AN APPROACH TO MAXIMIZE THE PERFORMANCE OF WIRELESS SENSOR NETWORK FOR SAMPLING TIME LESS THAN THE OPTIMUM VALUE

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ABSTRACT: Sampling time of the sensor node is defined as the time interval between successive sampling of the physical phenomenon of interest. In high speed sensor applications like sensors used in oceanography, high speed robots for obstacles detection, and gas detectors etc., the sampling times are usually low, lying in the range of 0.1 seconds to 0.2 seconds. In such cases the battery is stressed more which result in its premature exhaustion. This is due to pronounced Recovery effect of the battery at lower sampling interval. It would result in increased investment in terms of battery. And if such sensors are used in impenetrable terrains where the chances of replacing the exhausted battery are very less, the sensor nodes have to be abandoned as their batteries get drained out sooner and hence lifetime extension of battery becomes imperative. An innovative technique is presented in this paper with which the sensor node performance can reach to the levels nearer to optimum sampling time. Experimental results have shown lifetime improvement of the battery by 17.42%. At the same time Quality of Service (QoS) has also improved by 34.84%.

KEYWORDS: Battery, Lifetime, Quality of service, Sampling time, Sensor node

INTRODUCTION

There is no field of human interest which is untouched by sensors. The applications of wireless sensor networks (WSN) where the human intervention is difficult and sometimes impossible are energized by non-rechargeable battery. Therefore, it is important to discharge the battery in an intelligent manner so that it results in increased discharging efficiency of the battery along with its increased lifetime. Satyanarayana Chanagala and Zafar J.Khan, in their work have demonstrated experimentally that the lifetime of battery can be extended with optimum sampling time. Also it has been shown that, fairly good QoS was achieved with optimum sampling time. However, it may not be possible to always operate the sensor node at optimum sampling time. For the sampling time as low as 0.1 or 0.2 seconds which is far less than the 0.62 seconds, which is the optimum sampling interval obtained by the authors, therefore the stress on the battery will be more and it leads to quick drain out of the battery due to pronounced Recovery effect of the battery. Hence there is a need to mitigate this problem of premature exhaustion of battery at lower sampling time. This paper presents an innovative approach to extend the life time of the battery when the sampling time of the sensor node is 0.2 seconds, which is lower than the optimum value of 0.62 seconds obtained by the authors.

EXISTING METHODOLOGIES FOR EXTENDING LIFETIME OF WSN

Abu Bakr B and Leszek T.Lilien have achieved significant extensions of WSN lifetime by adding spare nodes with Low-Energy Adaptive Clustering Hierarchy (LEACH) spare management protocol.
Basagni S. et al have prolonged the lifetime of the wireless sensor network by the controlled sink movements.
Caredei M. and Du D. have carried out research on enhancing the lifetime of WSNs with time scheduling of the sensor nodes. This has resulted in network operating time which is equal to lifetime of the individual sensor node multiplied by the number of sets.

Hassan Marwa M. et al researched to find the best sink location that maximize the reliability of the path for each sensor, sink pair.
Hua C. and Peter Yun T.S. succeeded in prolonging the lifetime using data aggregation coupled with optimal routing.
Lin Kai et al in their work have mitigated the problem of decrease in the lifetime of the WSN due to unbalanced distribution of the data among the sensor nodes.
Long H. et al have mitigated the premature failure of the network with a novel battery allocation formulation.
Luo Dijun et al have designed a mathematical model to find a shortest path tree with long lifetime.
Satyanarayana Chanagala and Zafar J.Khan have demonstrated that by optimizing the sampling time of the sensing nodes a lifetime improvement of 18% can be achieved.
Shan Feng et al have constructed a routing tree such that the network lifetime is maximized while keeping the routing path between each sensor and the base station minimized.
Sushil K.Prasad and Akshaya Dhawan have designed a set of distributed algorithms with which a life time improvement of 10% to 20% has been expected.
Kai Lin et al in their work have mitigated the problem of decrease in the lifetime of the WSN due to unbalanced distribution of the data among the sensor nodes.
Yu Yang et al have demonstrated energy minimization with Rate adaptation technique.

