



Performance Evaluation of Hierarchical and Location Based Routing in Wireless Sensor Networks

A. SADAF⁺⁺, H. ZAFAR, S.R. HASSNAIN*, M.S. LAIQ, F. ALI

Department of Electrical Engineering, University of Engineering and Technology, Peshawar, Pakistan

Received 17th August 2014 and Revised 6th November 2014

Abstract: A Wireless Sensor Network (WSN) contains special distributed autonomous devices called sensor nodes in order to keep track of physical and ecological conditions for instance temperature, strain, vibration, noise, moisture, motion or toxins and also to coordinately pass the information from the network to particular location. Routing in WSN is very challenging because of features that separate these kinds of networks from other wireless networks. To extend network lifetime creating efficient routing protocols is crucial. Despite the fact that WSN are generally intended for surveillance as well as reporting activities, because they are application based so a single routing protocol is not suitable for all applications regarding WSN. This contrast of routing protocols uncovers the important capabilities that must be considered while creating and analyzing new routing protocols regarding sensor systems. This work thoroughly investigates key Hierarchical and Location based routing protocols using Network Simulator 2 (NS2) and evaluates the performance of these protocols against some performance metrics that helps to select performance wise best protocol.

Keywords: Wireless Sensor Network, Hierarchical routing, Location based routing, Network Simulator 2.

1. INTRODUCTION

Today Wireless Sensor Network (WSN) (Pantazis and Vergados, 2007) is getting acclaim in numerous commercial, industrial and modern parts. WSN give powerful, adaptable, ease, vigor effective and simple to convey system which are the fundamental requests of applications. WSN are used in environmental monitoring, habitat monitoring, military, healthcare, surveillance, education, and agricultural fields. Unlike traditional wired or wireless networks, WSN have strict resource constraints in terms of operation, storage, and routing. Many protocols have been proposed to avoid all the constraint issues in WSN. Routing protocols must be capable to deal with challenges like energy efficiency, scalability, delay, low operational and routing overhead (Pantazis *et al.*, 2013).

In WSN main purpose of routing is directing data from source to destination, whenever data is present as a result of either any event or query generated by network node. In order to route data to the destination routing paths must be defined by nodes. These routing paths should conserve energy in order to avoid energy limitation. Applying energy efficient routing protocols enable WSN to get through stringent routing constraints. Energy efficient routing protocols enable the sensor nodes to select such optimal energy efficient routing paths that helps to conserve energy, increase network lifetime and increase network performance.

This paper evaluates key hierarchical and location based routing protocols that would help in

selecting best suited energy efficient routing protocol for an application.

2. MATERIALS AND METHODS

We select some of hierarchical routing protocols and a location based routing protocol in order to investigate their performance. The selected routing protocols are:

2.1 LEACH:

Low Energy Adaptive Clustering Hierarchy (LEACH) (Heinzelman *et al.*, 2000) (Handy *et al.*, 2002) is a cluster-based Hierarchical approach that involves cluster formation. It randomly elects some sensor nodes as cluster heads that help in uniform distribution of energy among network nodes. These cluster head nodes compress, aggregate the data coming from other nodes and transfer that data to base station thus reducing the amount of information forwarded to base station. The functioning of LEACH is divided into setup phase and steady state phase. During setup phase clusters are formed and cluster heads are decided on while in steady state phase data transmission to base station occurs. The steady state phase lasts for more time as compared to step up phase thus minimizing the overhead.

2.2 LEACH-C:

It is also a hierarchical protocol. LEACH-Centralized (LEACH-C) (Vidhate *et al.*, 2010) (Heinzelman *et al.*, 2002) is an improvement to LEACH and it belongs to LEACH family. LEACH-C protocol has exactly the same setup state as that of LEACH, but

⁺⁺Corresponding Author: A. Sadaf, aatrasadaf@yahoo.com, Ph. No +92-91-9216498

*Department of Electronics Engineering, University of Engineering and Technology, Peshawar (Abbotabad Campus), Pakistan

it has a difference in the cluster head formation stage. Centralized means that all nodes send their energy levels along with their ID and status to the base station and then it is the function of base station to decide a cluster head for them. The rest of operation is exactly the same as that of LEACH protocol.

