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Routing Layer Parameters in Wireless Sensor Network

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Abstract

A wireless sensor network is consists of hundreds or thousands of nodes that are densely deployed in a large geographical area. These networks can be used in various applications like military, health and commercial. In WSN all nodes are not directly connected. Therefore, the data is exchanged by multihop communications. Therefore, a variety of routing metrics has been proposed for selecting the best path. This paper depicts some vital evaluation of general metrics that are essential for designing, developing and evaluating the performance of routing protocols for wireless sensor networks.

Keywords: *Routing protocol; General routing metrics; Performance Analysis; Wireless Sensor Network.*

1. Introduction

Wireless Sensor Network is the wireless network which is the combination of autonomous sensors to monitor or control environment conditions. Information that are to be collected or sensed are temperature, pressure , humidity, motion, heat, sound, light, electromagnetic field, vibration, images, pollutants etc.[1,2,3,4,5,6,7]. The popularity of WSN has increased due to growth in Micro-Electro-Mechanical Systems (MEMS) technology. The concept of wireless sensor networks is based on a simple equation: Sensing + CPU + Radio = Thousands of potential applications [8]. The sensor node has limited resources like energy, size, memory, computational power, communication range, bandwidth, so a large no of sensor nodes are distributed over a area of interest for collecting the information. So these nodes communicate with each other either directly or through intermediate nodes and thus form a network. So each node work as a router.Routing means providing the path for the data to flow in the network i.e. sending information from source to the sink via intermediate nodes[9]. The central goal of the routing in the network layer is to find out the minimum cost path for the packets from source to the sink. Data are routed from one node to other node using routing protocols. Routing protocols specifies how routers (sensor nodes) communicate with each other. Routing algorithm chooses the routes between nodes. There is no general solution for WSN problems. It depends upon application, budget (cost) & resource availability. WSN term can be broadly sensed as devices range from laptops, PDAs or mobile phones to very tiny and simple sensing devices. At present, most available wireless sensor devices are considerably constrained in terms of computational power, memory, efficiency and communication capabilities due to economic and technology reasons [1,2,3]. That‘s why most of the research on WSNs has concentrated on the design of energy and computationally efficient algorithms and protocols, and the application domain has been confined to simple data-oriented monitoring and reporting applications. WSNs nodes are battery powered which are deployed to perform a specific task for a long period of time, even years. If WSNs nodes are more powerful or mains-powered devices in the vicinity, it is beneficial to utilize their computation and communication resources for complex algorithms and as gateways to other networks. New network architectures with heterogeneous devices and expected advances in technology are eliminating current limitations and expanding the spectrum of possible applications for WSNs considerably.

2. Network Characteristics

The characteristics of sensor networks and application requirements have a decisive impact on the network design objectives in term of network capabilities and network performance **[10,12]**. As compared to the traditional wireless communication networks such as mobile ad hoc network (MANET) and cellular systems, wireless sensor networks have the following unique characteristics and constraints **[10]:**

2.1 Dense sensor node deployment: Sensor nodes are usually densely deployed and can be several orders of magnitude higher than that in a MANET.

2.2 Battery-powered sensor nodes: Sensor nodes are usually powered by battery and are deployed in a harsh environment where it is very difficult to change or recharge the batteries.

2.3 Severe energy, computation, and storage constraints: Sensors nodes are having highly limited energy, computation, and storage capabilities.

2.4 Self-configurable: Sensor nodes are usually randomly deployed and autonomously configure themselves into a communication network.

2.5 Unreliable sensor nodes: Since sensor nodes are prone to physical damages or failures due to its deployment in harsh or hostile environment.

2.6 Data redundancy: In most sensor network application, sensor nodes are densely deployed in a region of interest and collaborate to accomplish a common sensing task. Thus, the data sensed by multiple sensor nodes typically have a certain level of correlation or redundancy.

2.7 Application specific: A sensor network is usually designed and deployed for a specific application. The design requirements of a sensor network change with its application.

2.8 Many-to-one traffic pattern: In most sensor network applications, the data sensed by sensor nodes flow from multiple source sensor nodes to a particular sink, exhibiting a many-to-one traffic pattern.

2.9 Frequent topology change: Network topology changes frequently due to the node failures, damage, addition, energy depletion, or channel fading.

