International Journal of Computer Applications (0975 – 8887)
Volume 65– No.4, March 2013

Energy Optimization using Cross-Layer Protocols in Wireless Sensor Networks

B.Brahma Reddy
ECE, VBIT
Hyderabad, India

K.Kishan Rao
Vaagdevi College of Engineering
Warangal, India

ABSTRACT
Wireless Sensor Network (WSN) is an emerging technology. It is predicted that in future, WSN will change the human life totally. Energy optimization in Wireless Sensor Network (WSN) is one of the challenging issues. Wireless Sensor Network composed of a set of tiny sensor nodes. The nodes are continuously sense and transmit the data. WSN nodes operate on batteries; due to this WSN has a limited lifetime. So increasing the lifetime of Wireless Sensor Network and Minimizing energy cost in wireless sensor network are twin important problems. Proper selection of routing protocol helps achieve maximum efficiency in energy consumption which intern increases network lifetime. In this paper, three protocols namely Ad-hoc on-Demand Distance Vector (AODV), Destination Sequence Distance Vector (DSDV) and Ad-hoc on-Demand Multipath Distance vector (AOMDV) are compared and analyzed. They are compared with IEEE802.11 and IEEE802.15.4 MAC protocol. MinMax, and MinTotal are used as metrics for this comparison. Matlab and NS-2 are used for simulation.

KEYWORDS AODV, AOMDV, DSDV, Energy Consumption, Network lifetime, Wireless Sensor Networks.

1. INTRODUCTION
Wireless Sensor Networks (WSNs) comprises of small sensing nodes with built-in features for collecting data, organizing data in proper format and wireless communications. Wireless sensors often have limited energy due to the use of batteries as source of energy. More often these batteries are non-renewable. Apart from this, the total network capacity is limited by the use of weather influenced wireless links that limit the range, reliability, and throughput of communication between nodes.

Wireless sensor networks have several significant applications in weather forecasting, medical monitoring, military target tracking and environmental detection. One of the advantages of wireless sensors networks (WSNs) is their ability to operate in harsh environments in which human monitoring schemes are difficult, inefficient and sometimes infeasible. Sensor nodes transmit the data through multiple hops to the sink which is located far from the source of data. Since sensor nodes have a limited battery lifetime, how to effectively save the energy of battery and increase the network lifetime has been the important research issue in wireless sensor networks.

Sensor nodes have many modules; the communication module consumes the most electricity. The cost of communication is closely related to the way of routing protocol set up. If routing protocol operates efficiently, the energy that every node consumes would be minimized. Therefore, it is desirable that the routing protocols should resolve issues like energy efficiency, load balance, minimum delay, etc. Especially, energy efficiency is the important key issue for keeping a longer network lifetime.

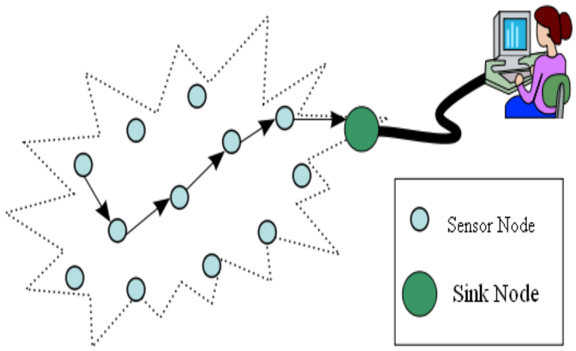

Fig.1 Typical wireless sensor network

Another important area to energy saving in WSN is MAC protocol. The medium access control protocols for the wireless sensor network have to achieve two objectives. The first objective is the creation of the sensor network infrastructure. In any typical WSN, a large number of sensor nodes are deployed and the MAC scheme must establish the communication link between the sensor nodes. The second objective is to share the communication medium fairly and efficiently. A good MAC protocol considers [1] provides Energy efficiency, Latency, Throughput, and Fairness. Major sources of energy waste in wireless sensor network are basically of four types [1] [2]: Collision, Overhearing, Packet overhearing, and Idle listening.

There are a large number of routing protocols are available for WSN, but in this paper, three most relevant protocols DSDV, AODV and AOMDV are compared and analyzed. Their performance is compared using 802.11 and 802.15.4 MAC protocols. Though main emphasis is given on Energy consumption, but End-to-End delay, Packet received and Packet drop ratio can also be examined.