LIMITATIONS OF THE ABOVE METHODS

Satyanarayana Chanagala and Zafar J.Khan have adopted a different approach to enhance the lifetime of the sensor node. They have demonstrated that discharging efficiency of the battery used in the sensor node and hence its lifetime can be enhanced by exploiting the Recovery effect of the battery. Through the experiment the idle time duration for which the battery overcomes the recovery effects is found to be 0.62 seconds. Furthermore, when the sensor sampling time is made equal to the idle time of the battery which is defined as optimum sampling time, a significant lifetime improvement is observed.
However, it is not always mandatory that the sampling time must be always being equal to the optimum value. However in certain applications the physical parameters to be sensed might need sampling time much lower than 0.62 seconds. For instance the sampling time required in gas detectors is 0.2 seconds. From the results shown in the figure 3, figure 4, and figure 5 it is evident that the performance in terms of power consumption, QoS and lifetime of the sensor node is poor at 0.2 seconds.

PROPOSED APPROACH

In this approach, five nodes are used out of which four nodes are configured as slave nodes or sensing nodes and one node is configured as receiving node or sink node. The arrangement of the nodes is given in the figure 1. Assuming the reference time at which the first sensing node transmits the data as 0 seconds, the first sensing node transmits the data and get into sleep mode. After 0.2 seconds, the second sensing node transmits the data and get into the sleep mode. Again after 0.2 seconds, the third sensing node transmits the data and get into sleep mode. And finally after 0.2 seconds, the fourth sensing node transmits the data and get into sleep mode. Thus the sampling time of 0.2 seconds is met. Now after completion of first pass, again the first node transmits the data and get into sleep mode and after 0.2 seconds the second sensing node transmits and the process repeats till the batteries of the sensing nodes are exhausted.
In the above process it can be observed that in the second pass when the first node transmits the data, it has already rested for 0.60 seconds. Similarly, before the second node transmits after 0.2 seconds, it has got an idle time of 0.60 seconds. Thus every sensing node gets an idle time of 0.60 seconds. Therefore the respective batteries of all the sensing nodes rest for 0.60 seconds. Moreover this is close to the optimum sampling time of 0.62 seconds, which can be called as near optimum sampling time. As a consequence battery in each node gets an idling time close to optimum sampling time during which it overcomes the Recovery effect to a greater extent. For this reason the stress on the battery is removed substantially even though sampling time is 0.2 seconds.

EXPERIMENTAL SETUP

Sensor node is designed and fabricated with three sensors viz., temperature sensor, accelerometer and light sensor. These sensors are interfaced to the microcontroller. Further the sensed signals of sensors are conditioned by LM324. The microcontroller used in the present work is PIC18F252 made by Microchip. It is a 28 pin controller. Further, it is equipped with enhanced flash memory and a 10 bit analog to digital converter. Sensed physical quantity by the sensors, which is in the analog form, is converted into digital by the microcontroller. In the present work, the resolution of analog information is set to 4.88mV. USART of the microcontroller is set at 9600 baud rate while transmitting the data to the receiver node or sink node. Timer ‘1’ of the microcontroller is used for measuring the sampling time. A 20MHz crystal oscillator is used for the microcontroller. Sink node or receiving node acts as the master node, with which the sampling

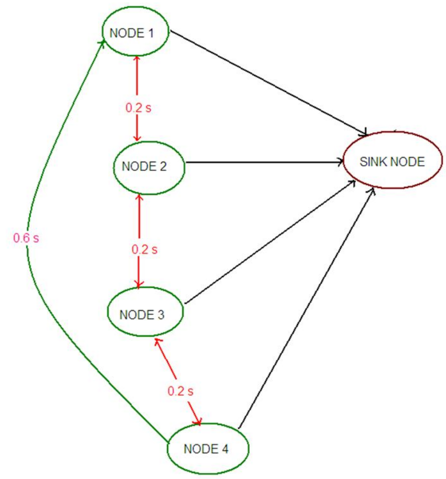

Figure 1. Configuration of nodes to achieve near optimal performance

time of the slave node or sensor node is controlled. Each sensed physical quantity is converted into two byte digital data. Since there are three sensors, there will be six bytes of the sensed information. Along with these, two data bytes are used for providing the information regarding the power consumed by the microcontroller and the sensors followed by one byte for start bit and another for stop bit. Thus, total numbers of ten bytes are transmitted nine times during each sampling interval to make the communication between sensor or slave node and the master node or receiver node to improve the quality of service. Further, an additional nine bytes are used to provide the guard band. In total ninety nine bytes are transmitted by the sensor or slave node to the receiver node or the sink node.

