Performance Evaluation of Clustering Algorithms in Wireless Sensor Networks

SHOLLA, SAHIL and G.H. RASOOL BEGH*
National Institute of Technology Srinagar, India
sahilsholla@gmail.com

GH. RASOOL BEGH
National Institute of Technology Srinagar, India

ABSTRACT

Wireless Sensor Networks (WSNs) is one of the emerging and fast growing fields in the scientific world which has a wide range of applications like monitoring physical world events, preparing forecasts, severe environment detection, disaster relief, battlefield surveillance etc. WSNs are highly integrated technologies using sensors, microcontrollers and wireless networking capabilities that operate unattended in harsh environments with limited energy supplies. Thus network lifetime is constrained by the limited power supply of nodes. Clustering plays an effective role in judicious use of dwindling energy resources of the deployed sensor nodes. Nodes are grouped into clusters and a specific designated node, called the cluster head is responsible for its cluster. In this paper, we study the energy efficiency of clustering algorithms S-Web and LEACH. Our results show that the S-Web clustering achieves a noticeable improvement in the network lifetime.

Categories and Subject Descriptors: C.2.1 [C**omputer-Communication Networks**]: Network Architecture and Design—*Wireless communication*;

Additional Keywords and phrases: Clustering, SWEB, Wireless Sensor Networks, LEACH, Network Lifetime.

IJCIR Reference Format:

Sholla, Sahil and G.H. Rasool Begh. Performance Evaluation of Clustering Algorithms in Wireless Sensor Networks International Journal of Computing and ICT Research, Vol. 8, Issue 1 pp 68-73. http://www.ijcir.org/volume8-issue 1/article 6.pdf.

1. INTRODUCTION

Recent advances in miniaturization and low-power design have led to the development of small-sized battery-operated sensors that are capable of detecting ambient conditions such as temperature and sound [Abbasi and Younis M. 2007]. A typical node of a WSN is equipped with four components: a sensor that performs the sensing of required events in a specific field, a radio transceiver that performs radio transmission and reception, a microcontroller: which is used for data processing and a battery that is a power unit providing energy for operation [Chaurasiya et al. 2011]. These sensor nodes can be deployed randomly to perform such applications as monitoring environment, battlefield reconnaissance, border protection and security surveillance, preparing forecasts, volcano monitoring etc.

The limited energy of each node, supplied from non-rechargeable batteries, with no form of recharging after deployment and the possibility of having damaged nodes during deployment is one of the most crucial problems in WSN. Given the importance of energy efficiency in WSNs, most of the algorithms proposed for WSNs concentrate mainly on maximizing the lifetime of the network by trying to minimize the energy consumption [Abbasi and Younis

* Author's Address: Sholla Sahil, National Institute of Technology Srinagar India, *sahilsholla@gmail.com* and G.H. Rasool Begh, National Institute of Technology Srinagar India

International Journal of Computing and ICT Research, ISSN 1818-1139 (Print), ISSN 1996-1065 (Online), Vol. 8, Issue 1, pp. 68-73, June 2014

M. 2007). Other application specific design objectives like high fidelity target detection and classification, security, real time communication etc may also considered.

Clustering plays an effective role in judicious use of dwindling energy resources of the deployed sensor nodes, which groups nodes into clusters and a specific designated node, called the cluster head is responsible for collecting data from the nodes in its clusters, aggregating them and sending to the BS, where data can be retrieved later. Besides energy efficiency, clustering has many other advantages, it reduces the routing overhead, conserves communication bandwidth, stabilizes the network topology, supports network stability etc (Akkaya and Younis 2005; Sherali et al 2005; Umamaheswari and Radhamani 2012; Younis et al. 2003).

In this paper we analyze the energy efficiency of S-Web and LEACH clustering algorithms. The rest of the paper is organized as follows. Section 2 presents LEACH algorithm, section 3 describes S-Web algorithm, performance evaluation is in section 4. Finally section 5 concludes the paper.

