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A Fault Tolerant Sleep Schedule for Wireless Sensor Networks

Beenu Baby[1], Joe Mathew Jacob[2],

[1]M.Tech Student (CSE), Mahatma Gandhi University
Viswajyothi College of Engineering and Technology, Muvattupuzha, Kerala, India.
babytresa@gmail.com,

[2]Assistant Professor (CSE), Mahatma Gandhi University
Viswajyothi College of Engineering and Technology, Muvattupuzha, Kerala, India.
joemathewjacob@gmail.com

Abstract *– Energy efficiency is a major consideration in Wireless Sensor Networks, while designing the sensor nodes. The lifetime of sensor nodes are expected to be of long period without recharging their batteries. Delay efficient Sleep scheduling techniques are employed in wireless sensor networks, which may reduce the communication delay in large scale WSNs. Sometimes due to the failure of some of its nodes, the sensor network communication fails. Therefore, fault tolerance is one of the critical issues in WSNs. Here propose a fault tolerant sleep scheduling technique, which schedules the sleep and wake up in the network and also propose a fault tolerance in the corrupted nodes in the network. For the alarm transmission, propose two traffic paths called up link and down link. Schedule a specific wake up patterns for the sleep schedule technique. Fault tolerance mechanism adopts fault detection and fault recovery of the sensor nodes.*

Key Terms *– Wireless Sensor Network, Energy consumption, Sleep Schedule, Fault tolerance.*

1. INTRODUCTION

Wireless sensor Network is a self-organized network which consists of a large number of low-cost and low powered sensor devices, called sensor nodes [1]. This can be deployed in the air, in vehicles, on the ground, on bodies, under water, and inside buildings. Each sensor node in the network is equipped with a sensing unit, which is used to capture the critical event, and a wireless transceiver, which is used to transform the captured events back to the base. In the recent years wireless sensor networks have received significant attention due to their potential applications. WSN have a number of unique characteristics such as small-scale sensor nodes, energy harvesting, dynamic network topology, limited power supply, node failures, mobility of nodes, mobility of detected events, large scale deployments etc. Figure 1 shows the basic diagram of wireless sensor networks.

Energy is a very scarce resource for sensor systems and has to be managed wisely in order to extend the life of the sensor nodes for the duration of a particular application. We identified the following major sources of energy wastage [1]. The first one is collision. When a receiver node receives more than one packet at the same time, these packets are called "collided packets" even when they coincide partially. When a transmitted packet is corrupted it has to be discarded, and the follow on re-transmission increase energy consumption. So latency will increase. Although some packets could be recovered by a capture effect, a number of requirements have to be achieved for its success. The second is overhearing, meaning that a node picks up packets that are intended for send to other nodes. Third source is control packet overhead. Sending and receiving control packets consumes energy too, and less useful data packets can be transmitted. So minimal number of control packets should be used to make a data transmission. The last major sources of inefficiency are idle listening. If nothing is sensed, nodes are in idle mode for most of the time. Maximizing the lifetime of sensor is one of the most challenging and complex problem in the WSN. Sleep scheduling should increase the network life time. In sleep scheduling method [2], sender nodes should wait until receiver

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nodes are active and ready to receive the message scheduling method [2], sender nodes should wait until receiver nodes are active and ready to receive the messages.

