International Journal of Multimedia and Ubiquitous Engineering
Vol.9, No.5 (2014), pp.27-36
http://dx.doi.org/10.14257/ijmue.2014.9.5.03

Proficient Energy Consumption Aware Model in Wireless Sensor Network

Robin Singh Bhadoria[1], Geetam Singh Tomar[2] and Sungmin Kang[3*]

[1] Dept. of Computer Science & Engineering, IITM, Gwalior (MP), India
[2] Dept. of Electrical & Computer Engineering,
The University of West Indies, Trinidad
[3]School of Business Administration, College of Business & Economics,
Chung-Ang University
84, Heukseok-ro, Dongjak-gu, Seoul 156-861, Korea
smkang@cau.ac.kr

Abstract

In this paper, focus is on energy aware model of wireless sensor networks in which each sensor node randomly and alternatively stays in an active or sleep mode. The active mode consists of two phases, the full-active phase and the semi-active phase. When a particular sensor node is in the full-active phase of the active mode, it may sense data packets, transmit the sensed packets, receive packets, and relay the received packets. However, when the phase of the sensor node switches from the full active phase to the semi-active phase, it is only able to transmit/relay data. When the particular sensor node is in a sleep mode, it does not interact with any other node. In this work, emphasis is also given on numerical analysis for energy aware model. An energy aware model for WSN is being also developed with active and sleep features and justified with mathematical analysis and results thereon.

Keywords: *Energy consumption, Energy Aware Model, Wireless sensor networks, Active Phase*

1. Introduction

Wireless sensor networks are applicable for data acquisition that can be fitted to non-accessible places or region. It provided with dynamic and mobility architectural topology that can measured performance better than that compared to wired system. Wireless Sensors have broadly applications into various fields into motion detection, pressure, water, temperature as well as for data aggregation in monitoring devices. Coverage area for any sensor is, typically less than 10m. Every sensor implements the sensing; execute data and communication that data via available wireless subnet among wireless network. In general, sensors are applicable for data aggregation purposes. They have a stable format of data flow. Sensors, periodically, send data on short span of time intervals. The data may be in few bytes. Commonly the data value contains more than one sensed characteristics from different node in the wireless subnet. On each successive data broadcast by a sensor node depends on application during time interval. For example: for a sensor used into surveillance usage, the data collection will be quite frequent for environment monitoring it could be significantly infrequent.

* Corresponding Author

ISSN: 1975-0080 IJMUE

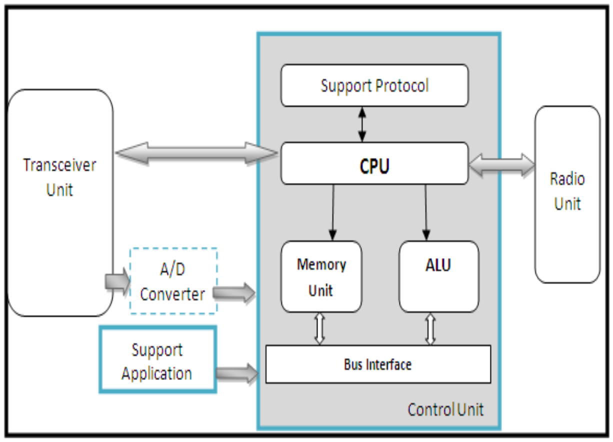

Figure 1. Various Component for wireless Sensor

In general, characteristics of any sensors are quite associated with architectural configuration. Any WSN can be a fixed network or ad-hoc network. With ad-hoc network, any node as sensor node can establish themselves in clusters or sub-networks that achieve better performance for routing the packet over wireless subnet. With fixed network, a greater connectivity can be achieved by using called an access point (AP) that help in establishing the communication among sensors from one cluster to another cluster over wireless subnet. Sensors of different clusters or groups converge using such AP. Consequently, for such fixed WSN, functionality of Internetworking Protocol (IP) layer could be terminated. WSN are provided with dynamic connectivity in which service discovery the sensor node and device auto-configuration are included. Such features are supported by higher layer services which function over TCP/IP. For sensor protocol stack, it is difficult to eliminate TCP/IP. Also, there is a number of legacy implementation of such services but none of them is adopted as a standard. In the above discussion, we see that TCP/IP protocol stack does not fit well into the requirements and limitations imposed by wireless sensor design, wireless sensor network and wireless sensor data transmission.