The rest of the paper is organized as follow: Section-2 gives brief explanation of IEEE802.11, IEEE802.15.4, AODV, DSDV, and AOMDV operations. Section-3 highlights some of the related works done by earlier Authors. Section-4 describes the system model used for simulation. Section-5 discusses and analyzes results of the simulation. Finally, Section-6 concludes the paper.

2. MAC PROTOCOLS USED FOR COMPARISON

2.1 IEEE 802.11 MAC
The IEEE 802.11 [3] is a well known contention based medium access control protocol which uses carrier sensing and randomized back-offs to avoid collisions of the data packets. The Power Save Mode (PSM) of the IEEE 802.11 protocol reduces the idle listening by periodically entering into the sleep state. This PSM mode is for the single-hop network where the time synchronization is simple and may not be suitable for multi-hop networks because of the problems in clock synchronization, neighbor discovery and network partitioning.

2.2 IEEE 802.15.4 MAC

The new IEEE standard, 802.15.4, [4] defines the physical layer (PHY) and medium access control sublayer (MAC) specifications for low data rate wireless connectivity among relatively simple devices that consume minimal power and typically operate in a range of 10 meters or less. An 802.15.4 network can be a star, tree, cluster-tree topology. A device in an 802.15.4 network can use either a 64-bit IEEE address or a 16-bit short address assigned during the association procedure, and a single 802.15.4 network can accommodate up to 64k devices. Wireless links under 802.15.4 can operate in three license free industrial scientific medical (ISM) frequency bands. These accommodate over air data rates of 250 kb/sec (or expressed in symbols, 62.5 ksym/sec) in the 2.4 GHz band, 40 kb/sec (40 ksym/sec) in the 915 MHz band, and 20 kb/sec (20 ksym/sec) in the 868 MHz. Out of total 27 channels allocated for 802.15.4, 16 channels are in the 2.4 GHz band, 10 channels are in the 915 MHz band, and 1 channel is in the 868 MHz band.

2.3 DSDV protocol

In Destination-Sequenced Distance Vector routing protocol (DSDV), routing messages are exchanged between neighboring mobile nodes. Updated messages are sent in case routing information from one of the nearby node changes. Packets for which route to destination is unknown are cached, and queries are sent out to find route to destination. The packets are allowed to receive till route-replies are received from the destination. The pre-defined maximum buffer size of memory is available for collecting those packets, waiting for routing information. If the packets are received beyond that size then, that packets may be dropped. A sequence number to each entry is allotted. This numbers are generated by destination, and it is mostly even number if a link is present otherwise it is an odd number. Further, it is necessary for the transmitter to transmit the next update with this sequence number [5]. Routing protocol DSDV is explored by C. Perkins and P. Bhagwat in 1994. It is based on the Bellman- Ford algorithm and it is a table-driven protocol. This algorithm is suitable to solve the routing loop problems in the networks consist of a small number of nodes. Since DSDV has limitations to use for dynamic network, its improved versions are available.

2.4 AODV Protocol

The AODV algorithm is an improvement of DSDV protocol. It reduces number of broadcasts by creating routes on demand basis, as against DSDV that maintains routes to each known destination [6]. When source requires sending data to a destination and if route to that destination is not known then it initiates route discovery. AODV allows nodes to respond to link breakages and changes in network topology in a timely manner. Routes, which are not in use for long time, are deleted from the table. Also AODV uses Destination Sequence Numbers to avoid loop formation and Count to Infinity problem. An important feature of AODV is the maintenance of timer based states in each node, regarding utilization of individual routing table entries. A routing table entry is expired if not used recently. A set of predecessor nodes is maintained for each routing table entry, indicating the set of neighboring nodes which use that entry to route data packets. These nodes are notified with (Route error) RERR packets when the next-hop link breaks. Each predecessor node, in turn, forwards the RERR to its own set of predecessors, thus effectively erasing all routes using the broken link. Route error propagation in AODV can be visualized conceptually as a tree whose root is the node at the point of failure and all sources using the failed link as the leaves [6].