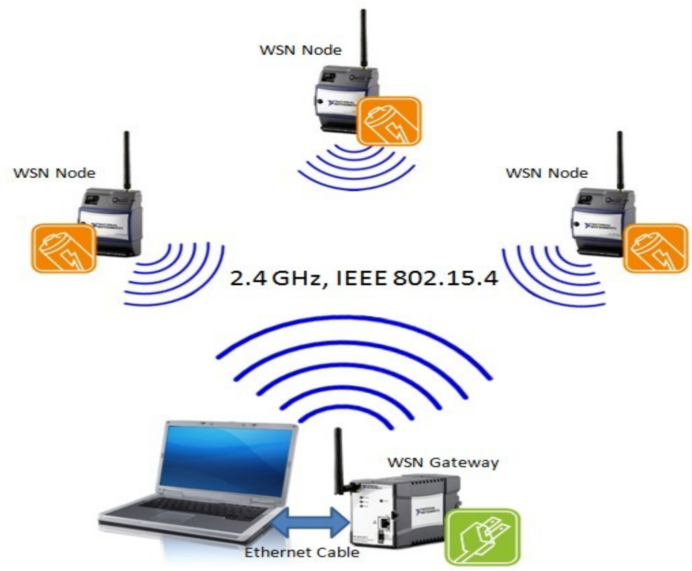

Figure1: Wireless Sensor Network

But sometimes it may increase broadcasting delay. Whenever the network scale increases, the broadcasting delays also increase. So, delay efficient sleep scheduling methods needs to be designed to provide low broadcasting delay from any node in the WSN. Most of sleep scheduling methods in WSN focuses to minimize the energy consumption in the networks. To minimize the broadcasting delay in WSN, the time wasted for waiting during the broadcasting needs to be minimized. So there is a need for balance both energy consumption [3] and broadcasting delay in wireless sensor network.

2. TYPES OF FAULT IN NETWORKS

The main task of WSN is to collect data at the deployment area of the environment. Data collection task is to deliver the collected data to the sink node efficiently and reliably. If some node or link fails then the data send by the sensors will be lost which is shown in [4] [5]. So, a communication link fault on a sensor requires the reallocation to other nodes within communication range.

A. Node Failure

When a sensor network deployed in a harsh and dangerous environments such as gas leak monitoring, forest fire monitoring, this scenario is mostly true. This type of failure is expected to be quite common in WSN, due to their limited energy budget and environmental degradation. When a number of sensor nodes fail, the resulting network topology may be disconnected. So the nodes which have not failed become disconnected from the network.

B. Network Fault

Network fault is also known as link fault. Faults at the wireless communication links may cause network fault. Faults at the routing layer can lead to dropped messages, or delays at that layer. If there is no error on hardware, then link faults in WSNs are usually related to surrounding environments.

3. FAULT TOLERENT SLEEP SCHEDULE

Delay efficient sleep scheduling [6] is a novel sleep scheduling technique which is based on the level-by-level offset schedule [7], to achieve low broadcasting delay in WSN. When an alarm message may be originated by any possible node, set two phases for the alarm broadcasting in this sleep scheduling method. When a node detects an unwanted event, an alarm message originates by the corresponding node and quickly transmits it to a center node along a predetermined path with a level-by-level offset way. Then the center node broadcasts the alarm message to the other nodes along another path. A special wake up pattern is designed for the two possible traffics in the network. In WSNs, the failure of nodes is almost unavoidable. We conducted an investigation on frequent faults that occur in WSN deployments.

We know that any alarm could be originated at sensor node which detects a critical event in the WSN. To reduce the broadcasting delay compared with previous techniques, the fault tolerance sleep scheduling method includes three phases: 1) a node which detects a critical event, that sends an alarm packet to the center node along a predetermined path; 2)after receiving, the center node broadcasts the alarm packet to the entire network; 3) to achieve fault tolerance in the networks: we include two considerations ,1) failure detection; 2) failure recovery.

A. Traffic Paths

Fault tolerant sleep scheduling method defines two traffic paths. One path for uplink and other path for downlink traffic.

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Uplinks are predetermined traffic path for sending an alarm packet to the center node from the event detection node. Downlinks are the path for broadcast alarm from center node to the entire network according to level-by-level offset schedule. Each node needs to wake up properly for both of the two traffics. To minimize the broadcasting delay establish a breadth first search (BFS) tree for the uplink traffic and a colored connected dominant set for the downlink traffic, respectively. Uplink traffic construction, divides all nodes into layers H_1, H_2, H_3,…, H_D where H_i is the node set with minimum hop i to center in the WSN. To establish the downlink traffic path, establish the Colored Connected Dominated Set with three steps: 1) construct a maximum independent set (MIS) ; 2) select connector nodes to form a connected dominated set (CDS), 3) color the CDS to be CCDS with no more than 12 channels.