2. LEACH

Low-Energy Adaptive Clustering Hierarchy or LEACH (Heinzelman et al. 2000) forms clusters by using a distributed algorithm, where nodes make autonomous decisions without any centralized control. Initially a node decides to be a CH with a probability p and broadcasts its decision. Each non- CH node determines its cluster by choosing the CH that can be reached using the least communication energy. The algorithm provides a balancing of energy usage by random rotation of CHs. It forms clusters based on the received signal strength and uses the CH nodes as routers to the base-station. All the data processing such as data fusion and aggregation are local to the cluster. LEACH provides the following key areas of energy savings: No overhead is wasted making the decision of which node becomes cluster head as each node decides independent of other nodes, CDMA allows clusters to operate independently, as each cluster is assigned a different code, Each node calculates the minimum transmission energy to communicate with its cluster head and only transmits with that power level. Changing the CH is probabilistic in LEACH; there is a good chance that a node with very low energy gets selected as a CH. When this node dies, the whole cluster becomes non functional. LEACH also forms one-hop intra- and inter cluster topology where each node can transmit directly to the CH. Then the aggregated data is transmitted to the base station.

3. S-WEB

Sensor Web or S-Web (Poliah et al. 2008) organizes sensors into clusters based on their geographical location without requiring the sensors to have a Global Positioning System or actively locate themselves. The S-Web enables nodes to route data packets while consuming low energy in a decentralized manner. The model is self-organizing and distributed without the need of global network knowledge. Each cluster is identified by angle order (β) and the order of Signal Strength threshold (δ). The BS in S-WEB will send beacon signals for every α degree angle, one at a time. Sensors that receive the beacons at time slot i will measure their signal strength to determine their relative distances to the BS. Let T be a predefined distance (which is inversely proportional to the received signal strength). All sensors which receive beacon signals at angle order βi (=i*α) with signal strength of δj*T (within sector j) will be in the same group/cluster, denoted as (βi,δj). Nodes with the same (β,δ) belong to the same cluster. Since nodes in the same cluster know about each other, the role of being a CH can be rotated to prolong the lifespan of CH.

4. PERFORMANCE EVALUATION

We implement the S-Web and LEACH clustering algorithms and consider 20 sensors deployed randomly in the area 40 X 40 m^2 field and the BS located at the position (0, 0). Scanning angle α is 10 degree and maximum sensor distance to BS is 70 m. All nodes have the same initial energy of 0.5 Joule. The radio model used for energy consumption is presented in (Heinzelman et al. 2000). A data packet here has k = 2000 bits. We assume that the sensors do not have data to send all the time. We also assume all nodes are homogeneous and they have the same capabilities.

This section is divided into several scenarios, energy efficiency of each scenario analyzed and corresponding network lifetimes estimated. The result shown is the average of number of hops and energy consumed per message. To evaluate the WSN lifespan, we use a round as a measure unit. A round is defined as when 200 messages reach their destination.

a. First scenario (Normal Node to Normal Node)

In the first scenario, we consider communication between any random pair of normal nodes. Table 1 is the performance result of communication between pairs of normal nodes.

Table 1: Communication Normal Node to Normal Node

	Energy (µJ)	Hops
LEACH	3812.28	6
S-Web	1932.86	3

S-Web has lower average number of hops and energy consumption per message than LEACH. The reason for high energy consumption in LEACH is that the cluster heads are only aware of the nodes in their own cluster. Also the BS does not have global network knowledge. However, in S-Web, the cluster heads in addition to maintaining the local cluster information also contain limited global topology information. Thus, frequent communication with BS is avoided and energy saved.

Fig. 1 illustrates network lifetime, in terms of percentage number of nodes alive against number of rounds. Fig. 1 shows, the network lifetime increases from 13 rounds in LEACH to 24 rounds in S-Web.

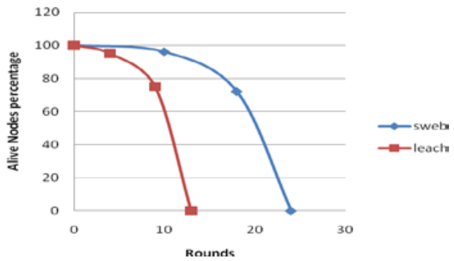

Fig. 1 Network Lifetime Normal Node to Normal Node

b. Second scenario (Normal Node to Cluster Head)

In the second scenario, we consider communication between a random pair of normal node and cluster head. Table 2 shows the energy expended for the two algorithms.