2.5 AOMDV Protocol

An extension to AODV is Ad-hoc on-demand Multipath Distance Vector (AOMDV) routing protocol which computes multiple loop-free and link disjoint paths. For each destination, along with the respective hop counts it maintains a list of the routing entries of the next-hops. Unique sequence number is allocated to all next hops. This helps for keeping track of a route. A node maintains the assigned hop count, which is the maximum hop count for all the paths at each node. Loop freedom is assured for a node by accepting another path to destination if it has a less number of hop counts than the assigned for that destination. AOMDV allows intermediate nodes to reply to RREQs, while still selecting disjoint paths. During route discovery, its message overhead is high, due to increased flooding. Since it is a multipath routing protocol, the destination replies to the multiple RREQs those results are in longer overhead [7].

3. RELATED WORK

R. Vinodkumar [8] studied the performance of several routing protocols for VBR traffic. Manveen Singh Chadha [9] evaluated the performance of AODV, AOMDV and DSR using ns-2. Amit [10] has compared AODV and DSR using simulation for cellular networks including malicious node aspects. Jiwei Chen [11] presented a detailed simulation study of the performance of the predominant mesh routing protocols being considered in IEEE 802.11s: AODV and OLSR. And gracefully integrated advantages of OLSR and Fisheye routing protocol (FSR). Sapna [12] did a realistic comparison of three routing protocols DSDV, AODV and DSR. S.Mittal & P Kaur [13] compared FSR, LAR1, LANMAR w.r.t packet delivery ratio. Javaid [14] modeled transmission probabilities of 802.11p for VANETs and effect of these probabilities on average transmission time and studied performance of DSR, FSR and OLSR. Surbhi Sharma [15] presents the effect of node density on the performance of four reactive routing protocols AODV, DSR, DYMO, ANODR for CBR traffic. S. Sathish [16] presents performance evaluation of three different routing protocols i.e. Dynamic Source Routing Protocol (DSR), Ad hoc On-demand Distance Vector (AODV), Fisheye State Routing (FSR) and Zone Routing Protocol (ZRP) with respect to variable pause times.

4. PROPOSED ANALYSIS

4.1 Definitions

The IEEE defined physical and MAC layer characteristics for establishing connectivity between devices with low-power consumption, low cost, and low data rate. Conventional Wireless Sensor Network (WSN) mainly deals with scalar data such as temperature, humidity, pressure and light which are very suitable for low rate and low power IEEE 802.15.4 based networking technology. However none of the above focused on IEEE802.15.4 MAC in their studies. Our present analysis has taken IEEE802.15.4 and 802.11 MAC while comparing energy savings of AODV, AOMDV, and DSDV routing protocols.

Three metrics MinMax, MinTotal, and Network lifetime are used for comparing the results in this paper. Formal definitions of these metrics are explained below:

Definition 1: **MinMax**: Maximum power that needs to be transmitted by any node to make network connected.

Definition 2: **MinTotal**: Minimum of total power transmitted by all nodes together in optimized connected network.

Definition 3: **Network life time**: Time elapsed before any node discharges its battery energy to a level which is not sufficient to transmit to its first-hop neighbor.

A network can be represented as an undirected graph **G = (V,E)** where **V = {v_1, v_2, ..,v_n}** is a set of nodes randomly deployed in a two-dimensional plane. Each node **v** ∈ **V** has a unique id, **(v_i)= i** where **1** ≤ **i** ≤ **n** and is specified by its location. **E** is set of edges. Let P_i is energy consumed by each node. P_i comprises of $\mathbf{e}_i$ (energy consumed in idle mode), $\mathbf{e}_s$ (energy consumed in sleep mode), $\mathbf{e}_t$ (energy consumed in transmit mode), and $\mathbf{e}_r$ (energy consumed in receive mode). 6

$P_i = \mathbf{e}_i + \mathbf{e}_s + \mathbf{e}_t + \mathbf{e}_r.$

Total energy consumed by all the nodes during the simulation time is taken as MinTotal. Similarly, P_i which is maximum power consumed by any single node during the simulation is taken as MinMax. While MinTotal can help in designing network architecture, MinMax is useful to measure lifetime of the network. 7

MinTotal = $\sum_{?=?}^{?}$??

