Energy Based Scheduling Scheme for Wireless Sensor Networks

Mohamed H. Taha, Nour El Din M. Khalifa, Hesham N. Elmahdy and Imane A. Saroit

***Abstract*—**Wireless sensor networks (WSNs) have become an attracted research and industry interest. In WSN, each node is attached to a battery, which supply the node with energy required for data sensing, processing and transmission. Transmitted packets are queued at intermediate nodes. Each node schedules the queued packets by assigning priorities to each packet. Priorities are assigned to packets according to their deadlines. This method in packet prioritization does not take into consideration either the network life time or energy consumption. Besides, it may lead to dropping high energy valuable packets. In many applications, WSN lifetime is considered a very critical issue, while setting up the network. In this paper, we paper we introduce new scheduling schema, called Energy Based Scheduling schema. In this schema, packets are not only prioritized according to their deadlines but also to some energy measures related to the network. These energy measures are obtained from the network nodes and are used in packet prioritization. The proposed schema is integrated with the AODV routing protocol. The unused bits in the AODV packets are used by the proposed schema in assigning sending priorities to each packet in the network. Through this paper, we will compare the proposed scheduling schema against the Basic Priority Scheduling schema, using NS-2. Comparisons are done according the network life time and energy consumption.

***Keywords*—**Wireless sensor networks, Scheduling schema, AODV, NS-2.

I. Introduction

Wireless sensor networks consist of spatially distributed sensor nodes. They are an important emerging technology that will revolutionize sensing for a wide range of scientific, military, industrial and civilian applications. In a WSN, each sensor node is able to independently perform some processing and sensing tasks. Wireless Sensor Networks are composed of battery powered and should operate without attendance for a relatively long period [1]. In most cases, it is very difficult and even impossible to change or recharge batteries for the sensor nodes. Sensor nodes communicate with each other in order to forward their sensed information to a central processing unit or conduct some local coordination such as data fusion [2]. In many WSN applications, the deployment of sensor nodes is performed in an ad hoc fashion without careful preplanning and engineering. Once deployed, the sensor nodes must be able to autonomously organize themselves into a wireless communication network. Wireless Sensor Networks (WSNs) have been widely considered as one of the most important technologies for the twenty - first century. Large amounts of research activities have been carried out to explore and solve various design and application issues, and significant advances have been made in the development and deployment of WSNs [3].

The continuous decrease in the size and cost of sensors has motivated intensive research addressing the potential of collaboration among sensors in data. Current research on routing and scheduling in wireless sensor networks focused on protocols that are energy aware to maximize the lifetime of the network. These researches are scalable to accommodate a large number of sensor nodes, and are tolerant to sensor damage and battery exhaustion. Sensor networks are deployed to collect information for later analysis, monitoring or tracking of phenomena in real-time [4].

The primary challenges here are how to prioritize and schedule packets. Other challenge in real-time sensor network applications is how to carry out sensor data dissemination given source-to-sink end-to-end deadlines when the communication resources are scarce [5]. In a sensor node, energy is consumed by sensing, communication and data processing. More energy is required for data communication than for sensing and data processing. Through this paper, we will focus on how to minimize transmission energy consumption through the whole network. WSN energy is the main challenge as it affects the network lifetime [6].

New packet scheduling schemas have been developed for real-time data communication. These schemas work on prioritizing packets according to their deadlines. Packet prioritizing cannot support real time applications or assure network lifetime. In extreme traffic environments, large queues may lead to packet delay and packet dropping. Packet dropping leads to energy loss, as a packet could have consumed high energy in order to be delivered to its destination [7].

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Energy usage in packet transmission is much greater than its usage in data processing and sensing. Efficient usage of sensor's energy resources and maximizing the network lifetime are the main design considerations for the most proposed protocols and algorithms. However, depending on the type of application, the generated data packets may be differ in their energy consumptions [8].

This paper introduces a new scheduling schema that will not only prioritize packets according to their deadlines but also according to their sizes, energy consumption during transmission and energy path level. The new schema efficiently manages packet dropping at each node in order to avoid dropping packets, which consumed high energy during transmission. In addition, the new schema can work with Ad hoc On Demand Distance Vector (AODV) Routing Protocol.

II. Related Work

Old solutions for packet scheduling prioritized packet transmission according to the deadline distance from the sink or the available time slack. These methods do not deal with the energy consumed by a packet during transmission.

Just-in-Time Scheduling (JiTS) algorithms take the advantage of the available slack of time. In JiTS, every packet is delayed for duration of time at every hop to the destination. Further, it distributes the available slack time to allow the network to tolerate transient periods of high contentions [9].