Table 2: Communication Normal Node to Cluster Head

	Energy (µJ)	Hops
LEACH	1937.32	3
S-Web	807.06	2

Since a cluster head itself forms the destination of data here, the energy consumption is less compared to the previous scenario. Here also, S-Web performs better because cluster heads maintain limited global topology whereas cluster heads in LEACH clustering scheme require querying the BS to contact the cluster heads of other regions. Fig. 2 shows network lifetime, in terms of percentage number of nodes alive against number of rounds.

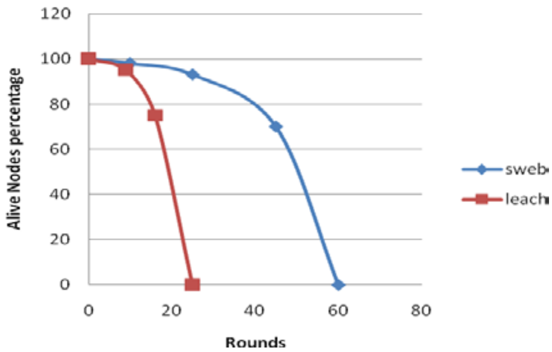

Fig. 2 Network Lifetime Normal Node to Cluster Head

Owing to lesser energy consumption, the lifetime of both the algorithms has extended, more so for S-Web. For the given scenario, the network lifetime increases from 25 rounds in LEACH to 60 rounds in S-Web.

c. Third scenario (Cluster Head to Normal Node)

In this scenario, the source and destination of message have been reversed compared to scenario *B.* Table 3 shows the performance result for this scenario.

Table 3: Communication Cluster Head to Normal Node

	Energy (µJ)	Hops
LEACH	3191.94	5
S-Web	792.23	2

For the S-Web algorithm, the current scenario is analogous to the second scenario, so energy consumption would be approximately the same. However, in case of LEACH algorithm, when a node needs to communicate to a node belonging to other cluster, its cluster head has to query the BS to know addresses of other cluster heads. Moreover the BS itself does not contain global network topology information. This explains the high energy difference for LEACH algorithm between the current scenario, 3191.94 µJ as against the second scenario, 1937.32 µJ.The network lifetime of the two algorithms is show in the Fig.3

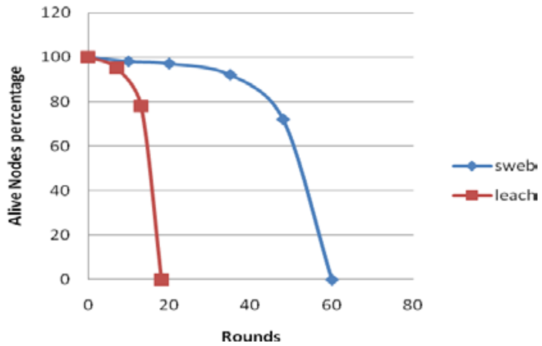

Fig. 3 Network Lifetime Cluster Head to Normal Node

As the graph indicates, the lifetime of S-Web has remained largely unchanged while as for LEACH, it drops from 25 rounds (second scenario) to 18 rounds. Overall, network lifetime increases from 25 rounds in LEACH to 60 rounds in S-Web.

d. Fourth scenario (Cluster Head to Cluster Head)

In the fourth scenario, we consider communication between cluster heads randomly. This is the simplest among all the scenarios. Table 4 shows energy expended for this scenario.

Table 4: Communication Normal Node to Normal Node

	Energy (µJ)	Hops
LEACH	1312.79	2
S-Web	422.95	1

Here a cluster head itself forms both the source and destination of data, hence energy consumption is the minimum. Fig. 4 shows the corresponding network lifetime.

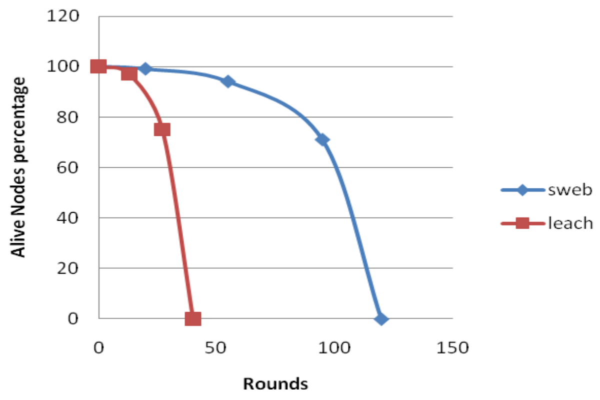

Fig. 4 **Network Lifetime Cluster Head to Cluster Head**

As can been seen from the Fig. 4, the lifetime of both the algorithms has largely extended, 40 rounds in LEACH and 120 rounds in S-Web.

e. Fifth scenario (Random)

This scenario represents a high level abstraction of the previous scenarios in which communication takes place between a random pair of sensors. This scenario captures the overall trend of the network lifetime in the two algorithms. Table 5 is the performance result of communication between random pairs of nodes.