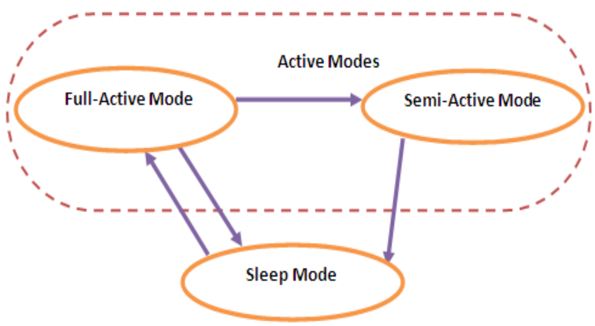

Figure 2. Mode of Sensors [10]

We considered a WSN in which each sensor node may alternatively stay in two major modes:

- Active mode
- Sleep modes.

The active mode further categorized into two more modes:

• Full-active mode
• Semi-active mode.

From Figure 2, we know that a sensor can switch from the full-active phase to the sleep mode or to the semi-active mode. It can also change from the semi-active phase to the sleep mode or from the sleep mode to the full-active phase.

(a) The time for sensor in sleep mode is distributed exponentially with a mean of $1/\beta$. If any sensor is in the sleep mode, then it disconnects from the external world. After the sleep mode duration, the sensor returns to the full-active mode or semi-active mode.

(b) The period for sensor in the full-active mode is the random time that has an exponential distribution with a mean of $1/\alpha$. During this period, the sensor node may:
- Make packets conferring to a Poisson process at a rate of λ;
- Relay packets coming from other sensors in conferring to a Poisson process at a rate of λE;
- Process the data packets with random exponential time with a mean of $1/\mu$.

(c) The period in the full-active mode, the sensor node may change from either semi-active mode or sleep mode. The earlier requires that there has to at least one data packet waiting to be processed and then later happen when there are no data packets waiting for processing. In the semi-active mode, the sensor node may only process the data packets with random exponential time with a mean of $1/\mu$, and it cannot send or receive any data that are communicate from other sensor nodes. After processing all data packets in semi-active mode, the senor node will move to the sleep mode automatically.

(d) Every sensor node has enough space and buffer with countless size for store the data that generated or forwarded by other sensor nodes for relaying dedications.

2. Background and Related Work

We are currently aware of energy model, particularly, in design to use for online monitoring, the model from Dunkels *et al.* [5]. However, its energy model, particularly the model of the communication system, which appears to be relatively simple. This categorizes into only two states for the microcontroller and the radio chip, respectively. Obviously, these do not considered all nodes for conceivable energy which stated in [8].

Some sensor network test beds measure the consumption of energy by its nodes. In the “MoteLab” test bed [6] for example, only single sensor node’s residual energy is calculated and considered. The “JAWS” test bed provides capabilities or residual energy for all existing nodes in the network [7]. Though, capacities of nodes may be accurate and specifications are restricted by the sensor nodes internally in ADC System (analog digital converter) and in Bluetooth [9].

Commonly in random selection protocol for any Cluster Head (CH), transmissions era may be categorized into stages or phase and into each phase a random Cluster Head (CH) selection protocol is used. This can be categorized into three phases namely- Setup phase, Steady State phase and Data transmission to sink phase as shown in Figure 3.

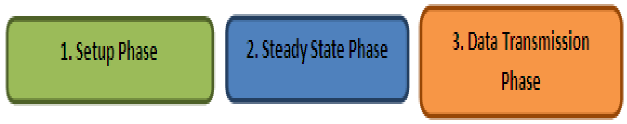

Figure 3. All Phase into Communication for Wireless Sensor Network

In Setup phase, Cluster Heads are selected among the regular sensor nodes based on certain parameters (For *e.g.*, nodes energy level and number of times this node has been selected as CH previously). Selected CH broadcast an advertisement message to all other nodes. All remaining nodes get themselves associated to their nearest CHs. *In Steady state phase*, during the contention period, all nodes keep their radios on. The cluster-head builds a TDMA schedule and broadcasts it to all nodes within the cluster. There are m frames and one data slot allocated to each node in each frame. Data are transferred from each node to their respective CH within the TDMA time slot previously assigned to them. *In Data transmission to sink phase*, the collected data at each CH or Base Station (BS), is forwarded to the sink. The process of selection of CH is based on the protocol shown in Figure 3.