MinMax= min (P_i)

Table.1 Network parameters used for simulation

Parameter	Value
Node placement	Random
No of source nodes	4
No of sink nodes	1
Area of simulation	584x2135
Simulation time	100 sec
Type of traffic	CBR/Poisson
Transport protocol	TCP/UDP
Packet size	512 bytes (CBR/Poisson)
TCP/UDP packet size	1500 bytes
Packets generated by each source	20000
Model	Energy model
Routing protocols	AODV/DSDV/AOMDV
Transmit energy	0.1
Receive energy	0.1
Idle energy	0.01
Sensing energy	0.0175
SYNC bytes for SMAC	1
Duty cycle for SMAC	10
BO for 802-15-4	3
SO for 802-15-4	3

4.2 Proposed Simulation Model

The network model consider for simulation is as shown in Fig1. It consists of single sink node and multiple source nodes. Model is designed for the Multi-hop situation. The simulation parameter and node configuration is listed in Table1. Node zero (N_0) is sink node. All nodes from 1 to 4 (N_1-N_4) are source nodes. Every source node will generate 20000 packets, which may contain data of size 512 bytes in each packet. Therefore, total number of events send from all sources is 80000. The simulation area is considered 584x2135. The results are generated using Network Simulator NS-2.35 version on Ubuntu 11.10 [17]. It is a discrete-event simulator, and it has accurate implementation with TCP, UDP and fully compatible with other transport protocols. The radio power values used to compute energy consumption in various modes, such as idle, transmitting, receiving, and sleeping mode. More often data traffic in WSN is generated at constant rate in regular monitoring application. And it is a Poisson process in case of event detection applications. In the present paper, both these traffics (CBR and Poisson) are modeled and simulated.

5 SIMULATION RESULTS AND ANALYSIS

As shown Fig.2 & Fig.3 802-15-4 MAC is out performing in all three protocols for TCP/CBR traffic. AODV has lower MinMax among the all three routing protocols. However, 802.11 & AODV combination has produced lower MinTotal

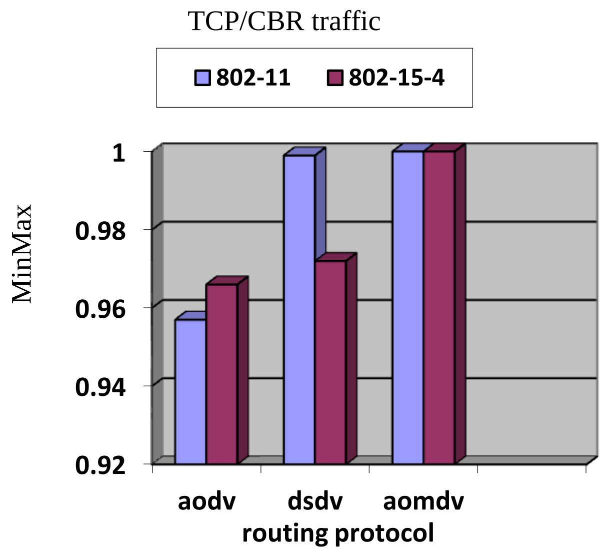

Fig.2 MinMax comparison for different routing protocols for TCP/CBR traffic

As shown in Fig.4 & Fig.5, 802.15.4 has outperformed 802.11 MAC for all three protocols for UDP/CBR traffic. This is true for both MinMax and MinTotal.