Simple and Efficient Scheduling in Sensor Networks (SES-SN) is another scheduling schema presented in [10]. It delays the data packets exponentially before reaching the sink. It is considered an update to JiTS.

Another technique for scheduling, which is the default scheduling schema in the NS-2, depends on prioritizing the packets according to their usage. It is called Basic Priority Scheduling. Priority values are assigned to every packet in the network regardless its energy consumption. High priority values are usually given to control packets, while medium or low priority values are given to data packets. Data Packets are served in FIFO order [11].

The main design goal of Real-Time Architecture for Sensor Networks (RAP) is to develop a fair scheduling algorithm for data communication in wireless sensor network. This would help in minimizing the miss ratio of real-time data traffic. Since packet priority should be decided based on both distance and deadlines as illustrated before, the Velocity Monotonic Scheduling (VMS) was proposed. VMS assigns the priority of a packet based on its requested velocity. A packet with a higher requested velocity is assigned a higher priority. VMS improves the number of packets that meet their deadlines because it assigns the assumed priorities to packets based on their different urgencies on the current hop [12].

III. Energy Based Scheduling Scheme

The primary challenges of packet prioritizing according to deadline or available time slack, is that it may lead to dropping high energy valuable packets. Packets arriving from far sources may consume much energy. Dropping these valuable energy packets may lead to shorten the network lifetime. In addition, packet transmission path is a major issue that should be considered in packet scheduling. Packet transmission decision should not only be affected by the packet deadline, but also by packet energy consumption and packet transmission path. Routing protocols are responsible for the path selection. According to the selected path, packets are sent from source to destination. During packet transmission, each node queues the packets to its buffer.

The proposed schema depends on the fact, that Energy usage in packet transmission is so greater than its usage in data processing and sensing. Scheduling schemas have the responsibility of whether to drop, delay or send the packet according to some measures, form node queues. The problem is how to prioritize packets according to four constraints packet deadline, packet size, packet energy consumption during transmission and packet energy path level, which is a new energy measure that reflects the value of the energy nodes across a specific path. According to this measure, we can find the path stability and strength that a packet uses through its transmission from source to sink. The following notations are used in the discussion.

- PD: packet deadline
- PS: packet size
- PEP: packet energy path level
- PEC: packet energy consumption during transmission

Subscript '*i*' is often used with these parameters to indicate that they are for a node *i*, while subscript '*x*' is used to indicate that they are for a packet *x*.

For packet *x*, PEP_x at node *d*, is calculated through the following equation:

$$PEP_x(d) = \sum_{i \in R_x} \frac{E(i)}{IE_i} \qquad (1)$$

where *E(i)* is the current energy for node *i* while receiving packet *x* and IE_i is the initial energy for node *i*. *R* denotes the set of nodes that packet *x* uses through transmission from its source to node *d*. It shows the path strength and stability according to the energy of each node. To calculate the PEC_x for packet *x* at node *d*, we use the following equation:

$$PEC_x(d) = \sum_{i \in RT_x} \frac{ET_x}{E(i)} + \sum_{i \in RR_x} \frac{ER_x}{E(i)} \qquad (2)$$

where ET_x is the energy transmission cost for packet *x* and ER_x is the energy cost for packet *x* reception. RT_x and RR_x are set of nodes used for transmission and reception respectively.

So, the problem is simplified to find a suitable priority for each packet during its transmission. This priority should consider packet deadline, packet size, packet energy path level and packet energy consumption during transmission. According to this priority, any packet buffered in a queue, could be sent or delayed. Therefore, the equation used for packet priority calculation in our scheme should reflect the effect of its related parameters. In order to apply the proposed schema, the maximum packet size and deadline values, used by the network, are required. These values are used to normalize the packet size and deadline. The following equation is used to calculate the packet sending priorities (PSP) for each packet x at each node d in:

$$PSP_x(d) = \frac{PSN_x \times \frac{PEC_x(d)}{N_x - 1}}{\frac{PEP_x(d)}{N_x} \times PDN_x} \cdot \alpha \qquad (3)$$

where α is a constant factor for insurance that the packet deadline would be met, N_x represents the number of nodes, which packet x used and *PSN* and *PDN* are the normalized values for packet size and deadline. According to *PSP* value, each node would decide whether to send the packet at once or delay it. This schema would help in increasing the network lifetime for the remote node of the networks. Packets from remote nodes would have increasing sending priorities through their path to the destination. We use *PEP* in order to overcome the problem of higher sending priorities for packets from remote nodes.

