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Performance Evaluation of Random Node Shutdown Technique in Wireless Sensor Network for Improving Energy Efficiency

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ABSTRACT

Rapid advances in wireless communication technology recently have led to the development of sensor nodes to form wireless sensor network (WSN). However, these nodes have limited battery power and due to the nature of this technology which enables communication between nodes which can be deployed anywhere including hard-accessed area, thus it is not feasible to recharge or replace the batteries. Therefore power consumption of each sensor node should be minimized so that overall network lifetime will be increased. In order to minimize power consumption, some nodes which can be considered redundant, can be put to shutdown mode. In this paper, a shutdown technique is being proposed. The technique is Random Node Shutdown. In this technique, nodes are randomly shutdown according to the criteria and conditions defined. This technique is examined and simulated using the NS2 simulation environment to find the best scenario for the proposed algorithm.

Keywords

Wireless Sensor Network, energy efficiency, power cycle, node shutdown

1. INTRODUCTION

Recent advances in the micro-sensor and semiconductor technology have led to the development of low-cost, low power, multifunctional sensor nodes [1,2,3].The electronic miniaturization and the advances in the semiconductor manufacturing process are the enabling factor for low-power and low-cost hardware. Small and smart devices equipped with a processing unit, storage capacity, and small radios provide new application opportunities. Augmented with different kind of sensors, e.g., for temperature, pressure, and humidity measurements, noise and movement detection, or lighting conditions, physical phenomena can be observed by deploying such sensor devices close to them [4].

Deployment of these sensor nodes offers wide range applications. Among the applications of WSN include habitat and environment monitoring, disaster control and operation, military and intelligence application, object tracking, video surveillance, traffic control, industrial surveillance and automation, as well as health care and home automation. Thus in the future, environment sensing will become more and more universal and be part of our life.

The emerging field of wireless sensor networks (WSN) combines sensing, computation, and communication into a single tiny device. The power of wireless sensor networks lies in the ability to deploy large numbers of tiny nodes that assemble and configure themselves [5]. The most straightforward application of wireless sensor network technology is to monitor remote environments for any abnormality in the data trends. For example, a national forest could be easily monitored for fire by placing hundreds of sensors that automatically form a wireless interconnection network and immediately report the detection of any fire occurrence at any part of the forest.

2. PROBLEM STATEMENT

Sensor networks are composed of a large number of sensing devices, which are equipped with limited computing and radio communication capabilities. They operate in various kinds of fields, performing tasks such as environmental monitoring and surveillance. Although sensors may be mobile, they can be considered to be stationary after deployment. A typical network configuration consists of sensors working unattended and transmitting their observation values to some processing or control center, the so-called sink node, which serves as a user interface. Due to the limited transmission range, sensors that are far away from the sink deliver their data through multihop communications, i.e., using intermediate nodes as relays. In this case a sensor may be both a data source and a data router. Most application scenarios for sensor networks involve battery-powered nodes with limited energy resources. Recharging or replacing the sensors battery may be inconvenient, or even impossible in harsh working environments. Thus, when a node exhausts its energy, it cannot help but ceases sensing and routing data, possibly degrading the coverage and connectivity level of the entire network. Thus, optimization of energy resources is mandatory in sensor networks [6,7]. The well known problem in WSN is 2 he Hot Spot issue. In a deployed sensor network, when the transmission range is fixed for nodes throughout the network, the amount of traffic that sensors are required to forward increases dramatically as the distance to the data sink becomes smaller. Thus, sensors closest to the data sink tend to die early. However, early retirement of the sensor nodes which are located closest to the sink node will also means that network connectivity is also affected and causing data unsuccessfully delivered to the destination.