B. Wake Up pattern

After all nodes get the traffic paths, a wake-up pattern is needed for sensor nodes to wake-up and receive alarm packet to achieve the minimum delay for both of the two traffic paths. Here different slots are used for different hopes. All nodes in H obtain slots for uplink traffic according to their hops in H and the sequence number of duty cycles and nodes in H' obtain slots for downlink traffic according to their hops in H' and the sequence number of duty cycle. For example, a sensor node nj in H_1 obtains slot L - 1 in odd duty cycles for uplink traffic and node, nj may also be in H'_2, and it obtains slot 2 in even duty cycles for downlink traffic. So in this scheme the alarm can be quickly forwarded to center node in uplink path and center node could immediately begin to broadcast the alarm with downlink path, the broadcasting delay is much lower. Similarly the energy consumption of nodes is also very low, because most nodes stay awake for only one time slot in each duty cycle.

C. Fault Tolerance

A Wireless Sensor Network is a set of multiple connected components. Low-cost sensor nodes distributed over a large area with one or possibly more powerful sink nodes gathering readings of sensor nodes. The sensor nodes are integrated with sensing, processing and wireless communication capabilities. Sometimes due to the failure of some of its nodes, the sensor network communication fails. Fault tolerance [8] is the ability of a system to deliver a desired level of functionality in the presence of faults. Since the sensor nodes are prone to failure, fault tolerance should be seriously considered in many sensor network applications. If a node or link will be fail then this system find out other resourceful nodes to maintain operations after failures. Figure 2 shows fault in the network.

Normally, each node sends its alarm to next hope nodes during the time slots scheduled by sink node. When a node cannot receive the expected acknowledgement from the corresponding nodes, it changes its destination to next neighbor nodes. If nodes that detect the occurrence and approximate locations of the fault then alert the source node or the base station.

To tackle faults in a WSN, the system should follow two main steps. The first step is fault detection. It is to detect that a specific functionality is faulty, and to predict it will continue to function properly in the near future. After the system detects a fault, fault recovery is the second step to enable the system to recover from the faults.

1. Fault Detection

When a node detects an event from its coverage region, it generates an alarm packet and sends its alarm to the base station. After receiving the alarm at base station, it broadcast to all other sensor nodes. During this transmission using up link and down link traffic, the system will check whether there is any fault occur in the network. If the near-by node receive no acknowledgement from a particular node then base station assume that there is a fault in the traffic path. After detecting fault in a particular node/link then, base station terminate that node from the traffic.

Steps:

1) Normally, each node sends its data to its parent during the time slots scheduled by the sink node

2) When a node cannot receive the expected ACK from its parent, it triggers the sink node. Then find out a new path for the data transmission.

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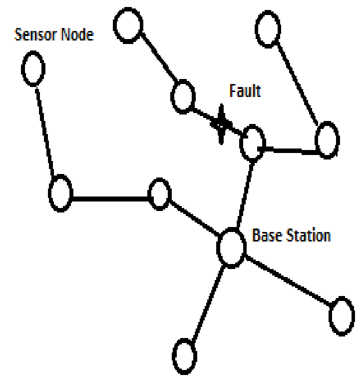

Figure 2: Network Fault in the network

2. Fault Recovery

After detecting a fault from the network, then the base station going to find out a new node for the transmission of packets through the network. So neighbor nodes can be found out with the help of dijkstras algorithm. Using the new neighbor nodes the alarm transmission will continue. The algorithm works by keeping the shortest distance of vertex v from the source in an array. The shortest distance of the source to itself is zero. For all other vertices is set to infinity to indicate that those vertices are not yet processed. After the algorithm finishes the processing of the vertices will have the shortest distance of vertex w to s.

