserts a packet to the queue, the node finds the packet's location in a ready queue according to priority. This method forms a basic solution but suffers the problem of starvation. It can be solved by checking deadline and sorting packets according to remaining time to deadline. But, this greatly increases computation.

In the second method, Multi-FIFO-Queue each sensor node consists of two or three queue according to location of node in network. Each queue has different priority such as low, high or mid. When a node gets a packet, the priority of the packet is decided by the node according to hop count data field of packet. As leaf nodes have only its own data to send, they have only a single queue

G. Dynamic Multilevel Priority (DMP)

Dynamic Multilevel Priority (DMP) Scheme proposed by Nidal Nasser et al. in [5] is a multi-queue packet scheduling scheme which uses of zone based topology of WSNs. Nodes have separate queues for real-time data packets, non real-time remote data packets received from other nodes and non-real- time local data packets generated at the node itself. All the intermediate nodes have three queues whereas leaf nodes have only two queues, one each for real time and non-real-time data packets.

In this scheme, nodes are virtually organized into a hierarchical structure based on hop distance from the base station. Nodes at different levels send their data packets using a TDMA scheme in which timeslots are allocated according to the level. Real-time data packets are given highest priority, followed by non-real time remote data packets and then by non-real time local data packets. Real time packets can pre-empt data packets in other queues, thus enabling emergency data to reach base station with minimum delay. Giving more priority to remote data reduces the waiting time of data from nodes far away from base station. Non-real-time data packets with the same priority are scheduled using shortest job first (SJF) scheduling scheme. All these techniques help DMP to reduce average waiting time and end-to-end delay.

IV. CONCLUSION

Wireless Sensor Networks is an important area in networking research, which is increasingly being used for real-time applications. This demands techniques to send the sensed data to base station as soon as possible. It is done by scheduling data packets in a wireless sensor network according to their importance and urgency. In this paper, various packet scheduling techniques for wireless sensor networks were discussed.

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