3. METHODOLOGY

In this work, the proposed Random Node Shutdown algorithm is simulated using NS2 [8]. The algorithm is being executed with 0% (no shutdown), 10%, 20%, 30% and 40% nodes being shutdown at one particular time. Once the simulation for the entire shutdown criteria is done, the result obtained from each of the criteria is compared against each other to evaluate the performance for each of the criteria.The performance metrics where each shutdown percentage will be compared against are node energy level, throughput, and network connectivity. The best criteria which meet all the performance metrics will be chosen as the proposed criteria for Random Node Shutdown algorithm

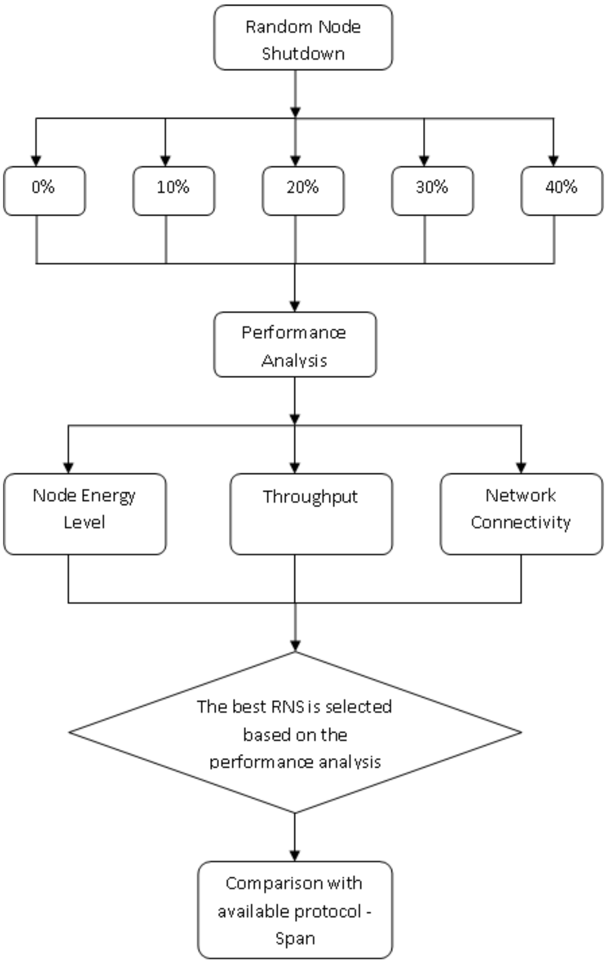

Figure 1 : Methodology of Random Node Shutdown algorithm

4. SIMULATION RESULT & DISCUSSION

For this project, Network Simulator 2 with NRLSensorSim (extended version of NS2 to support wireless sensor network) was used for the simulation, in particular NS2 version 2.27. NRLSensorSim modeled the presence of phenomena in NS2 with broadcast packets transmitted through a designated channel. The node that received the packet will route the packets to the Base Station according to the specified routing protocol [9,10,11]. In this case, AODV protocol (Ad hoc on demand distance vector) is used, as this routing protocol is readily available in NS2 code structure [12]. The topology defined in the simulation is 7x7 sensor nodes with 1 node act as sink node/base station in the middle of the topology layout. The Random Node Shutdown experiment is done by simply performing “shutdown” and “on” command that is available in NS2. of the topology layout. The Random Node Shutdown experiment is done by simply performing “shutdown” and “on” command that is available in NS2

Table 1 : Parameter settings for Random Node Shutdown experiments

Number of sensor node	48
Number of sink node	1
Topology	1001m x 1001m
Radio-propagation model	Propagation/TwoRayGround
Antenna model	Antenna/OmniAntenna
Packet size	50
Routing protocol	AODV
Transmitting power in mW	0.175
Receiving power in mW	0.175
Sensing power in mW	0.00000175;
Idle power in mW	0
Initial energy in Joules	0.5
Phenomenon	Carbon Monoxide (CO)
Phenom pulse rate	2 seconds
Simulation time	60 seconds

4.1 Performance Analysis of Random Node Shutdown

4.1.1 Node Energy Level

Node energy level is analyzed by monitoring the Network Animator (NAM) output after completion of the simulation. In the NS2 code, the node will turn to yellow or red colour if the node energy falls below certain threshold. In the experiment, the initial node energy is set to 0.5 Joule. If the node energy level falls below 20% (<20%) or in other word 0.1 Joule, the node colour will turn into red. This indicates that the node energy is in critical level. Meanwhile, if the node energy level falls between 20% and 50% (20%<x<50%) or 0.25 Joule, the node will turn into yellow colour (low energy level). The Base Station is located in the middle of the layout and is green in colour.