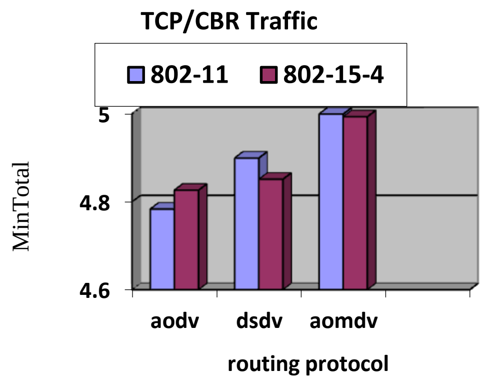

Fig.3 MinTotal comparison for different routing protocols for TCP/CBR traffic

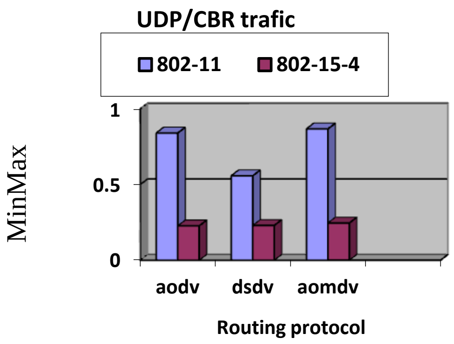

Fig.4 MinMax comparison for different routing protocols for UDP/CBR traffic

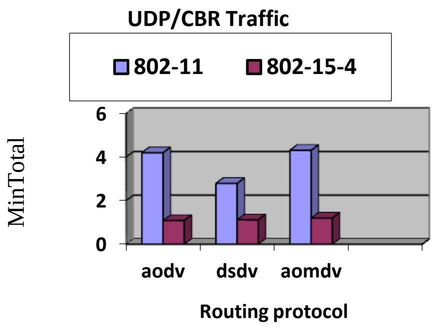

Fig.5 MinTotal comparison for different routing protocols for UDP/CBR traffic

As shown Fig.6 & Fig.7 802-15-4 MAC is out performing in all three protocols for UDP/Poisson traffic. AODV has lower MinMax among the all three routing protocols. However, DSDV has produced lower MinTotal.

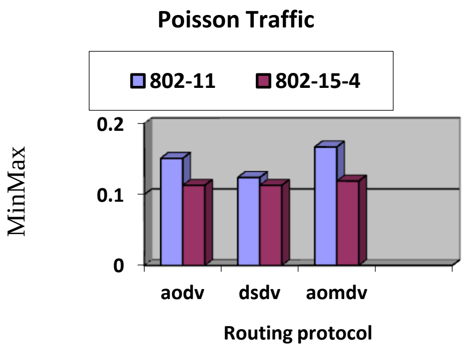

Fig.6 MinMax comparison for different routing protocols for UDP/Poisson traffic

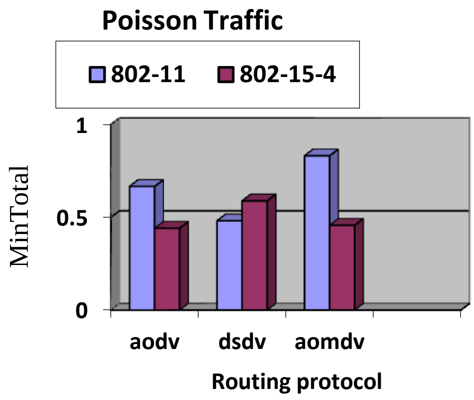

Fig.7 MinTotal comparison for different routing protocols for UDP/Poisson traffic

6. CONCLUSIONS

7. Wireless sensor network is highly energy sensitive. Selection of appropriate routing protocol is extremely crucial. In this article, three protocols i.e. DSDV, AODV and AOMDV are compared with IEEE802.11 and IEEE802.15.4 standards. From the all the graphical results, which are explored using NS2 simulator, it is observed that, IEEE802.15.4 standard is more efficient. These results may be immensely useful to the designers and engineers for deployment of actual wireless sensor network in energy sensitive applications.

REFERENCES

[1] Wei Ye, J.Heidemann and D. Estrin: An Energy- Efficient MAC Protocol for Wireless Sensor Networks, IEEE INFOCOM, New York, Vol. 2, pp. 1567-1576 (June 2002).

[2] Tijs van Dam, Koen Langendoen: An Adaptive Energy Efficient MAC Protocol for Wireless Networks, in Proceedings of the First ACM Conference on Embedded Networked Sensor Systems (November 2003).

[3] IEEE Standard 802.11. Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications (1999).

[4] Yu-Doo Kim, IL-Young Moon, Sung-Joon Cho, “A comparison of improved AODV routing protocol based on IEEE802.11and IEEE802.15.4”, Journal of Engineering Science and Technology Vol. 4, No. 2 (2009) 132 – 141

[5] Charles E. Perkins et al. “Highly Dynamic Destination - Sequenced Distance-Vector Routing (DSDV) for Mobile Computers”, published in SIGCOMM, London, UK, 1994, pp.234-244.