2.1. Comparison into Energy Consumption

For individual sensors sense data and transmit to cluster heads (CH) using single hops as in [11]. Here we assume that all sensor nodes within a cluster use time division multiple access (TDMA) to access their CH. Data is generated in individual sensor nodes [3]. The CH (current CH) processes and aggregates collected data from its own sensors, child CHs (previous CHs) and transmit to its parent CH (next CH) towards to the base station or sink via other CHs with multiple hops. Every communication round base station get equal amount of data. Clustering reduces the data to be transmitted to the base station by processing all data locally.

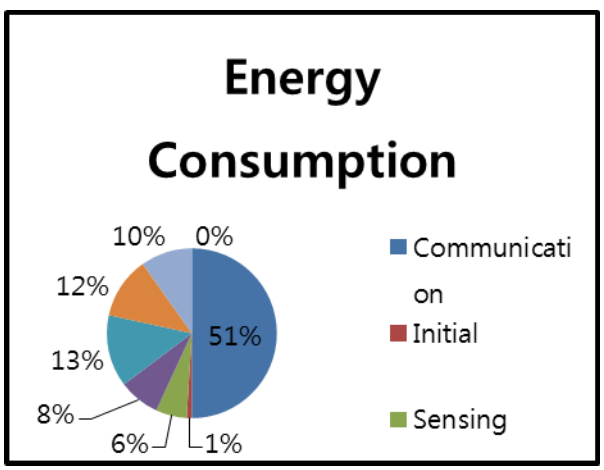

Figure 4. Survey for energy consumption

In the paper [4], it has been observed that the term 'network life time' is stated as either time until the last (or first) node dies or the time until a particular percentage of nodes in wireless network dies. We accept the first definition, in which last node dies. It is central consider in note that every node or Cluster Head (CH) can die either because it goes out of battery, or death of other Cluster Heads isolates it from to its BS(Base Station).

The energy utilize by a sensor node that can be attributed to: microcontroller processing, radio transmission and receiving, sensor sensing, transient energy, sensor logging and actuation. We assume that all sensor nodes (except Cluster Heads) are homogeneous, therefore energy utilize for all activities (excluding for communication energy due to different transmit distances to its Cluster Head), are the same for each sensor node.

The total number of data packets in single round is totality of data packets received from sensor nodes in its own cluster and incoming data packets from sub-cluster heads (CHs). Therefore, the transmitting and receiving energy used by Cluster Head (CH) is higher than that of a normal sensor node because of the additional data aggregation and processing tasks associated with it.

3. Energy Model

A sensor consumes its energy in order to carry out three main functions: acquisition, communication and data processing:

1) *Acquisition:* It is the energy utilization to perform the gaining is generally negligible. Nonetheless, it differs in considerable proportions reliant on the type of monitoring being carried out over network.

2) *Communication:* It utilizes more energy than any other assignment or task. It includes the communications in terms of emission and reception via an antenna [6].

3) *Data processing:* The energy utilize for the calculation process is very low in compared to communication energy. The energy required to send 1KB over a 100m distance is roughly equivalent to energy needed to perform 3 million instructions with speed of 100 MIPS (million instructions per second).

3.1. Performance Characteristics

Consider h_i>1 be a weighting factor that applies to Cluster Head (CH) to specify by how much it utilize more energy than a general sensor node for energy source i, with i=1,2,3,4 for processing, transmitting and receiving, sensing and sensor logging, respectively.

The sensing scheme relations to the sensor node power consumption are: signal sampling and conversion of physical signals to electrical signals, signal conditioning, and analog to digital conversion (ADC). Let I_{sens} be the total current required for sensing activity and T_{sense} be the time duration for sensor node sensing. We evaluate the total energy dissipation for sensing activity for b bit packet,E_{sense_N} at the sensor node per round by

$$E_{sense_N}(b) = b\ V_p I_{Sense} T_{Sense}$$

And, the total energy dissipation for sensing activity at the Cluster Head per round by

$$E_{Sense_{CH}(h_3,b)} = h_3 E_{sense_N}(b)$$

Where V_p is the provided voltage.

