April 2012

HIERARCHICAL ROUTING PROTOCOLS FOR WIRELESS SENSOR NETWORK–A SURVEY

RENGUGADEVI G

ECE Department Bannari Amman Institute of Technology, Sathyamangalam, TamilNadu,
renuga_gangapathy@yahoo.in

SUMITHRA M. G

ECE Department Bannari Amman Institute of Technology, Sathyamangalam, TamilNadu,
mgsumithra@rediffmail.com

Follow this and additional works at: <https://www.interscience.in/ijssan>

Part of the [Digital Communications and Networking Commons](#), and the [Electrical and Computer Engineering Commons](#)

Recommended Citation

G, RENGUGADEVI and G, SUMITHRA M. (2012) "HIERARCHICAL ROUTING PROTOCOLS FOR WIRELESS SENSOR NETWORK–A SURVEY," *International Journal of Smart Sensor and Adhoc Network*: Vol. 2 : Iss. 3 , Article 11.

DOI: 10.47893/IJSSAN.2013.1164

Available at: <https://www.interscience.in/ijssan/vol2/iss3/11>

This Article is brought to you for free and open access by the Interscience Journals at Interscience Research Network. It has been accepted for inclusion in International Journal of Smart Sensor and Adhoc Network by an authorized editor of Interscience Research Network. For more information, please contact sritampatnaik@gmail.com.

HIERARCHICAL ROUTING PROTOCOLS FOR WIRELESS SENSOR NETWORK—A SURVEY

RENGUGADEVI G¹ & SUMITHRA M.G²

^{1,2}ECE Department Bannari Amman Institute of Technology, Sathyamangalam, TamilNadu
E-mail: renuga_gangapathy@yahoo.in, mgsumithra@rediffmail.com

Abstract— Wireless sensor networks are a web of sensor nodes with a set of processor and limited memory unit embedded in it. Reliable routing of packets from the sensor node to its base station is the most important task for the networks. The routing protocols applied for the other networks cannot be used here due to its battery powered nodes. This paper gives an overview of the different hierarchical routing strategies used in wireless sensor networks and gives a brief working model of energy efficient routing protocols in WSN. In this paper performance of different routing protocols are compared based on metrics such as mobility support, stability, energy efficiency.

Index terms— clustering, hierarchical routing, energy consumption, lifetime, wireless sensor network.

I. INTRODUCTION

Wireless sensor networks are widely used all over the world in many applications such as traffic monitoring, military surveillance, habitat monitoring, combat field reconnaissance and object tracking. This has been made practically feasible by significant advances in micro electro-mechanical systems (MEMS) technology, radio communications and digital electronics [1, 3]. Sensors are tiny devices that are deployed in an ad-hoc manner in the area of interest to monitor events and gather data about the environment. They have the ability of sensing, data processing and communicating with each other. Multi-hopping in the networks can cause a sensor node to communicate with a node which is far away from it. This allows the sensor nodes in the network to expand the monitored area and hence proves its scalability and flexibility property [3].

In WSNs, each of the sensor nodes collects and route data either to an external base station (BS) or to other sensors. Therefore, each node plays the dual role of data originator and data router in a multi-hop sensor network. The sensor nodes communicate either among each other or directly to an external base station. A base station may be a fixed or mobile node which helps in communications among the sensor nodes. The sensor nodes can be networked in many applications like target field imaging, space exploration, weather monitoring, distributed computing, intrusion detection, combat field surveillance, detecting ambient conditions such as temperature, movement, sound, light or the presence of certain objects, disaster relief, security and inventory control.

The key limitations of WSNs are the storage, data processing and efficient energy consumption. Due to dense deployment nature of WSNs, the node batteries of these sensor nodes are difficult to recharge again -

and again [2]. Also it is not feasible to replace the batteries of thousands of nodes. Hence, energy awareness and maximizing the lifetime of the sensors are essential design issues in WSNs [4]. The protocol of WSN can be classified into two kinds of protocol, planar routing protocol and hierarchical routing protocol. Hierarchical routing based clustering not only advances network scalability and reduces data delay, but also it supports data aggregation in varying degrees to prolong the network lifetime [12]. In WSNs, it is seen from the literature, 70% of the total energy is consumed for data transmission. Hence the methods used for data collection and transmission can greatly help in achieving energy efficiency. Since long transmissions consume much more energy, the long transmissions and data redundancy should be minimized to conserve the scarce energy resources [3]. The sleep-awake cycles, clustering etc techniques have been proposed for reducing the energy consumption but still a big chunk of energy is consumed in data transmission from sensor nodes to cluster head or sink, which can be checked by improving the transmission quality over wireless channel.