During the implementation process, this algorithm takes the node location and distances from each node for the calculation of shortest path. If a node is fail for the transmission then using these values, for the calculation of shortest distance in the traffic. After calculating a new shorter distance from the sender node, then it is included in the traffic. Using this new traffic the alarm propagation will continue.

4. RESULT ANALYSIS

The transmission time due to any node failure in the traffic in the basic sleep scheduling gives infinite values. Because of the transmission of packet from sender node to the receiver node does not reach at the destination. ie; the traffic cut in to two. But in the case of proposed method the transmission time is very near to the basic sleep scheduling method which does not have fault node. Fault tolerance evaluates how reliably each sensor node can route messages in permanent faults. Permanent faults indicate nodes that are unable to send any packets. For the result analysis, conduct five experiments and record the time for transmission in each one. Following table shows the values of time in milliseconds.

Table 1 gives the time for transmission in the case basic sleep scheduling without fault tolerance and sleep scheduling with fault tolerance. Field node specifies the corresponding node id in which the event was detected. Transmission time field gives the value of time for alarm transmission from detecting node to last hope nodes which receive broadcast messages. Transmission time with fault shows the value of time for transmission, if there is a node fault in the traffic path. Here the values are infinite because the traffic was cut in to two due to the fault. But value of transmission time in fault tolerance shows that time was reduced from infinity to a specific value. Figure 3 shows the transmission time analysis graph. Using the above table values graph generate three series in each category.

Exp No	Node ID	Transmission Time with Fault(ms)	Transmission Time with Fault Tolerance(ms)
1	Hp5	∞	120
2	Hp9	∞	125
3	Hp11	∞	140
4	Hp14	∞	149
5	Hp16	∞	160

Table 1: Transmission time for fault tolerant sleep scheduling

Each series shows transmission time in sleep schedule without fault tolerance, sleep schedule with fault, fault tolerant sleep schedule respectively

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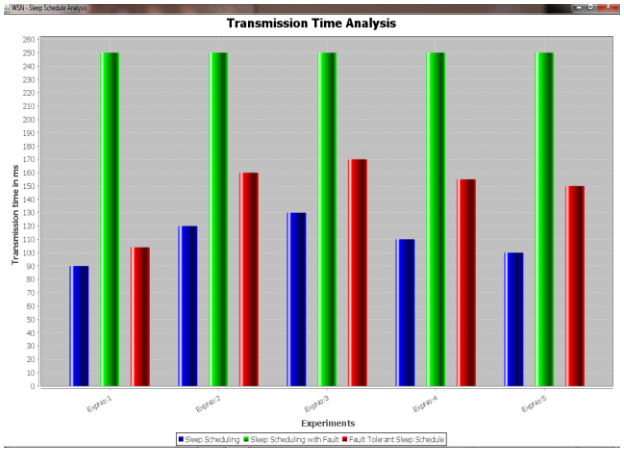

Figure 3: Transmission Time Analysis

5. CONCLUSION

A fault-tolerant sleep scheduling technique reduces the energy consumption, transmission delay as well as node fault/ link fault in the network. Here a new sleep and wake up patterns are used for reducing the energy consumption in the network for each node. Each node sleeps in particular time and wake up in allotted time slots. This will reduce the energy consumption of each node in the network. Two determined traffic paths are designed for the transmission of alarm message, and level-by-level offset based wake-up pattern according to the paths, respectively. When a critical event occurs, an alarm is quickly transmitted along one of the traffic paths to a center node, and then it is immediately broadcast by the center node along another path without collision. Therefore, two of the big advantages are that the broadcasting delay is independent of the density of nodes and its energy consumption is ultra low Fault in the network is handled by using fault detection and recovery schemes. So the network identifies all the node fault in the network during the transmission time. It was done with the help of checking acknowledgement sending by the nodes in the network. If it doesn't receive the system identify a fault. After the detection of fault in the network, then it is reduced by the fault recovery mechanism. For this purpose it uses dijkstras algorithm for find out the shortest path in the network.

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