2.3 PEGASIS:

Power Efficient Gathering in Sensor Information System (PEGASIS) (Lindsey and Raghavendra, 2002) is a chain based hierarchical approach. PEGASIS protocol is a well-known protocol for information gathering and uses the concept that all nodes in network knows the position of other nodes in that network, which means that information about topology is provided to all nodes. Every node in network take turns to become a leader node which must have sufficient transmission range in order to hop data to base station. PEGASIS use greedy algorithm in order to build a chain of nodes, originating from that node which is distinct from base station so this protocol actually divide the energy load among the sensor nodes in the network. At each move, closest local neighbor that has not been visited before is included in the chain. A chain is constructed before data transmission and rebuilt a new chain whenever any node dies out eliminating that node.

2.4 GPSR:

Greedy Perimeter Stateless Routing (GPSR) (Karp and Kung, 2002) is one of the earliest location based routing methods pertaining to ad hoc networks that can also be applied for WSN. GPSR utilizes greedy forwarding technique where originators of packets designate the packet's destination location. Therefore, it enables the forwarding node to make an optimum greedy selection in selecting a next hop to forward the packet. In case a node is aware of their radio neighbor's location then the neighbor node that is geographically nearest to the packet's destination is the best selection of next hop. The benefit of greedy forwarding is its dependence solely on information about immediate neighbors of forwarding node. Comparison of LEACH, LEACH-C, PEGASIS and GPSR protocols is given in (Table 1).

3. RESULTS AND DISCUSSION

We simulate LEACH, LEACH-C, PEGASIS and GPSR and here the simulation results (Zafar et al., 2012) in Network Simulator 2 (NS-2) (NS-2, 2014) of all the three protocols are compared based on key important metrics which are throughput, network lifetime and energy consumption.

Network consist of 100 nodes, nodes are placed between (0,0) (100,100) coordinates. Base station is placed at (50,175). For 100 node network we

Table 1: Comparison of LEACH, LEACH-C, PEGASIS and GPSR

	LEACH	LEACH-C	PEGASIS	GPSR
Advantages	Low energy, adhoc, distributed protocol	The energy for data transmission is less than LEACH	Transmitting distance for most of nodes is reduced	Tries to balance energy consumption thus increasing network lifetime
Limitations	It is not applicable to networks deployed in large regions and dynamic clustering brings extra overhead	Overhead	There is no consideration of base station's location about energy of nodes when one of the node is selected as head node	Periodic table exchange
Scalability	Good	Good	Good	Good
Mobility	Fixed BS	Fixed BS	Fixed BS	Limited
Route Metric	Shortest path	Best route	Greedy route selection	Greedy forwarding, shortest energy efficient route
Periodic Message type	None	None	None	Hello message
Robust	Good	Good	Good	Good
Data Aggregation	Yes	Yes	No	No
Delivery Delay	Very Small	Very Small	Very large	Very small
Energy Efficiency	Very poor	Poor	Medium	Good
Load balancing	Medium	Medium	Medium	Good
Class	Hierarchical, clustering based	Hierarchical, clustering based	Hierarchical chain based	Location based

take 5 clusters as it is optimum number of cluster heads. Initial energy set for each node is 2joules and time frame for each round is 20seconds. Number of active nodes in network are 60.

3.1 Throughput:

Data sent to base station is plotted against time in order to evaluate and compare the throughput for these three protocols. Our simulation results are plotted in (Fig. 1). Graph shows that LEACH and LEACH-C are related to each other. LEACH-C is performing better than LEACH because base station performs centralized computation in order to select cluster heads and also take energy into consideration while selecting cluster heads. LEACH-C is 44.6% more efficient than LEACH. It is shown in graph that LEACH-C has better throughput than LEACH, as data send to base station by LEACH-C is higher than LEACH. It is found that PEGASIS is better than both LEACH-C and LEACH as PEGASIS eliminates the dynamic clustering overhead and transmission distance between non leader nodes. Results show that PEGASIS is 121% more efficient in terms of throughput than LEACH. We can see as GPSR uses greedy state routing so it is very much efficient as compared to other clustering protocols. GPSR is 167% efficient in performance than LEACH.