Three lithium-ion batteries with specifications of 2200mAh, 3.7V each are used to energize the sensor node. Microcontroller is energized with regulated five volts using IC 7805 regulator which is further given to IC 2941 to improve the supply efficiency of IC 7805 and this output is finally given to the microcontroller.

CC2500 Transceiver from Texas Instruments is used to provide the wireless communication between the sensor node and the receiver node. The CC2500 is a low-cost 2.4 GHz transceiver designed for very low-power wireless applications. The circuit is intended for the 2400-2483.5 MHz ISM (Industrial, Scientific and Medical) and SRD (Short Range Device) frequency band. The RF transceiver is integrated with a highly configurable baseband modem. The modem supports various modulation formats and has a configurable data rate up to 500 kBaud. CC2500 provides extensive hardware support for packet handling, data buffering, burst transmissions, clear channel assessment, link quality indication, and wake-on-radio. It is energized with +3.3 volts supply.

Receiver node also consists of CC2500 to receive the data bytes from the sensor node and it is so configured to change the sampling time of the sensor node as required by the experiment. The output of the receiver node is connected to the computer through USB port to record the results of the experiment. The experimental setup is as shown in the figure 2.

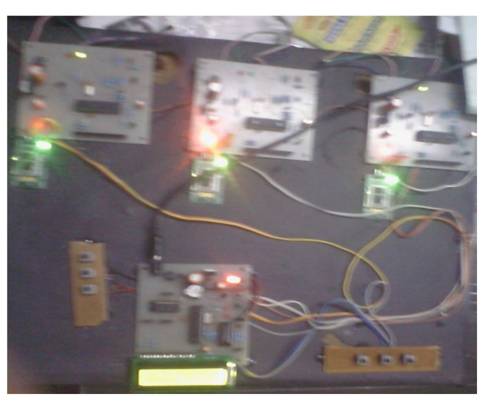

Figure 2. Experimental setup

RESULTS AND DISCUSSIONS

In this experiment, four sensor nodes and one receiver node is used and are connected through wireless communication using CC2500. The distance between the sensor nodes and the receiver node is ten meters. The receiver node is interfaced with the computer through USB port. A provision is made through the microcontroller to record the power dissipated by the sensor node, sampling time and display the same on the computer's monitor.

Graph of figure 3 shows the minimum power dissipation of the sensor nodes at 0.62 seconds, which is the optimum sampling time. However, when the sampling time is 0.2 seconds sensing nodes dissipate the maximum power putting more stress on the battery. Graph of figure 4 shows the maximum lifetime of the battery which is 722.5 minutes is achieved at optimum sampling time of 0.62 seconds. Also, lowest lifetime is recorded at required sampling time of 0.2 seconds. Further, when the sampling time is 0.2 seconds only 61 bytes are received by the receiver or sink node when 99 bytes are sent by the sensing nodes as shown in figure 5. However 97 bytes are received by the sink node at optimum sampling time of 0.62 seconds. Thus power dissipated by the nodes at 0.2 seconds is 55% more, lifetime of the battery at 0.2 seconds is 18% less, and 37% less number of data bytes received by the sink node as compared when the sampling time is 0.62 seconds, which is an indication of inferior QoS.