[6] Performance Comparison of Wireless Mobile Ad-Hoc Network Routing Protocols ,Arun Kumar Lokanatha C. Reddy,Prakash S. Hiremath ,IJCSNS volume 8 No6, June 2008

[7] M.K.Marina and S.R.Das, “On-Demand multipath distance vector routing in ad hoc networks” in: Proceedings of the 9th IEEE International Conference on Network Protocols (ICNP), 2001. http://www.elec.qmul.ac.uk/research/thesis/XuefeiLi2006-thesis.pdf.

[8] R. Vinodkumar, R. S. D. Wahidabanu, “Performance Comparison of Wireless Mobile AD-HOC

Networks",European Journal of Scientific Research ISSN 1450-216X Vol.61 No.2 (2011), pp. 299-304

[9] Manveen Singh Chadha, Rambir Joon, Sandeep, "Simulation and Comparison of AODV, DSR and AOMDV Routing Protocols in MANETs", International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-2, Issue-3, July 2012 375

[10] Amit N. Thakare Mrs. M. Y. Joshi , "Performance Analysis of AODV & DSR Routing Protocol in Mobile Ad hoc Networks", IJCA Special Issue on "Mobile Ad-hoc Networks" MANETs, 2010 pp 211-218

[11] Jiwei Chen, Yeng-Zhong Lee, Daniela Maniezzo, Mario Gerla,"Performance Comparison of AODV and OFLSR in Wireless Mesh Networks", University of California, Los Angeles, CA 90095-1596, U.S.A. cjw@ee.ucla.edu, fyenglee,maniezzo,gerlag@cs.ucla.edu

[12] Sapna S. Kaushik & P.R.Deshmukh "Comparison of AODV, DSDV and DSR routing protocols in mobile adhoc networks", International Journal of Information Technology and Knowledge Management July-December 2009, Volume 2, No. 2, pp. 499-502

[13] S.Mittal & P Kaur,"Performance comparison of FSR, LAR1, LANMAR routing protocols in MANETs", V.V Das et all (eds):BAIP 2010, CCIS 70, pp 397-400, Springer-Verlog Berlin Heidelberg 2010.

[14] N. Javaid, A. Bibi, S. H. Bouk, A. Javaid, I. Sasase$, "Modeling Enhancements in DSR, FSR, OLSR under Mobility and Scalability Constraints in VANETs" ArXiv: 1207.6751v1 [cs:NI] 29 July 2012

[15] Surbhi Sharma, Himanshu Sharma, " Performance Comparison of AODV, DSR, DYMO and ANODR using QualNet Simulator", International Journal of Computer Information Systems, Vol. 2, No. 6, 2011

[16] S. Sathish, K. Thangavel and S. Boopathi, "Performance Analysis of DSR, AODV, FSR and ZRP Routing Protocols in MANET", MES Journal of Technology and Management, pp 57-61

[17] Network Simulator - NS2. www.isi.edu/nsnam/ns/.

AUTHOR'S PROFILE

B.Brahma Reddy obtained his B.Tech from JNTU and M.Tech from IIT, Madras in 1980 & 1982 respectively. He has worked for Indian Institute of Science, Indian Telephone Industries, National Informatics Centre, DishnetDSL, Reliance Infocomm for nearly 25 years. Past 6 years he is working as Professor in JNTU affiliated college. Currently he is perusing his Doctoral programme and working at VBIT, Hyderabad.

Prof. K.Kishan Rao obtained his B.E., M.E., degrees both in Distinction from O.U.College of Engineering , Osmania University in 1965 and 1967 respectively and Ph.D. from IIT Kanpur in the year 1973. Joined Regional Engineering College ,Warangal in 1972 and Retired as Principal in 2002. He has Guided 3 Ph.D. Candidates,76 M.Tech. Dissertations ,5 Research Projects and published about 68 Technical Papers in National and international Journals and Conferences. He is a Senior Member of IEEE, Life Member of IETE, Life Member of ISTE and Life Member of APSA. His Research Interest are Wireless & Mobile Communications, Adaptive Digital Signal Processing and OFDMA Networks. Presently working as Director and Adviser to Vaagdevi Group of Technical Institutions, Warangal.