3. Network Design Challenges and Routing Issues

The design of routing protocols for WSNs is challenging because of several network constraints **[13-17]**. WSNs suffer from the limitations of several network resources, for example, energy, bandwidth, central processing unit, and storage. The design challenges in sensor networks involve the following main aspects:

3.1 Limited energy capacity: Since sensor nodes are battery powered, they have limited energy capacity. Energy poses a big challenge for network designers in hostile environments, for example, a battlefield, where it is impossible to access the sensors and recharge their batteries. Furthermore, when the energy of a sensor reaches a certain threshold, the sensor will become faulty and will not be able to function properly, which will have a major impact on the network performance. Thus, routing protocols designed for sensors should be as energy efficient as possible to extend their lifetime, and hence prolong the network lifetime while guaranteeing good performance overall.

3.2 Sensor locations: Another challenge that faces the design of routing protocols is to manage the locations of the sensors. Most of the proposed protocols assume that the sensors either are equipped with global positioning system (GPS) receivers or use some localization technique to learn about their locations.

3.3 Limited hardware resources: In addition to limited energy capacity, sensor nodes have also limited processing and storage capacities, and thus can only perform limited computational functionalities. These hardware constraints present many challenges in software development and network protocol design for sensor networks, which must consider not only the energy constraint in sensor nodes, but also the processing and storage capacities of sensor nodes.

3.4 Massive and random node deployment: Sensor node deployment in WSNs is application dependent and can be either manual or random which finally affects the performance of the routing protocol. In most applications, sensor nodes can be scattered randomly in an intended area or dropped massively over an inaccessible or hostile region. If the resultant distribution of nodes is not uniform, optimal clustering becomes necessary to allow connectivity and enable energy efficient network operation.

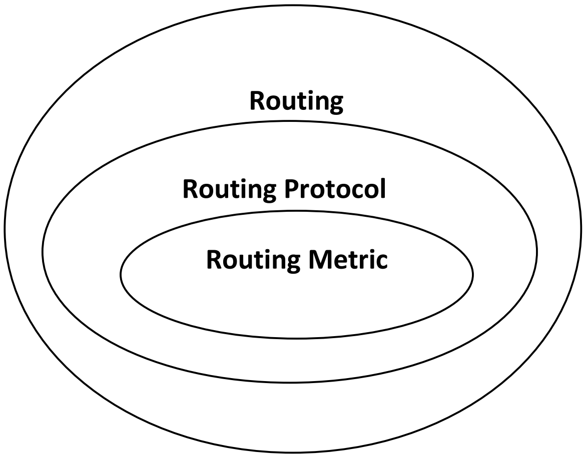
3.5 Network characteristics and unreliable environment: A sensor network usually operates in a dynamic and unreliable environment. The topology of a network, which is defined by the sensors and the communication links between the sensors, changes frequently due to sensor addition, deletion, node failures, damages, or energy depletion. Also, the sensor nodes are linked by a wireless medium, which is noisy, error prone, and time varying. Therefore, routing paths should consider network topology dynamics due to limited energy and sensor mobility as well as increasing the size of the network to maintain specific application requirements in terms of coverage and connectivity.

3.6 Data Aggregation: Since sensor nodes may generate significant redundant data, similar packets from multiple nodes can be aggregated so that the number of transmissions is reduced. Data aggregation technique has been used to achieve energy efficiency and data transfer optimization in a number of routing protocols.

3.7 Diverse sensing application requirements: Sensor networks have a wide range of diverse applications. No network protocol can meet the requirements of all applications. Therefore, the routing protocols should guarantee data delivery and its accuracy so that the sink can gather the required knowledge about the physical phenomenon on time.

3.8 Scalability: Routing protocols capabilities in terms of energy, processing, sensing, and particularly communication. Hence, communication links between sensors may not be symmetric, that is, a pair of sensors may not be able to have communication in both directions. This should be taken care of in the routing protocols should be able to scale with the network size.

4. Routing Layer Parameters or Routing metric



A routing metric is simply a measure used for selecting the best path, used by a routing Protocol.