Sensor logging utilizes energy used for scanning the ‘b’ bit packet of data and loading it into memory [3]. Sensor logging energy utilization for a sensor node per round is estimated by

$$E_{sense_N}(b) = E_{load} + E_{scan} = \frac{b\,V_p}{8}(I_{load}T_{load} + I_{scan}T_{scan})$$

Where E_{load} is energy utilization for writing data, E_{scan} is energy utilization for reading 'b' bit packet data, I_{load} and I_{scan} are current for loading and scanning 1 byte data. Energy utilization for logging sensor readings at the Cluster Heads per round can be estimated by

$$E_{log_{CH}}(h_4, b) = h_4 E_{log_N}(b)$$

The power consumption for aggregation and processing of data mainly utilize by the microcontroller is attributed to two components:

- ✓ Energy loss from swapping from one mode to another, E_{swap}
- ✓ Energy loss due to drop of current, E_{drop}

This energy consumed by drop of current, occurs when a sub threshold current flows between ground and source of power. Total energy dispersion or waste by the sensor node used for 'b' bits of data processing.

$$E_{disperse_N}(b_1, N_{cycle}) = b_1 N_{cycle} C_{avg} V_p^2 + b_1 V_p \left(I_0 e^{\frac{V_p}{n_c V_t}}\right)\left(\frac{N_{cycle}}{f}\right)$$

Total energy dissipation by the cluster head, $E_{disperse_{CH}}$ per round is given by

$$E_{disperse_{CH}}(h_1, b_1, N_{cycle}) = h_1 E_{disperse_N}(b_1, N_{cycle})$$

Where N_{cycle} is the number of clock cycles per task, C_{avg} is the average capacitance swapped per cycle, I_0 is the leakage current, n_c is constant which depends on the processor, V_t is the thermal voltage, and f is sensor frequency. Assuming that sensor nodes only sense data and transmit to its cluster Head once during each round.

This level might be much reliant on the circuitry installed in the nodes and the features requested. To receive a message of 'k' bits, the receiver then consumes:

$$E_{linear}(i) = \{(2i-1)(E_{elec} + i\,E_{amp}(d_i)^{\alpha})\}$$

Where E_{elec} represents energy utilize in transmission, E_{amp} amplification, k the message length, d the transmitter/receiver distance and α a factor defining attenuation.

Using above equations, the energy consumed during data transmission from source towards the destination going through intermediate nodes aligned in a row is written as:

$$E_{linear} = k\left\{\sum_{i=1}^{n}(2E_{elec} + E_{amp}(d_i)^{\alpha})\right\}$$

E_{linear} is minimum when all di are equal to D/n, when the number of hops is at its optimal value:

$$n_{optimal} = \left\lfloor \frac{D}{d_{char}} \right\rfloor$$

$$=> d_{char} = \left[\frac{2E_{elec}}{E_{amp}(\alpha - 1)} \right]^{\frac{1}{\alpha}}$$

The optimal number of hops depends on the propagation loss coefficient αand the transmitter and receiver parameters [11]. By replacing d_{char}in statementE_{linear}, we obtain the following relation:

$$E_{linear}^{optimal} = m\left\{ \frac{2\ n_{optimal}\ E_{elec}\ \alpha}{\alpha - 1} - e_{RC} \right\}$$

3.1.1. Packet received: If $x_i$stands for number of events detected by particular node, the number of packets relayed by this particular node is given by:

$$P_i = n - i + x_i\alpha$$

Consider the existence of an underlying supervision protocol, in charge of building and updating the routing tables for nodes. Then mean number of events seen by each node is:

$$n_e = \frac{[\sum_{i=1}^{n} x_i]}{n}$$

The average number of transmitted packets N_{pkt} at node i may be estimated as:

$$N_{pkt} = n - i + n_e\ \alpha$$

Where 'n' is number of nodes within the linear sensor network and i the node under consideration.

3.1.2. Total Energy cost for system: From the average number of sent packets, the average energy consumed within the linear sensor network may be computed as:

$$E_{linear-bit} = -n_{RC} + \sum_{i=1}^{n} [N_{pkt}(e_{TC} + e_{RC} + e_{TA}\ (d_i)^{\alpha})]$$

4. Experiment Result and Analysis

For simulation, we made wireless sensors with 21 nodes of four clusters having each 5 regular sensor nodes and one Cluster Head (CH). Node Id 21 is 'sink node' or Base Station (BS) for wireless network and Node Id 4, 8, 12 and 18 are Cluster Heads (CHs) as depicted in Figure 5.