Table 2 : Summary of node energy level with RNS

% of Random Node Shutdown	Number of nodes	
	Energy 20%-50%	Energy < 20%
0%	19	3
10%	15	1
20%	9	0
30%	7	0
40%	0	0

Table 2 summarized the result obtained for node energy level with different percentage of Random Node Shutdown applied. From the table above, at 0% Random Node Shutdown (no shutdown), 19 nodes have energy dropped to low energy level (between 20% and 50%) and 3 nodes dropped to critical energy level (<20%). At 10% Random Node Shutdown, only 15 nodes have low energy level and 1 node dropped critical level. The situation improved with higher percentage of nodes being shutdown. From the above experiments, it is shown that energy levels of the sensor nodes are better when Random Node Shutdown is applied.

Apart from that, the average energy level for overall sensor nodes is also analyzed in term of its energy efficiency. This is to assess the energy efficiency of the whole network with regard of the Random Node Shutdown criteria applied. From the figure shown below, it is also concluded that the energy efficiency of the whole network is getting better as more Random Node Shutdown is applied, which means that when more nodes are being shutdown at one particular time, the better the energy efficiency of the network becomes. However, although energy efficiency is higher when more nodes are being shutdown, there is certain limit for performing node shutdown as too many nodes being shutdown will cause unsuccessful delivery of data.

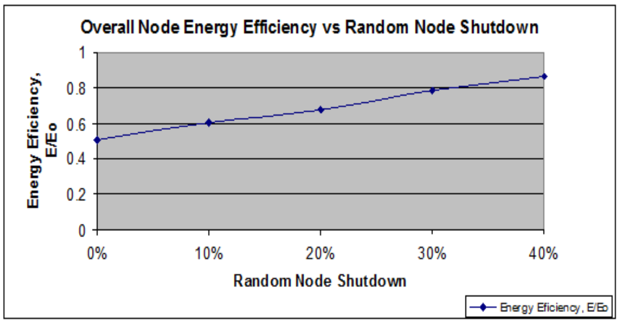

Figure 1: Average of overall node energy efficiency for each of the Random Node Shutdown criteria.

4.1.2 Throughput Efficiency

Throughput efficiency is analyzed by calculating the number of packets received divided by the number of packet sent during the whole simulation time. This information is obtained from the trace file which is available after the simulation has finished. The higher the throughput efficiency, the better the performance of the network. Table 3 summarizes the number of packets sent and received throughout the simulation time.

Table 3 : Summary of number of packets sent and received during the simulation time

% of Random Node Shutdown	No Of Packet Sent	No Of Packet Received	Efficiency
0%	248	243	97.98%
10%	240	233	97.08%
20%	228	226	99.12%
30%	188	164	87.23%
40%	172	136	79.07%

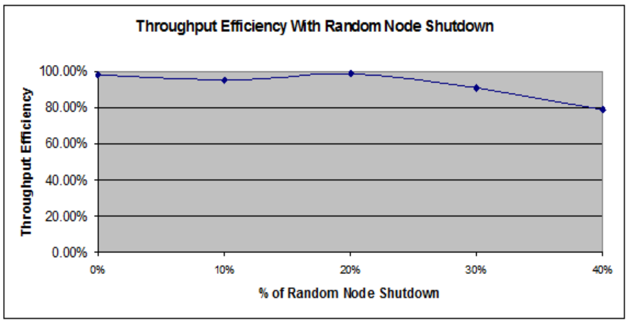

Figure 2 : Throughput efficiency vs % of Random Node Shutdown

From the above table and figure, it is shown that with 20% Random Node Shutdown, the throughput efficiency \\\