During the packet trip from its source to destination, it is buffered in every node queue across its path. Each node carries the responsibility of calculating the *PSP* for each packet in its buffer. In order to get the value of *PSP* for each packet, we modify the packet header by adding new header parameters to it. These parameters will be the values of *PEP*, *PEC* and the number of visited nodes without the current node. Using these parameters, each node will be able to calculate *PSP* for each packet in its queue. Before packet transmission, the node transmitting the packet must update the new added parameters in the packet header.

IV. Energy Based Scheduling Scheme for AODV

The Ad hoc On Demand Distance Vector (AODV) routing algorithm is a routing protocol designed for wireless mobile networks. It is selected as the baseline routing protocol because it is an on-demand protocol without global periodic routing advertisement. Besides, it consumes less overall network bandwidth as the network is silent until a connection is needed. It creates no extra traffic for communication along existing links [13].

A. Ad hoc On Demand Distance Vector (AODV) Routing Protocol

AODV was proposed by C. Perkins [14]. Being a reactive routing algorithm, AODV only maintains the routing paths which are used in packet transit. It is considered a destination based reactive protocol, which avoids routing loops by using of sequence numbers. In this protocol, the nodes use the sequence numbers to avoid loops and take the path information as updated as possible. When a source node wants to transmit information to a destination node, a short route request (RREQ) message will be initiated and broadcast by the source, with an estimated and pre-defined lifetime (TTL). RREQ is rebroadcast until the TTL reaches zero or a valid route is detected. Each node, receiving the RREQ will add a valid route entry in its routing table to reach the RREQ source, called reverse route formation. When the RREQ reaches the destination or a node that has a valid route to the destination, a route reply (RREP) message is uni-cast by this node to the source. The RREP message will go to the source, following the reverse route formed by the RREQ [15].

B. Schema Implementation for AODV

In order to apply our schema on AODV, the energy for each node in transmission path and the energy consumption during transmission should be assigned to packet, which used that path. For AODV, there are four types of packets, which are used for routing and path discovery. They are Route Request (*RREQ*), Route Reply (*RREP*), Route Error (*RERR*) and Route Reply Acknowledgment (*RREP-ACK*). According to [16], each packet has a number of unused bits, called reserved bits. The number of unused bits in each packet is shown in Table I. Our proposed schema works on making use of these unused bits to store the *PEP* and *PEC* for each packet, in order to use them in calculations. Figure 1 show how the proposed scheduling schema reacts with the different components of the WSN.

TABLE I
Amount Of Reserved Bits (Unused Bits)

AODV packet type	Number of unused bits
RREQ	11
RREP	9
RERR	15
RREP-ACK	8

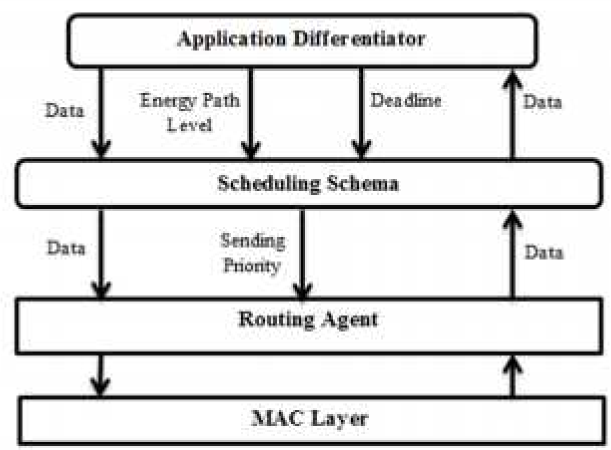

Fig. 1 Scheduling Schema in WSN architecture

V. Simulations

Simulation is used as a technique for performance evaluation of our proposed scheduling schema. Our schema was simulated using Network Simulator-2 (NS-2) version 2.29 [17]. In our simulation, the energy based scheduling schema is compared with the default scheduling schema in the NS-2. The comparisons will be according to performance evaluation metrics. They are *1) Average Network lifetime:* the amount of time network spends until most of its nodes are down. *2) Average Energy consumption for received packets:* the average energy consumption for correctly received packets. *3)*

Fairness Index: It is a measure used in network engineering in order to determine whether users or applications are receiving a fair share of system resources. Equation (4) is used to calculate the fairness index.

$$f(x) = \frac{\left[\sum_{i=1}^{n} x_i\right]^2}{n \sum_{i-1}^{n} x_i^2]} \quad (4)$$

where *n* represents the total number of sending nodes and x represent the goodput of every node.