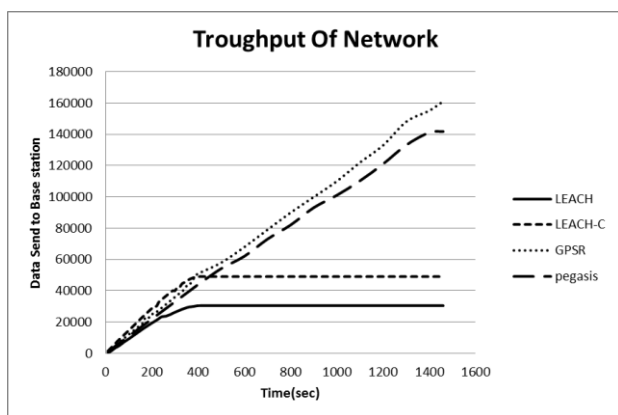


Fig. 1: Data send to Base station vs time

3.2 Network Lifetime:

Here alive nodes are plotted against time in order to evaluate and compare the network lifetime for these three protocols. Our simulation results for network lifetime are plotted in (Fig. 2). Graph shows that GPSR has higher network lifetime than other three protocols because it selects shortest and energy efficient path. Thus, less energy depletion of nodes as compare to other protocols. GPSR is 43% much better in performance than LEACH in terms of network lifetime. PEGASIS is chain based approach that distributes the energy load between all the network nodes thus increasing the network lifetime and network quality. PEGASIS is better than both LEACH and LEACH-C in terms of network lifetime. It is found that PEGASIS is 38% efficient than LEACH. In LEACH-C base station selects the cluster heads by considering energy levels of nodes and nodes with greater energy resources is selected which increases network lifetime as compared

to LEACH. LEACH-C is 9% efficient in terms of network lifetime than LEACH.

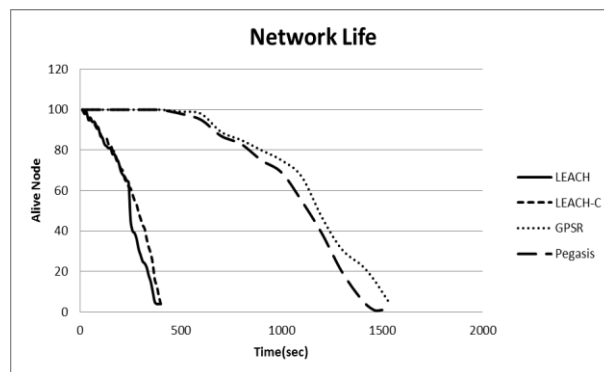


Fig.2: No. of Alive Nodes vs Time

3.3 Energy Dissipation:

Energy dissipated in network is plotted against time in order to evaluate and compare network energy dissipation. Simulation results for energy consumption are plotted in (Fig. 3) which shows that GPSR is very efficient in energy consumption. As stated earlier GPSR increases the life of the network, it became possible due to its efficiency in energy consumption. GPSR outperforms all the three protocols. In terms of energy consumption GPSR is 314% much efficient in performance than LEACH. PEGASIS is energy efficient than both LEACH and LEACH-C as network lifetime is greater because of energy load sharing among nodes. PEGASIS is 201% energy efficient than LEACH. LEACH-C is 5% better in terms of energy dissipation than LEACH.

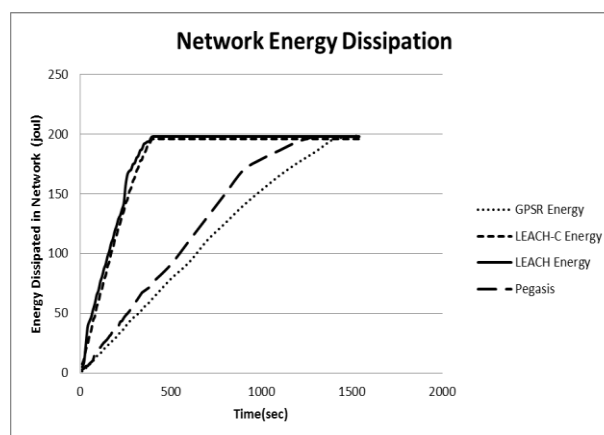


Fig. 3: Network Energy Dissipation vs Time

From the above results we analyze that LEACH-C is better than LEACH in terms of throughput, network lifetime and energy dissipation because base station computes the clusters by taking location and energy of node into consideration, and best cluster heads are selected based on energy resources. PEGASIS outperforms both LEACH-C and LEACH as