Table 5: Communication between Random pairs of nodes

	Energy (µJ)	Hops
LEACH	2563.58	4
S-Web	988.77	2

The average energy consumption of LEACH is observed to be 2563.58µJ whereas in case of S-Web it is 988.77µJ. S-Web, thus has a lower overall average number of hops and energy consumption per message than LEACH.

Fig. 5 shows the network lifetime for communication between random pairs of sensors.
As the Fig. 5 clearly indicates, S-Web clustering mechanism achieves a noticeable improvement in the network lifetime**.** For the random scenario, the network lifetime increases from 27 rounds in LEACH to 50 rounds in S-Web. This is because sensors in S-Web can communicate with each other directly without having to go to the BS. The cluster heads in S- Web, in addition to the local topology information, also maintain information about the status of cluster heads in other clusters. This decoupling of BS from routing decisions greatly helps in improving the network lifetime.

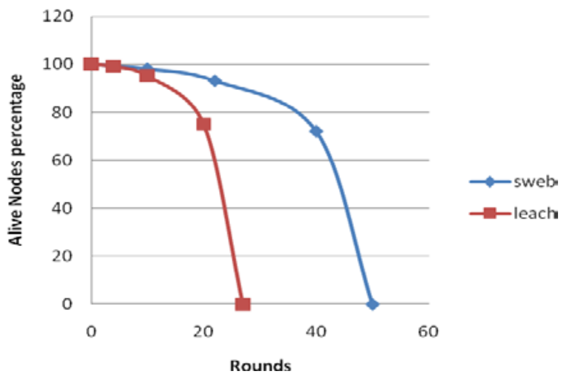

Fig. 5 Network Lifetime Random pairs of nodes

5. CONCLUSION

Energy efficiency is a critical design issue in WSNs particularly when they operate unattended in harsh environments. Clustering plays an effective role in prolonging the lifetime of WSNs by making efficient use of the limited energy resources. In this paper, we implemented S-Web and LEACH clustering algorithms and considered several scenarios to compare their energy efficiency. The simulation results show that S-Web achieves a noticeable improvement in prolonging the lifetime of a wireless sensor network than LEACH. Energy intensive setup phase, lack of routing information and global topology information at CH and BS respectively, account for high energy consumption in LEACH.

6.0 REFERENCES

ABBASI A., YOUNIS M. 2007. A survey on clustering algorithms for wireless sensor networks. *Computer Communications* 30 2826-2841.

AKKAYA K., YOUNIS M. 2005. A survey on routing protocols for wireless sensor networks. *Elsevier Journal of Ad Hoc Networks* 3 325–349.

CHAURASIYA, S.K., PAL, T., BIT, S.D. 2011. An Enhanced Energy-Efficient Protocol with Static Clustering for WSN. *International Conference on Information Networking* (ICOIN), 2011 Kuala Lumpur, Malaysia, 58 – 63.

HANH, HOANG AND POLIAH 2008.SWeb: an efficient and self-organizing Wireless Sensor Network Model. *The 2nd International Conference on Network-Based Information Systems*, Turin, Italy 2008.

HEINZELMAN W., CHANDRAKASAN A. AND BALAKRISHNAN H., 2000.Energy- Efficient Communication Protocol for Wireless Micro sensor Networks" *Proceedings of the 33rd Hawaii International Conference on System Sciences* 2 10.

HOU Y.T., SHI Y., SHERALI H.D. 2005. On energy provisioning and relay node placement for wireless sensor networks. *IEEE Transactions on Wireless Communications* 4 (5) 2579–2590.

UMAMAHESWARI & G RADHAMANI 2012, Clustering Schemes for Mobile Adhoc Networks : A Review, *International Conference on Computer Communication and Informatics*, 2012

YOUNIS M., YOUSSEF M.., ARISHA K. 2003. Energy-aware management in cluster-based sensor networks. *Computer Networks* 43 (5) 649–668.