For experimental purpose, we simulate our result on QualNet 5.2 with simulation area 100 X 100 meters and simulation time is taken 300 seconds. We analysis four energy model namely Generic, Mica, MicaZ and User specified.

In Generic Energy model, transmit circuitry power consumption is set with 100mW, receive circuitry power consumption 130mW, idle circuitry power consumption 120mW and sleep circuitry has no power consumption.

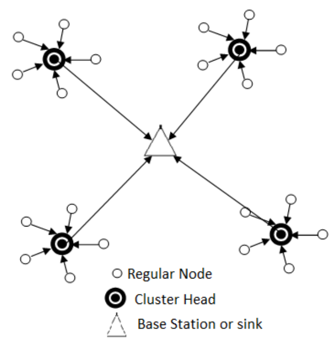

Figure 5. Architectural View for Sensor Node

We use user specified energy model to make comparable with existing energy models. User specified model is put with 280mAmp of transmission current load, 204mAmp reception load, 178mAmp idle current load and 14mAmp of sleep current load.

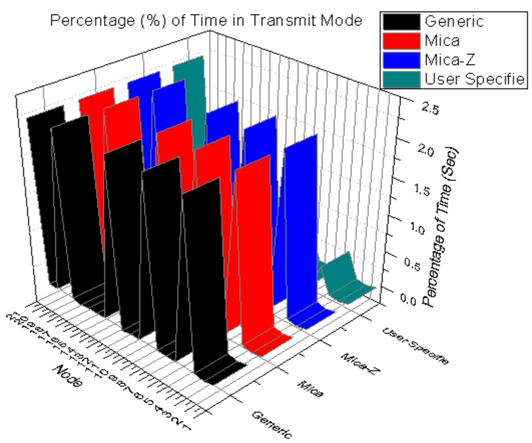

Figure 6. Percentage of time in Transmit Mode

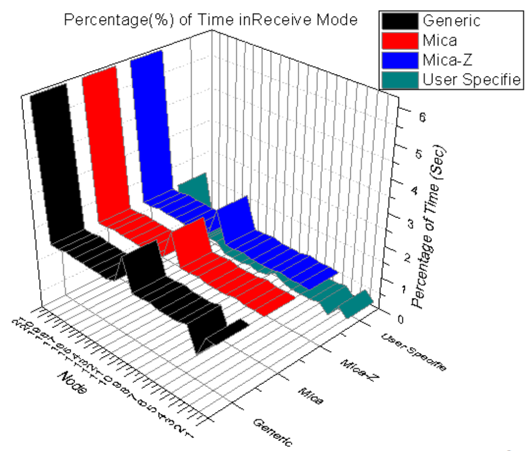

Figure 7. Percentage of time in Receive Mode

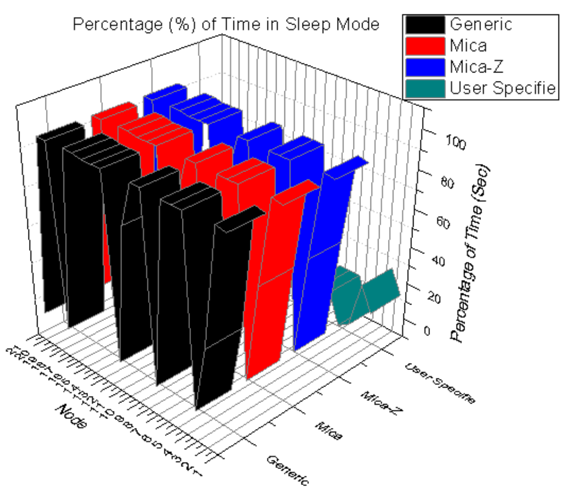