it uses greedy chain approach, eliminates dynamic clustering overhead, minimizing the transmission distances among non-leader nodes. Unlike LEACH and LEACH-C that have large transmission distance between nodes and cluster head, as data fusion occurs at each node thus limiting the number of transmission and reception between all nodes, utilizes one transmission to base station per round unlike LEACH and LEACH-C where number of transmissions depends on number of cluster heads, atmost two transmission to leader node unlike LEACH and LEACH-C where number of transmissions to cluster heads, nodes take turns in order to transfer fused data to base station in order to balance the node energy depletion, in each communication round the head node takes random position on chain which is necessary for nodes to die at random positions making protocol robust to different failures , distributes the energy load between nodes thus increasing network quality. As compare to other protocols, GPSR uses greedy routing approach, employs geography to attain small routing state for each node. Its main advantage is that it utilizes merely immediate neighbor details in order to make forwarding decisions thus minimizing extra overhead. In dense networks this protocol has extremely high packet delivery rate. GPSR yields the traffic in the amount independent of length of paths through the sensor network thus yields constant minimal volume routing protocol messages as mobility improves but does not endure lowered robustness to find routes. It has high reliability of packet delivery and less packet delivery delay. In case of high traffic it can easily find alternate shortest and energy efficient path from available routes. The protocol is robust in finding path to destination which is shortest and energy efficient. In case of path failure it can easily find alternate shortest and energy efficient path from available ones. Thus, GPSR a location-based outperforms all the three clustering protocols in terms of throughput, network lifetime, energy consumption.

4. CONCLUSION

In this paper, we compared the four protocols LEACH, LEACH-C, PEGASIS and GPSR. We setup experimental model and by comparison of simulation results we found that GPSR was better in performance in terms of throughput, network life time and energy consumption than PEGASIS, LEACH-C and LEACH, while PEGASIS was better than LEACH-C and LEACH, and LEACH-C was better than LEACH.

REFERENCES:

- Handy M. J., M. Haase and D. Timmermann (2002) "Low Energy Adaptive Clustering Hierarchy with Deterministic Cluster-Head Selection", In Proc. 4th International Workshop on Mobile and Wireless Communications Network, USA, vol. 1: 368-372.
- Heinzelman W., A. Chandrakasan and H. Balakrishnan (2000) "Energy-Efficient Communication Protocol for Wireless Microsensor Networks", In Proc. 33rd Hawaii International Conference on System Sciences, HI, USA, vol. 8: 110.
- Heinzelman W., A. Chandrakasan and H. Balakrishnan (2002) "An Application-Specific Protocol Architecture for Wireless Microsensor Networks", IEEE Trans. Wireless Commun. 1(4): 60-70.
- Karp B. and H. T. Kung (2000) "Greedy Perimeter Stateless Routing for Wireless Networks", In Proc. of the Sixth Annual ACM/IEEE International Conference on Mobile Computing and Networking (MobiCom 2000), Boston, MA.
- Lindsey S. and C. Raghavendra (2002) "PEGASIS: Power-Efficient GATHERing in Sensor Information Systems", In Proc. IEEE Aerospace Conference, USA, Montana, vol. (3): 1125-1130.
- NS-2 (The Network Simulator, 2) (2014) <http://www.isi.edu/nsnam/ns/>.
- Pantazis N. A. and D. D. Vergados (2007) "A Survey on Power Control Issues in Wireless Sensor Networks", IEEE ,Communications Surveys, 9 (4): 86-107.
- Pantazis N. A., S. A. Nikolidakis and D. D. Vergados (2013) "Energy-Efficient Routing Protocols in Wireless Sensor Networks: A Survey", IEEE Communications Surveys & Tutorials, 15 (2), 551-591.
- Vidhate D. A., A. K. Patil and S. S. Pophale (2010) "Performance Evaluation of Low Energy Adaptive Clustering Hierarchy Protocol for Wireless Sensor Networks", In Proc. International Conference and Workshop on Emerging Trends in Technology (ICWET 2010) TCET, Mumbai, India: 59-63.
- Zafar H., M. D. Z. Harle and I. Andonovic (2012) "A Review of Techniques for the Analysis of Simulation Output", IETE Technical Review, 29 (3): 223–228.