We have five types of routing metrics. These are
1. General Metrics
2. Performance Metrics
3. Security Metrics
4. Quality of Service Metrics
5. Link Quality Metrics

4.1 General Metrics
General Metrics [26,27].are those metrics which are important for the evaluation of both real time and non real time routing protocols in wireless sensor networks. These are
1. Network Lifetime (LSN)
2. Energy/Power Consumption (EC/PC)
3. Load Imbalance Factor (LIF)
4. Routing Load
5. Normalized Routing Load

4.2 Performance Metrics
The performance metrics are necessary for evaluating the performance of a routing protocol
1. Throughput or Packet Delivery Fraction
2. Ratio of Corrupted Pings
3. Route Discovery Time
4. Route Maintenance and Fault Tolerance
5. Average Path Length
6. Average End to End Delay of Data Packets
7. Packet Delivery Ratio
8. Number of Failed Sensors (NFS)
9. Path length Extension Rate (PLER)
10. Query Successful Delivery Rate (QSDR) and Reply Successful Delivery Rate (RSDR)
11. Average Route Acquisition Latency

4.3 Security Metrics
These security metrics are a good indicator of the security tradeoffs but they alone are not enough to determine a defense's usability. They must be used in addition to other metrics.
1. Resiliency
2. Connectivity

4.4 Quality of Service Metrics
While designing any routing protocol, QoS should be guaranteed because many application scenarios of WSN have intrinsic QoS requirements
1. Data Packet Delay
2. Bandwidth Efficiency
3. Jitter

4.5 Link Quality Metrics

Link quality of the entire network plays an equally important role in self-health monitoring for WSNs.

1. Expected Transmission Count (ETX)
2. Requested Number of Packets (RNP)

5. General Metrics

5.1.1 Network Lifetime or Lifetime of Sensor Network (LSN)

The main objective of any routing protocol is to extend the lifetime of the sensor network (LSN).The lifetime of a wireless sensor network is an application-specific[28]. Currently, the lifetime of a sensor network is defined as the time for the first node or a certain percentage of network nodes to run out of power. we can define the LSN for three major application categories: active query, event driven, and passive monitoring. In an **active query** like application, the LSN can be defined as the maximum number of queries the sensor network can handle before the sensor network terminates. For an **event-driven** application, the LSN can be defined as total number of events the sensor network can process before the termination of it. For **passive monitoring**, the LSN can be defined as the total amount of time slots before termination. The termination of the sensor network is defined as the time slot when the RLSN starts to keep stable that implies that the sensor network loses connectivity or the coverage of the sensor network below a predefined threshold, θ, which means that the sensor network becomes useless. Model of lifetime of wireless sensor networks can be used by

- Both sensor system and protocol designers
- Sensor network practitioners (application scientists).

The novel Lifetime definition is proposed upon energy which considers

- The relationship between lifetime of a single sensor and that of a whole sensor network.
- Sensor positions
- Link quality in communication
- Connectivity & Coverage of sensor network

Model of lifetime of wireless sensor networks can be used as a metric to evaluate the

- Efficiency
- Effectiveness
- Performance of the designed Protocols & Algorithms

5.1.2 Lifetime of wireless sensor networks can be calculated as [29, 41]

LFT=min i

$$\mathrm{i} = \begin{bmatrix} \ell(\mathrm{i}-1) > \ell(\mathrm{i}) \,\&\, \ell(\mathrm{i}+1) = \ell(\mathrm{i}) & \text{Connectivity} \\ \mathrm{Cov}(\mathrm{i}-1) > \theta \,\&\, \mathrm{Cov}(\mathrm{i}) \le \theta & \text{Coverage} \end{bmatrix}$$

Where,
ℓ = Remaining lifetime of whole sensor network
θ = Predefined threshold of the coverage of the sensor network based on application requirements
Cov = Coverage of sensor network

5.1.3 Definition of RLSN (remaining lifetime of the whole sensor network) [29,41]

Remaining lifetime of the whole sensor network is the sum of the weighted remaining lifetime of all individual sensors in the sensor network (RLIS). Thus the remaining lifetime of the whole sensor network is

$$\ell = \sum_{j=1}^{N_n} w_j L(j)$$

Where
L(j) = remaining lifetime of individual sensor jth
Wj= weight for jth sensorweight for each sensor.

Based on above analysis, the nearer the sensor to the sink, the more important it is. So we define the weight of each sensor as following[29,41]:

$$w_j = c\frac{1}{d^2 jis}$$

Where c is the constant.
d_{jis} =distance between jth sensor node to sink at ith moment

5.1.4 Remaining lifetime of individual sensor (RLIS or L(j))

5.1.4.1 First definition

The remaining lifetime of individual sensor is defined as the normalized remaining energy of the sensor at moment Nm.