is the best when compared to other Random Node Shutdown percentage. At 0%and 10% Random Node Shutdown, the throughput efficiency is slightly lower than at 20% Random Node Shutdown. Because of none or very few nodes being shutdown, too many redundant data being generated and this will cause data collision which will then reduced the throughput efficiency. As for 30% and 40% Random Node Shutdown, as too many nodes are being shutdown at a particular time, it is difficult to route the data to the destination thus decreasing the throughput efficiency. Thus the 20% Random Node Shutdown is the most ideal criteria in term of throughput efficiency.

4.1.3 Network Connectivity

Network connectivity is another important criterion in assessing the network performance. Network connectivity is measured by successful packet sent and received during every data transmission. In the simulation, in every 2s, the sensor node will detect the Carbon Monoxide occurrence and the data will be sent to the Base Station. Thus, data transmission interval in this case is assumed to take place in every 2s. If no packet is sent or received during any data transmission, it is assumed that the network connectivity is loss.

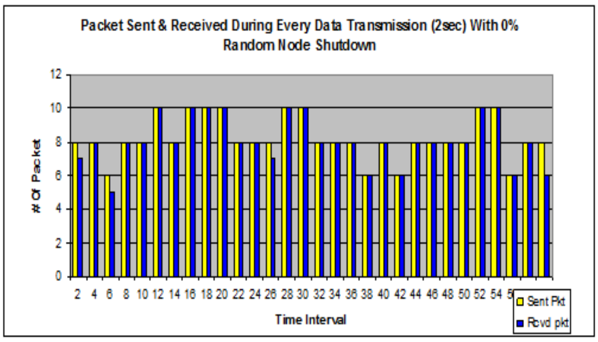

Figure 3 : Network connectivity with 0% RN S

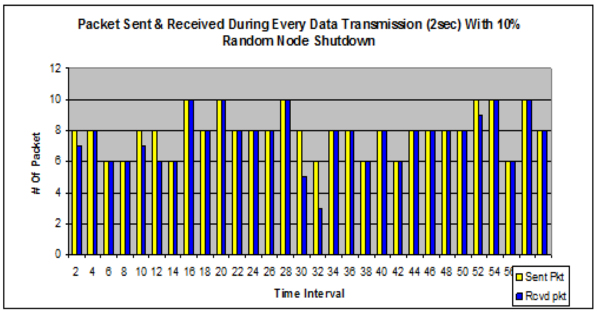

Figure 4 : Network connectivity with 10% RNS

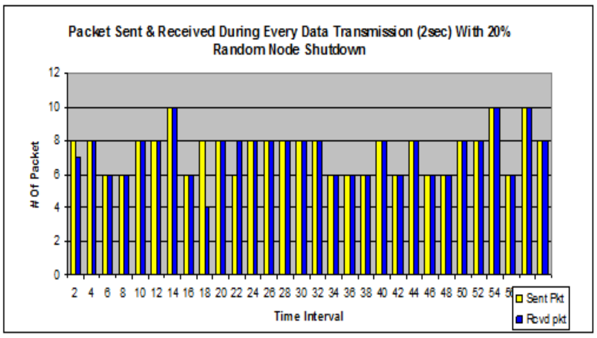

Figure 5 : Network connectivity with 20% RNS

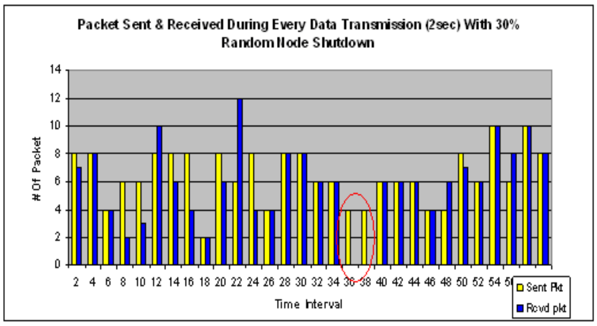

Figure 6 : Network connectivity with 30% RNS

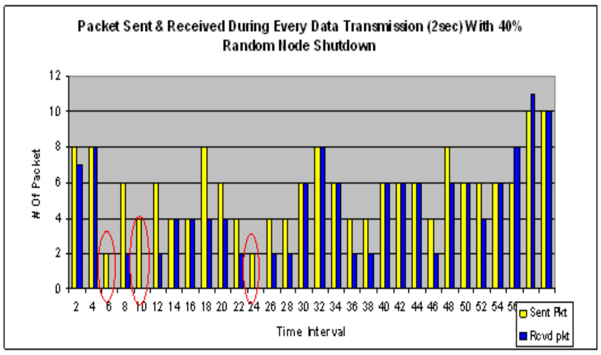

Figure 7 : Network connectivity with 40% RNS

From the above figures, it is found that with 0%, 10% and 20% Random Node Shutdown, the network connectivity is available during every data transmission. However, with 30% and 40% Random Node Shutdown, the network connectivity is lost at some particular data transmission times. With 30% Random Node Shutdown, network connectivity is lost at 36s and 38s during packet receiving. From the simulation, it is found that the network connectivity is lost during this period of time mostly due to MAC retry count exceeded and packet callback. Meanwhile, with 40% Random Node Shutdown, network connectivity is lost at 6s, 10s and 24s during packet receiving. From the simulation, it is found that the network connectivity is lost during this period of time mostly due to no route available for data transmission. This scenario is expected as more nodes being shutdown, the higher the chances of losing the network connectivity as it will be more difficult to route the data through the relay nodes to the Base Station.