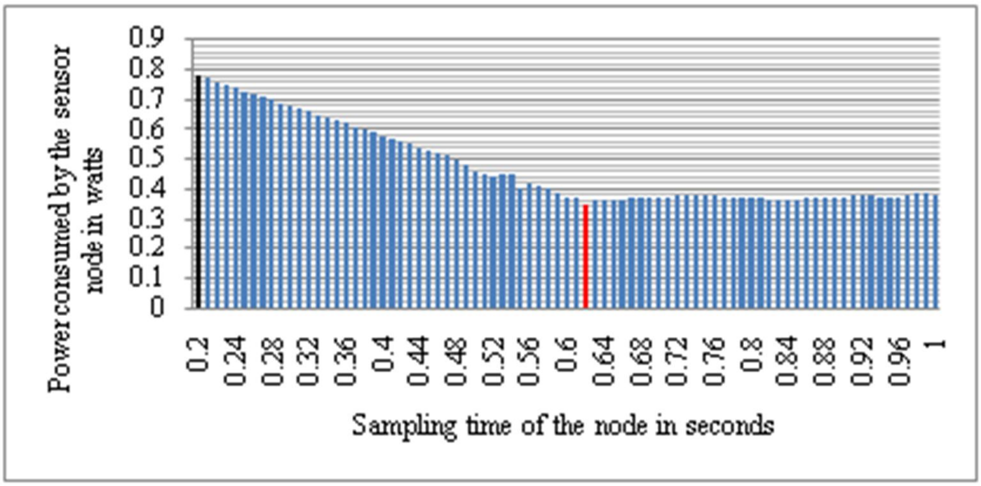

Figure 3. Graph showing sampling time verses power dissipated by the sensor node

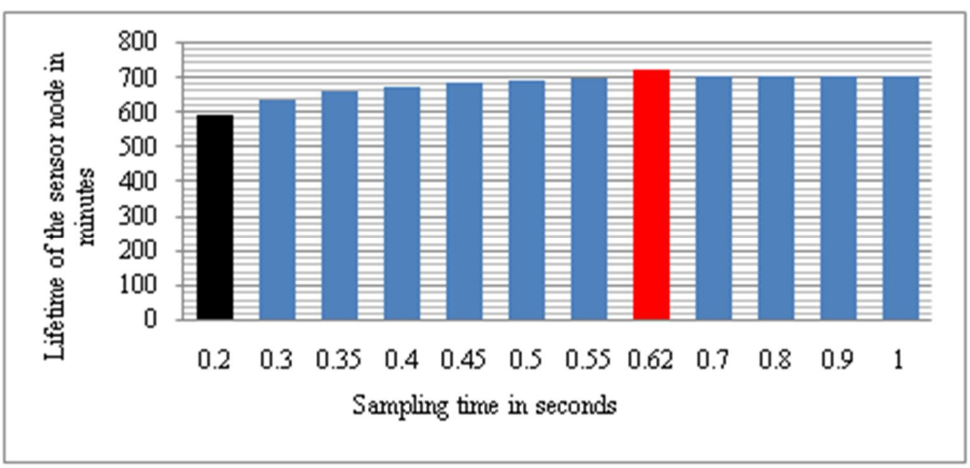

Figure 4. Graph showing the sampling time verses lifetime of the Battery

With the proposed approach, when the battery of the individual sensor nodes are rested for 0.60 seconds, power dissipation of the sensor node has decreased from 0.78 watts to 0.37 watts, lifetime of the battery has increased from 590 minutes to 714.5 minutes and the number of data bytes received have increased from 61 to 96. Results are shown in the graphs of figure 6, figure 7, and figure 8. The percentage improvement in the lifetime of the battery of the sensor nodes is 17.43%, the percentage improvement in the power dissipated by the nodes is 52.56% and the percentage improvement in QoS is 36.45%.

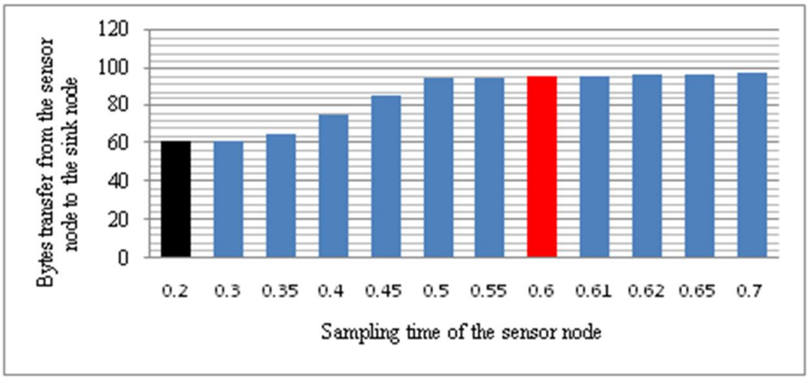

Figure 5. Graph showing the quality of service interms of number of bytes received by the sink node at different sampling times