Where,

Nm.= Moment, which is the
No of queries in active query applications
No of events in event driven applications
No of time slots in passive monitoring applications

5.1.4.2 Second definition

RLIS is ratio of the remaining energy to the initial energy, which can be defined as

$$L(j)=\frac{E_j-\sum_{i=1}^{Nm} E_{jiq} * Rt_{jiq} + E_{jir} * Rt_{jir}}{E_j}$$

Where,

E_J=Total initial energy of jth node
$E_J = E_0$ when nodes are homogenous

E_{jiq} =It is the amount of energy consumed at the ith moment,if one query message goes through the jth sensor

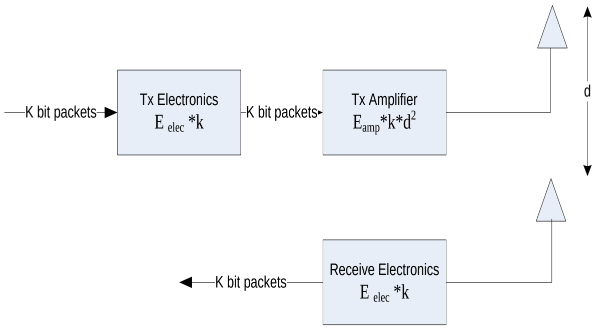
E_{jiq} =It is the amount of energy consumed at the ith moment,if one reply message goes through the jth sensor

5.2 Energy/Power Consumption (EC/PC)

The radio energy model is as given. For transmission of k bits message to a distance d, radio expends [24, 25, and 35].

$$E_{Tx\,(k,d)}=E_{Tx\text{- }elec(k)}+E_{Tx\text{- }amp(k,d)} \quad (1)$$

$$E_{Tx\,(k,d)}=E_{\,elec} *k+ E_{amp}*k*d^2 \quad (2)$$



Where,
$E_{Tx(k,d)}$ =Energy dissipated to transmit a k-bit message over distance d
$E_{Tx\text{-}elec(k)}$=Energy dissipated by transmitter electronics
$E_{Tx\text{-}amp(k,d)}$=Energy dissipated by amplifier electronics
E_{elec} = Constant energy of 50 nJ expended to run amp and transmitter circuitry

For reception, radio expends

$$E_{\,Rx(k)} =E_{Rx\text{- }elec\,(k)} \quad (3)$$

$$E_{\,Rx(k)} =E_{elec} *k \quad (4)$$

Where,
$E_{Rx\text{-}elec}$=Energy dissipated by receiver electronics

5.3 Load Imbalance Factor (LIF)

- As Lifetime of a sensor network depends upon the load imbalance factor (LIF) thus a good routing protocol should have a **feature of load balance** in order to extend the life of sensor network.
- LIF is used to quantitatively evaluate the load balance feature of the routing protocol
- It is formally defined as the variance of the remaining lifetime of the sensor network

The mathematical expression for Load Imbalance Factor (LIF) [24,25,28]

$$LIF=\sum_{j=1}^{n}(E_j-E_{avg})^2$$

Where,
n = Total number of sensors in the network
E_j= Remaining lifetime of sensor j
E_{avg} = Average remaining lifetime of all sensors nodes in the Wireless senor network

5.4.1 Routing Load [24,25,36].

- It is measured in terms of routing packets transmitted per data packets transmitted. The latter includes only the data packets finally delivered at the destination and not the ones that are dropped. The transmission at each hop is counted once for both routing and data packets. This provides an idea of network bandwidth consumed by routing packets with respect to “useful” data packets.
- Routing load measures the scalability of the protocols, how much overhead a protocol can take. The routing overhead measures by the total number of control packets sent divided

by the number of data packets sent successfully.

5.4.2 Routing overhead [24,25,36].

It is the total number of routing packets transmitted during the simulation. For packets sent over multiple hops, each packet transmission (hop) counts as one transmission.

5.4.3 Overhead (packets) [24,25,36].

It is the total number of routing packets generated divided by the sum of total number of data packets transmitted and the total number of routing packets

5.5 Normalized Routing Load [24,25,36].

The number of routing packets “transmitted” per data packet “delivered” at the destination
NRL Normalized Routing Load=Number of routing packets/ data packets
NRL = RF/PR
Where,
RF=Routing Packets (Number of routing packets sent or forwarded)
PR=Packet Received (Total number of packets received by the destination node)

5.6 Ratio Traffic Overhead

Ratio Traffic overhead is the ratio of the number of bits per second which the network uses to forward the useful bits from the source to the destination **[24, 25, 40]**.

5.7 Scalability

Scalability is the phenomenon which specifies that as the size of the network increases or the number of nodes increases the routing protocol should be able to adapt to the changes and provide consistent performance. **[24]**

6. Conclusion

Wireless Sensor Networks contains a large no of sensor nodes which are not directly connected to each other. Hence data is exchanged by multihop communications .So routing metrics has been proposed for selecting the best available path. This paper presents the evaluation of some vital general metrics that are useful for controlling and monitoring of routing activities.