Figure 8. Percentage of time in Sleep Mode

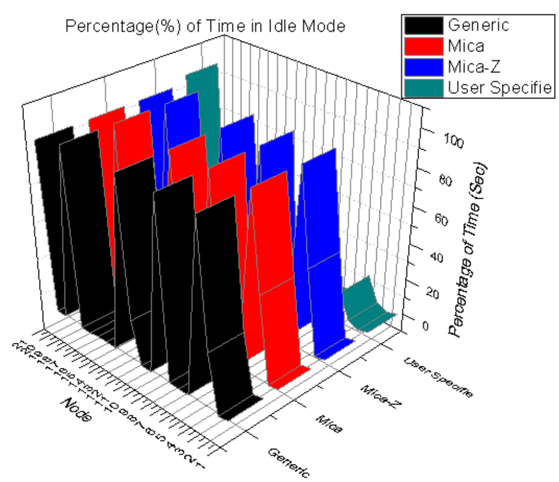

Figure 9. Percentage of time in Idle Mode

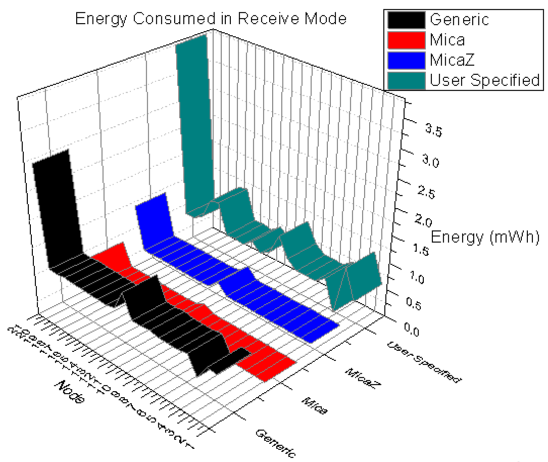

Figure 10. Energy Consumed (mWh) in Receive Mode

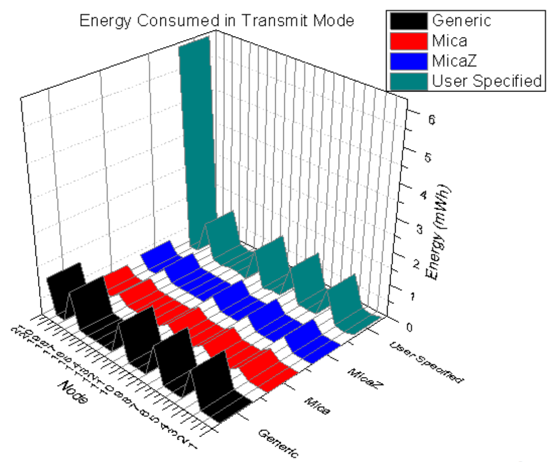

Figure 11. Energy Consumed (mWh) in Transmit Mode

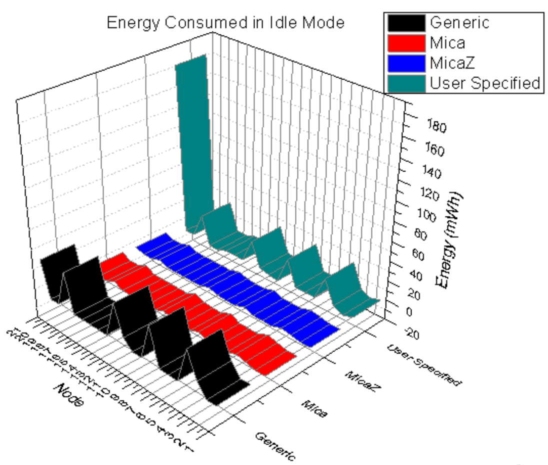

Figure 12. Energy Consumed (mWh) in Idle Mode

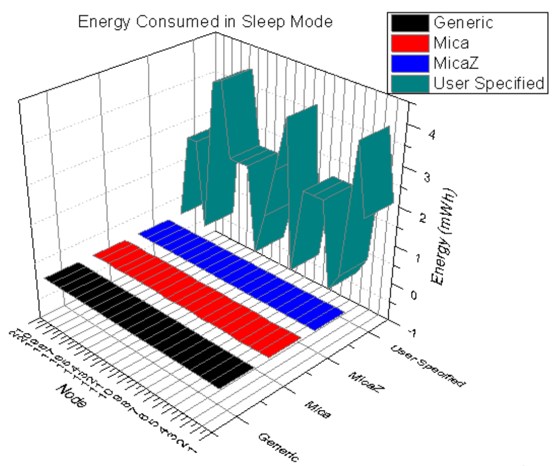

Figure 13. Energy Consumed (mWh) in Sleep Mode

5. Conclusion

In this paper, we have analyzed a realistic and comprehensive energy model for WSN. The energy utilization among different sources in considered setup of a sensor node was experimented over four different energy models. The results point out that regular energy models overvalue real sensor node lifetime. We also have applied our model to a LEACH-type protocol to get precise evaluation of the energy utilization and lifetime of node.