Basic Priority Scheduling and the Energy Based Scheduling Schema will be according to these performance evaluation metrics. Table II shows our simulation parameters [18].

TABLE II
SIMULATION PARAMETERS

Simulation Parameters	values
Mac layer Protocol	IEEE 802.11
Transmission Radio	250 M
Data Packet Size	32 B
Traffic type	CBR (udp)
Data Rate	2 packets/sec
Simulation Area	1000 M X 1000 M
Number of Sensor nodes	100
Node Initial Energy	100 J
Transmission Power	0.024
Reception Power	0.0135

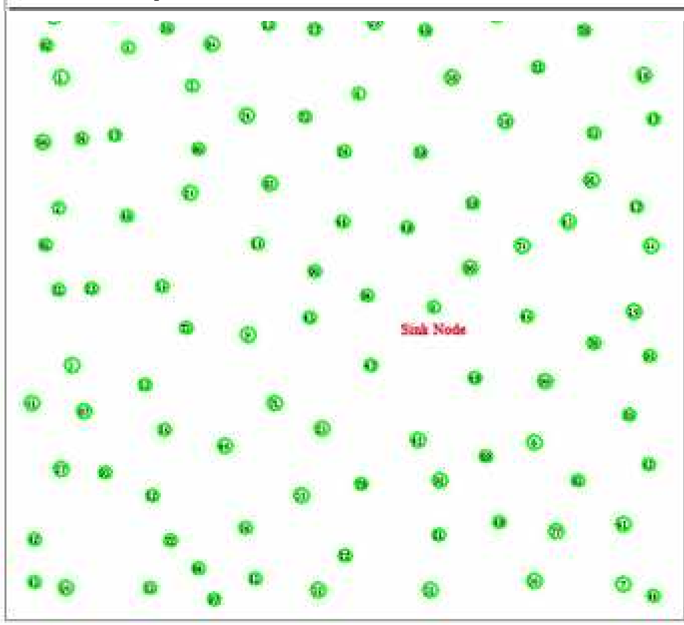

Fig. 2 The position of the sink node in the simulated WSN

A. Simulation Environment

NS-2 is used as the simulator, and all the simulations are based on 100 nodes randomly placed in a network of 1000 × 1000m2. Figure 2 shows the network structure used in our simulations. The sink node is placed roughly at the center of the network. In this paper, we compare our schema with the basic priority scheduling. In all simulations, we used the AODV as the routing protocol IEEE 802.11 as the Mac layer protocol. All nodes in the WSN have a queue size of 50.

B. Simulation Results

In order to find the efficiency of our schema, we compare it with the Basic Priority Scheduling. We find the effect of our schema on the WSN lifetime and packet delivery. The WSN lifetime has increased because our schema works on avoiding dropping packets with high energy usage. This means that, remote nodes from the sink will not have to retransmit the dropped packets. Because our schema avoids dropping packets with high energy consumption during transmission, network lifetime has increased. Figure 3 shows how our proposed schema extends the network lifetime. As packet size

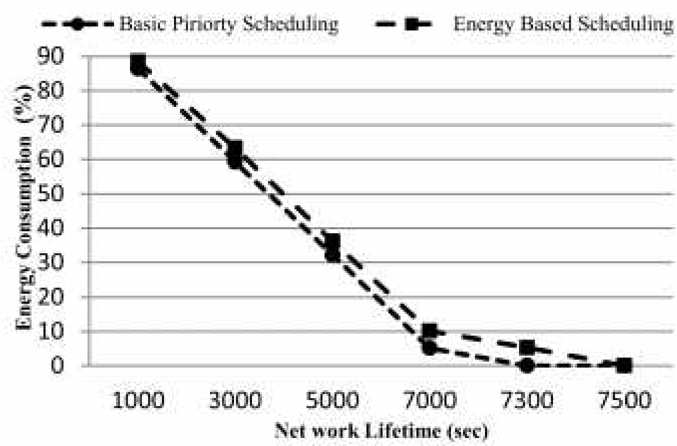

Fig. 3 Network average Energy Level across Network life time

affects the sending priority, dropping small packets which consumes low amount of energy, helps in saving network energy.