References

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "A survey on sensor networks," Communications Magazine,IEEE, vol. 40, pp. 102-114, 2002
[2] Ian F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless Sensor Networks: A Survey," Computer Networks Elsevier Journal, Vol. 38, No. 4, pp. 393-422, March 2002.
[3] Jennifer Yick, Biswanath Mukherjee, Dipak Ghosal, "Wireless sensor network survey," Computer Networks,Elsevier, vol. 52, pp. 2292-2330, 2008.
[4] D. Culler, D. Estrin, M.Srivastava, "Overview of Sensor Networks," Computer Magazine,IEEE, vol. 37, no. 8, pp. 41-49, August 2004.
[5] Römer, Kay; Friedemann Mattern (December 2004), "The Design Space of Wireless Sensor Networks", IEEE Wireless Communications 11 (6): 54–61, doi:10.1109/MWC.2004.1368897, http://www.vs.inf.ethz.ch/publ/papers/wsn-designspace.pdf
[6] Tiwari, Ankit et. al, Energy-efficient wireless sensor network design and implementation for condition-based maintenance, ACM Transactions on Sensor Networks(TOSN),http://portal.acm.org/citation.cfm?id=1210670
[7] K. Martinez,J.K. Hart, and R. Ong, "Environmental Sensor Networks," Computer Magazine,IEEE, vol. 37, no. 8, pp. 50-56, 2004
[8] J. L.Hill, "System architecture for wireless sensor networks," University of California, Berkeley, Ph.D. dissertation 2003
[9] Sanatan Mohanty,” Energy Efficient Routing Algorithms for Wireless Sensor Networks and Performance Evaluation of Quality of Service for IEEE 802.15.4 Networks”, Department of Electronics & Communication Engineering National Institute of Technology, Rourkela. A thesis submitted in Master of Technology (Research), January 2010
[10] Shio Kumar Singh, M P Singh,and D K Singh,” Routing Protocols in Wireless Sensor Networks – A Survey”, International Journal of Computer Science & Engineering Survey (IJCSES) Vol.1, No.2, November 2010
[11] Rajashree.V.Biradar , V.C .Patil , Dr. S. R. Sawant, Dr. R. R. Mudholkar,” classification and

comparison of routing protocols in wireless sensor networks", Special Issue on Ubiquitous Computing Security Systems, UbiCC Journal – Volume 4

[12]Jun Zheng and Abbas Jamalipour, "Wireless Sensor Networks: A Networking Perspective", a book

[13]published by A John & Sons, Inc, and IEEEE, 2009

[14]W. Heinzelman, A. Chandrakasan and H. Balakrishnan, "Energy-Efficient Communication Protocol for Wireless Microsensor Networks," Proc. 33rd Hawaii Int'l. Conf. Sys. Sci., Jan. 2000.

[15]F. Ye et al., "A Two-Tier Data Dissemination Model for Large-Scale Wireless Sensor Networks," Proc. ACM/IEEE MOBICOM, 2002. http://www.ieee802.org/15/

[16] Jamal Al-Karaki, and Ahmed E. Kamal, "Routing Techniques in Wireless Sensor Networks: A Survey", IEEE Communications Magazine, vol 11, no. 6, Dec. 2004, pp. 6-28.

[17] Kemal Akkaya and Mohamed Younis, "A Survey on Routing Protocols for Wireless Sensor Networks", Ad hoc Networks, vol. 3, no. 3, May 2005, pp. 325-349.

[18]Luis Javier García Villalba, Ana Lucila Sandoval Orozco, Alicia Triviño Cabrera and Cláudia Jacy Barenco Abbas, "Routing Protocols in Wireless Sensor Networks",Sensors 2009, 9, 8399-8421; doi:10.3390/s91108399, sensors ISSN 1424-8220 www.mdpi.com/journal/sensors

[19]Kemal Akkaya and Mohamed Younis,"A Survey on Routing Protocols for Wireless Sensor Networks"

[20] Jennifer Yick, Biswanath Mukherjee, Dipak Ghosal," Wireless sensor network survey", J. Yick et al. / Computer Networks 52 (2008) 2292–2330, doi:10.1016/j.comnet.2008.04.002

[21]Muhammad Saleem , Gianni A. Di Caro , Muddassar Farooq," Swarm intelligence based routing protocol for wireless sensor networks: Survey and future directions", M. Saleem et al. / Information Sciences 181 (2011) 4597–4624, doi:10.1016/j.ins.2010.07.005