II. HIERARCHICAL ROUTING PROTOCOL

In hierarchical routing protocols whole network is divided into multiple clusters. One node in each cluster plays leading role. As shown in the Fig 1, cluster - head is the only node that can communicate to Base station in clustering routing protocols. This significantly reduces the routing overhead of normal nodes because normal nodes have to transmit to cluster-head only. Description of some hierarchical routing protocols is discussed in next subsections.

Fig. 1: Wireless sensor network with hierarchical routing

A. LEACH (Low Energy Adaptive Clustering Hierarchy)

LEACH [5, 9] is one of the first hierarchical routing Protocols used for wireless sensor networks to increase the life time of network. LEACH performs self-organizing and re-clustering functions for every round. Sensor nodes organize themselves into clusters in LEACH routing protocol. In every cluster one of the sensor node acts as cluster-head and remaining sensor nodes as member nodes of that cluster. Only cluster-head can directly communicate to sink and member nodes use cluster-head as intermediate router in case of communication to sink. Cluster-head collects the data from all the nodes, aggregate the data and route all meaningful compress information to Sink. Because of these additional responsibilities Cluster-head dissipates more energy and if it remains cluster-head permanently it will die quickly as happened in case of static clustering. LEACH tackles this problem by randomized rotation of cluster-head to save the battery of individual node. In this ways LEACH maximize life time of network nodes and also reduce the energy dissipation by compressing the date before transmitting to cluster-head. LEACH routing protocol operations based on rounds, where each round normally consists of two phases. First is setup phase and second is steady state phase. In setup phase cluster-head and cluster are created. Whole network nodes are divided into multiple clusters. Some nodes elect themselves as a cluster-head independently from other nodes. These nodes elect themselves on behalf Suggested percentage P and its previous record as cluster-head. Nodes which were not cluster-head in previous $1/p$ rounds generate a number between 0 to 1 and if it is less then threshold $T(n)$ then nodes become cluster-head. Threshold value is set through this formula.

$$T(n) = \begin{cases} \frac{P}{1 - p \cdot \text{mod}(\frac{1}{p})} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

where G is set of nodes that have not been cluster-head in previous $1/p$ rounds, P represent suggested percentage of cluster-head, r represent current round. The node becomes cluster-head in current round, it will be cluster-head after next $1/p$ rounds. Elected cluster-head broadcasts its status using CSMA MAC

protocol. Cluster-head will create TDMA schedule for its associated members in the cluster. In steady state phase starts when clusters have been created. In this phase nodes communicate to cluster-head during allocated time slots otherwise nodes keep sleeping. Due to this attribute LEACH minimize energy dissipation and extend battery life of all individual nodes. When data from all nodes of cluster have been received to cluster-head it will aggregate, compress and transmit to sink. The steady state phase is longer than setup phase.

B. LEACH-C

LEACH-C [5] protocol offers a configuration algorithm to perform efficient clustering. The efficient heads are selected based on the minimum exchanged data between cluster heads and their cluster nodes. In LEACH-C, during the setup phase, for each iteration the base station receives information about node state, node location and each node's remaining energy. LEACH-C uses this information to calculate the mean value of network nodes energy, and then selects efficient cluster heads between nodes with higher energy level than mean energy value. The LEACH-C protocol can be used to detect nodes that have an energy value higher than the average and then the evolutionary algorithm is applied to select the optimum cluster heads, therefore achieving proper clustering. LEACH cluster formation algorithm has the disadvantages of guarantee about the number of cluster head nodes and its placement. Since the clusters are adaptive, so there is poor clustering set-up during a round will affect overall performance. However, using a central control algorithm to form the clusters may produce better clusters by distributing the cluster head nodes throughout the network.