From figure 4, we find that the Energy Based Schema achieves a better packet delivery ratio value than the Basic Priority Scheduling. Through the WSN energy consumption, the Energy Based Schema makes an efficient usage of the batteries attached to each node in the WSN. It increases the packet delivery ratio by giving the packets, which consumes more energy, higher sending priorities. Packets whose energy transmission path level (*PEP*) is low, are prioritized with high sending priority. As shown in Figure 4, the Basic Priority Scheduling achieves better delivery ratio at network energy level of 60%. This happens, because of the greedy nature our schema. Sometimes, remote data packets might take the higher priority through its journey to the destination. This might affect data packets from sink closed nodes. The Energy Based Schema works on achieving better packet delivery ratio than the Basic Priority Scheduling. In the Energy Based Schema, both control and data packets have the treatment. They get their sending priorities according to the energy consumption of each one of them.

The greedy nature of the Energy Based Schema is considered a normal behavior. Most of the packets, which consume more energy in transmission, are remote source packets. This means, that remote data packets have a great chance to get high sending priority than the other packets. In order to know how this greedy nature affects the WSN, we measure the fairness of the Energy Based Schema and compare it to the fairness of the Basic Priority Scheduling.

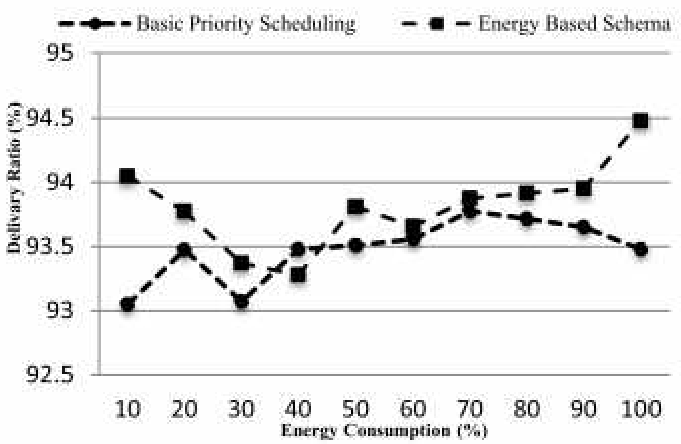

Fig. 4 Network Energy consumption vs. Packet Delivery Ratio

Figure 5, shows how the Basic Priority Scheduling overcomes our scheduling schema in the fairness. In the Basic Priority schema, packets are assigned sending priorities only according to their type. Assigning priorities to packets according to their types, helps in achieving better fairness among all the WSN nodes. Sending priorities assigned to packets from remote nodes are affected by the energy used to deliver the packets, the energy path level and packet size. Although, these parameters are considered in priority calculations for each packet, the fairness is affected. The fairness of the Energy Based Schema is affected because remote nodes have better chance to deliver their packets. Besides, there are no weights in calculating the sending priorities.

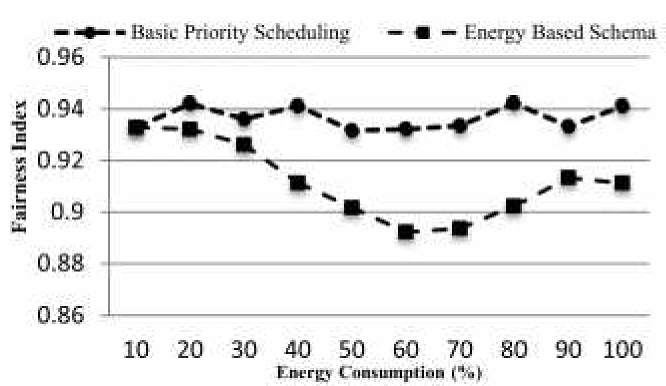

Fig. 5 Fairness Index

VI. Conclusion and Future Work

In this paper, a new scheduling schema, based on energy consumption, is introduced. In this schema, a set of parameters are used in calculating the send priority of each packet. According to the amount of consumed energy, each packet in the node's queue is assigned a sending priority. Besides, a new measuring parameter is introduced in order to calculate the packet energy path level (*PEP*). The new schema is compared with basic priority schema. We implemented our schema in NS-2, which is widely used open source software. AODV was integrated with the new schema. Based on the simulation, the Energy Based Scheduling Schema has extended the WSN lifetime. The new schema has achieved better packet delivery ratio. On the other hand, the fairness is affected slightly. In the future, we will integrate the proposed schema with the other routing protocols like Dynamic Source Routing or Destination-Sequenced Distance Vector routing. Further, we will investigate other related scheduling schemas and compare it with the proposed schema. Besides, an modifaction could be applied on the proposed schema in order to overcome the fairness problem.

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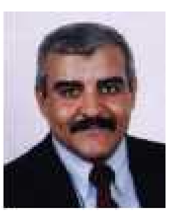

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