It is very critical to choose the best Random Node Shutdown criteria which can save energy level of the nodes and at the same time manage to maintain or improve the throughput efficiency as well as the network connectivity. From the simulation result obtained, it is proven that Random Node Shutdown mechanism is able to improve the energy level of sensor nodes. However, other criteria such as throughput efficiency and network connectivity need to be studied to ensure a good performance of the WSN. Based on the results from all the 3 performance metrics, ie, energy level, throughput efficiency and network connectivity, it is concluded that 20% Random Node Shutdown is the best scenario that satisfies all the above mentioned metrics.

5. CONCLUSION

Efficient power consumption is a challenging problem in a battery-powered wireless sensor networks. The fact that each node has a limited battery power and also impossible or infeasible to recharge the batteries, thus reducing power consumption is the key to increase the network lifetime. The network lifetime is directly proportional to the efficient power consumption, thus dysfunctional of any node causes serious damage to the network service considering nodes' dual role of data originator and data router.

To address the issue mentioned above, a technique which is called Random Node Shutdown has been proposed in this work. The technique was simulated in 5 different scenarios. They are Random Node Shutdown at 0% (without Random Node Shutdown), 10%, 20%, 30% and 40%. Based on the simulation results obtained, the best performance of the network can be achieved by performing Random Node Shutdown at 20%. The overall node energy efficiency increased to almost 70% as compared to the network without Random Node Shutdown (0%) which is at 50%. Apart from that, the throughput efficiency is also increased to 99% while without Random Node Shutdown, the throughput efficiency is at 98%. Another main criterion that is considered in this research is the network connectivity of the system. From the experiment performed, Random Node Shutdown at 20% manages to maintain the network connectivity and thus ensure that data delivery is successful in every data transmission.

6. FUTURE WORK

1. We can use more efficient routing mechanism instead of broadcasting using AODV protocol.

2. Investigate the performance of the algorithm with existing algorithm which is being used nowadays.

3. Perform data aggregation technique for further improvement on energy efficiency.

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