It has been observed that Mica and MicaZ Energy model specifies more reliable result over user specified model of energy. Into Some cases, Generic Energy Model has shown at par result, especially in sleep and idle mode for regular sensor node.

References

[1] Q. Wang and W. Yang, "Energy Consumption Model for Power Management in Wireless Sensor Networks" in e IEEE SECON 2007.
[2] R. N. Enam, M. Imam and R. I. Qureshi "Energy Consumption in Random Cluster Head selection Phase of WSN" in IPCSIT IACSIT Press, Singapore, vol. 30, (**2012**), pp. 38-44.
[3] M. N. Halgamuge, M. Zukerman, K. Ramamohanarao and H. L. Vu "An Estimation of Sensor Energy consumption" in Progress in Electromagnetic Research B, vol. 12, (**2009**), pp. 259-295.
[4] Q. Dong, "Maximizing system lifetime in wireless sensor networks," Proc. IEEE International Symposium on Information Processing in Sensor Networks Conf., 13–19, April (**2005**).
[5] A. Dunkels, F. Osterlind, N. Tsiftes and Z. He, "Software-based on-line energy estimation for sensor nodes," in Proceedings of the 4th workshop on Embedded networked sensors (EMNETS'07). New York, NY, USA: ACM, (**2007**), pp. 28–32.
[6] "The Mote Lab testbed website," http://motelab.eecs.harvard.edu/.
[7] J. Beutel, "Fast-prototyping using the BTnode platform," in DATE '06: Proceedings of the conference on Design, automation and test in Europe. 3001 Leuven, Belgium, Belgium: European Design and Automation Association, (**2006**), pp. 977–982.
[8] S. Kellner, M. Pink, D. Meier, and E.-O. Blaß "Towards a Realistic Energy Model for Wireless Sensor Networks" in The Fifth Annual Conference on Wireless On demand Network Systems and Services,Garmisch-Partenkirchen, Germany, January 23-25, (**2008**).
[9] M. Dyer, J. Beutel, L. Thiele, T. Kalt, P. Oehen, K. Martin and P. Blum, "Deployment support network - a toolkit for the development of WSNs," in Proceedings of the 4th European Conference on Wireless Sensor Networks. Springer, Berlin, January (**2007**), pp. 195–211.
[10] Y. Zhang and W. Li, "Modeling and energy consumption evaluation of a stochastic wireless sensor network" in EURASIP Journal on wireless Communication and networking, (**2012**).
[11] F. Shebli, I. Dayoub and J. M. Rouvaen "Minimizing energy consumption within wireless sensors networks" in Ubiquitous Computing and Communication Journal, (**2006**).
[12] Q. Wang and W. Yang "Energy Consumption Model for Power Management in Wireless Sensor Networks" in Proc. of IEEE SECON 2007, (**2007**), pp. 142-151.
[13] R. S. Bhadoria, N. Jain, L. Gupta and M. Dixit, "Power-Aware Consumption Routing in Wireless Sensor Networks" in IEEE 4th International Conference on Computational Intelligence and Communication Networks (CICN 2012), Mathura, India, pp. 169-173.
[14] R. S. Bhadoria and G. C. Deka, "Competent Routing protocol in Wireless Sensor Networks" in IEEE International Conference on Parallel, Distributed and Grid Computing (PDGC 2012), Shimla, India.

Author

Sungmin Kang, he is a professor of MIS at College of Business and Economics, Chung-Ang University. He graduated from Carnegie Mellon University, earning his B.S. and MBA in business administration. He received his Ph.D. in information systems from the University of Texas at Austin. His research interests include the electronic commerce, business value of Internet related information technologies, adoption/diffusion of information technologies, and organizational impact of information technologies. His research papers appeared in a number of journals such as Expert Systems with Applications, Springer-Verlag's Lecture Notes in Computer Science, etc.