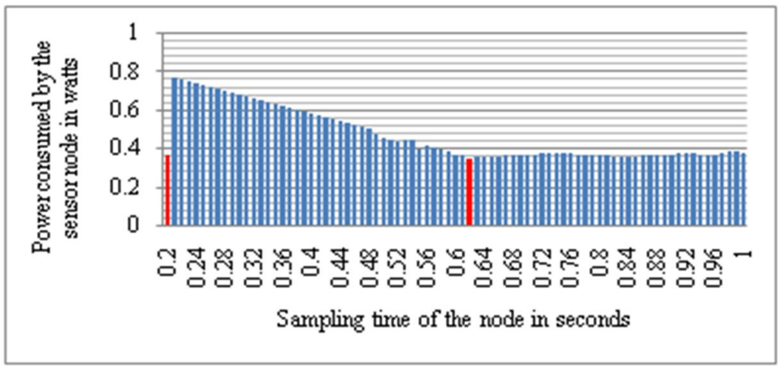

Figure 6. Graph showing sampling time verses power dissipated by the sensor node

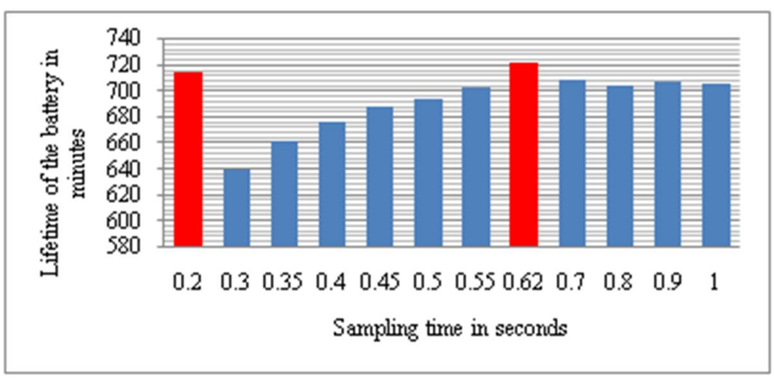

Figure 7. Graph showing the sampling time verses lifetime of the Battery

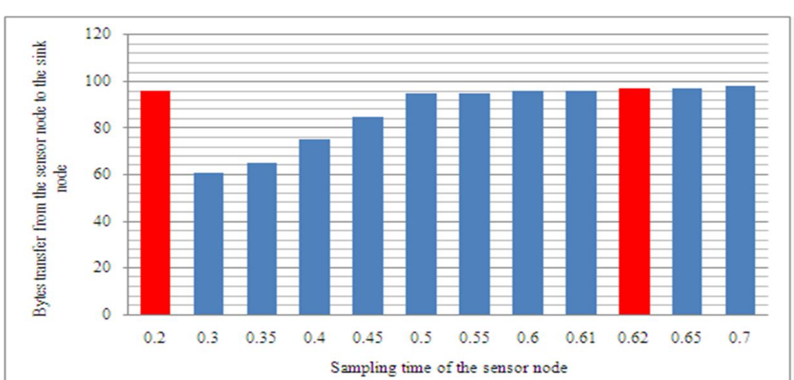

Figure 8. Graph showing the quality of service interms of number of bytes received by the sink node at different sampling times

Table 1 shows the comparative parameter improvement with the proposed technique. An empirical formula shown in equation 1 is framed which approximately finds the number of sensor nodes N required to achieve near optimum performance at non optimum sampling time. This is applicable only when the required sampling time is less than the optimum sampling time.

Table 1: Parameter improvement with the proposed technique

Sampling time-0.2 seconds	Parameters without the proposed technique	Parameters with the proposed technique	% improvement in the performance
Power dissipated by the sensor node	0.78 watts	**0.37 watts**	**52.56%**
Quality of service in terms of bytes received by the sink node	61 Bytes	**96 Bytes**	**34.46%**
Lifetime of the battery	590 minutes	**714.5 minutes**	**17.43%**

$$N = \left[\frac{T_{Optimum\ sampling\ time}}{T_{Required\ sampling\ time}}\right] + 1 \qquad \text{Eqn.1.}$$

CONCLUSION

In this work, a technique has been developed to obtain near optimum performance even at sampling time other than and also than optimum value. Without adopting this technique the power dissipated by the sensor node when the sampling time is 0.2 seconds is 0.78 watts, quality of service is 61.61%, and the lifetime of the sensor node is 590 minutes. To circumvent this problem, the developed technique is used. In this process an empirical formula is also developed with which the number of nodes can be calculated. When the sampling time is 0.2 seconds the number of nodes required to achieve near optimum performance is four. With this four nodes arranged in the manner as shown in figure 1, a remarkable performance improvement is observed, further the obtained performance parameters are close to optimum values.

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