[22]Adamu MurtalaZungeru , Li-MinnAng , KahPhooiSeng," Classical and swarm intelligence based routing protocols for wireless sensor networks: A survey and comparison" A.M. Zungeru et al. / Journal of Network and Computer Applications 35 (2012) 1508–1536, http://dx.doi.org/10.1016/j.jnca.2012.03.004

[23]K. Padmanabhan," A Study on Energy Efficient Routing Protocols in Wireless Sensor Networks", European Journal of Scientific Research ISSN 1450-216X Vol.60 No.4 (2011), pp. 517-529 © EuroJournals Publishing, Inc. 2011 http://www.eurojournals.com/ejsr.htm

[24]Wazir Zada Khan, N.M. Saad, Mohammed Y Aalsalem,"An Overview of Routing Metrics for the Evaluation of Routing Protocols in Wireless Sensor Networks", European Journal of cientific Research ISSN 1450-216X Vol.79 No.2 (2012), pp.208-224 © EuroJournals Publishing, Inc. 2012 http://www.europeanjournalofscientificresearch.com

[25]Wazir Zada Khan, N.M.Saad, Mohammed Y Aalsalem," An Overview of Evaluation Metrics for Routing Protocols in Wireless Sensor Networks", 2012 4th International Conference on Intelligent and Advanced Systems (ICIAS2012)

[26] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless Sensor Networks: A survey", Computer Networks Journal, Elsevier Science, 2002, 38(4) , 393–422

[27]Y Yang and J Wang,, "Design Guidelines for Routing Metrics in Multi-hop Wireless Networks", InfoCom - 2008, 13-18, Phoenix, AZ, USA, 2008.

[28]K Sha, J Du, and W Shi, "WEAR: A Balanced, Fault-Tolerant, Energy-Aware Routing Protocol in WSNs", International Journal of Sensor Networks, 1 (2), 2006.

[29]Kewei Sha and Weisong Shi, "Modeling the Lifetime of Wireless Sensor Networks", Technical Report MIST-TR-2004-011, Wayne State University, 2004

[30]W.R.Heinzelman, A.Chandrakasan, and H.Balakrishnan, IEEE Transactions on Wireless Communications 1, 660 (2002).

[31]A.W oo, T.T ong, and D.Culler , Proc. of the First ACM SenSys'03 14 (2003).

[32]J.Zhao and R.Go vindan, Proc. of the First ACM SenSys'03 1 (2003).

[33] G.Zhou, T.He, S.Krishnamurthy , and J.A.Stank ovic, Proc. Of ACM MobiSys'04 125 (2004).

[34] K Sha, J Du, and W Shi, "WEAR: A Balanced, Fault-Tolerant, Energy-Aware Routing Protocol in WSNs", International Journal of Sensor Networks, 1 (2), 2006.

[35] R A Santos, Luis A. V Gonzalez, J Sanchez, José R. Gallardo, " Performance Analysis of Routing strategies for wireless sensor networks", (WSAN 2007). Albacete, Spain, September 24 – 26, 2007

[36]Monica R Mundada, Savan Kiran , Shivanand Khobanna, Raja Nahusha Varsha and Seira Ann George," a study on energy efficient routing protocols in wireless Sensor networks", International Journal of Distributed and Parallel Systems (IJDPS) Vol.3, No.3, May 2012

[37] Zuniga, M. Z.; Krishnamachari, B. (2002), "Integrating Future Large-Scale Wireless Sensor Networks with the Internet," - Department of Electrical Engineering, UNiversity of Southern California.

[38] Alonso, J., Dunkels, A., Voigt. T, (March 2004), “Bounds on the energy consumption of routings in wireless sensor nodes” WiOpt'04: Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks,” Cambridge, UK.

[39] A A Basset Almamou, R Wrede, P Kumar, H Labiod, J Schiller, “Performance Evaluation of Routing Protocols in a Real-World WSN”, IEEE GIIS - 2009.

[40] Kewei Sha and Weisong Shi,” Poster Abstract: Revisiting the Lifetime of Wireless Sensor Networks”, SenSys’04, November 3–5, 2004, Baltimore, Maryland, USA.

[41] Prof.K. Manikandan, Dr.T.Purusothaman,” An Efficient Routing Protocol Design for Distributed Wireless Sensor Networks”, International Journal of Computer Applications (0975 – 8887) Volume 10– N.4, November 2010