C. Multi-hop LEACH

When the network diameter is increased beyond certain level, distance between cluster-head and base station is increased enormously. This scenario is not suitable for LEACH routing protocol in which base station is at single-hop to cluster-head. In this case energy dissipation of cluster-head is not affordable. To address this problem Multi-hop LEACH was proposed. Multi-hop LEACH is another extension of LEACH routing protocol to increase energy efficiency of the wireless sensor network. Multi-hop LEACH is also complete distributed clustering based routing protocol. Like LEACH, in Multi-Hop LEACH [4] some nodes elect themselves as cluster-heads and other nodes associate themselves with elected cluster-head to complete cluster formation in setup phase. In steady state phase cluster-head collect data from all nodes of its cluster and transmit data directly or through other cluster-head to Base station after aggregation. Multi-Hop LEACH allows two types of communication operations. These are inter-cluster communication and intra-cluster

communication. In Multi-hop inter-cluster communication, when whole network is divided into multiple clusters each cluster has one cluster-head. This cluster-head is responsible for communication for all nodes in the cluster. Cluster-head receive data from all nodes at single-hop and aggregate and transmit directly to sink or through intermediate cluster-head. In Multi-hop inter-cluster communication when distance between cluster-head and base station is large then cluster head use intermediate cluster-head to communicate to base station.

D. Angled LEACH

The motivation of the angled LEACH is to reduce the traffic at the sink node. The Angled-LEACH assumes that the sensor nodes are placed randomly within a WSN and some of the nodes introduce themselves to be the cluster heads by broadcasting advertisement messages to the other nodes. Since all the nodes would be collecting the data at their respective cluster heads and the cluster heads would be transferring the data to the sink node, there must be some nodes which do not belong to any cluster. These nodes would be transferring the data to the sink node directly which causes traffic at the sink node and affects load balancing and hence energy efficiency too. Angled-LEACH [3] scheme calculates the angles among the nodes. The nodes would be transferring the data to the cluster heads which would be reachable to it and lies at angle less than or equal to 45° to it. This reduces the overall traffic in the network and gives efficient energy utilization. The angles of the nodes to their respective cluster heads and the sink node is calculated by the dot product of the position of the nodes, cluster heads and the sink. If the angle calculated lies between 0° and 45° , then the information is collected at the cluster head and then at the sink node else the node searches for another node which lies in the specified range.

E. Power-Efficient Gathering in Sensor Information Systems (PEGASIS)

PEGASIS [10] is an extension of the LEACH protocol, which forms chains from sensor nodes so that each node transmits and receives from a neighbor and only one node is selected from that chain to transmit to the base station (sink). The data is gathered and moves from node to node, aggregated and eventually sent to the base station. The chain construction is performed in a greedy way. Unlike LEACH, PEGASIS avoids cluster formation and uses only one node in a chain to transmit to the BS (sink) instead of using multiple nodes. A sensor transmits to its local neighbors in the data fusion phase instead of sending directly to its CH as in the case of LEACH. In PEGASIS routing protocol, the construction phase assumes that all the sensors have global knowledge about the network, particularly, the positions of the

sensors, and use a greedy approach. When a sensor fails or dies due to low battery power, the chain is constructed using the same greedy approach by bypassing the failed sensor. In each round, a randomly chosen sensor node from the chain will transmit the aggregated data to the BS, thus reducing the per round energy expenditure compared to LEACH. PEGASIS is able to increase the lifetime of the network twice as much the lifetime of the network under the LEACH protocol. Such performance gain is achieved through the elimination of the overhead caused by dynamic cluster formation in LEACH and through decreasing the number of transmissions and reception by using data aggregation. Although the clustering overhead is avoided, PEGASIS still requires dynamic topology adjustment since a sensor node needs to know about energy status of its neighbors in order to know where to route its data. Such topology adjustment can introduce significant overhead especially for highly utilized networks.

F. Hybrid, Energy-Efficient Distributed Clustering (HEED)

HEED [1, 6] extends the basic scheme of LEACH by using residual energy and node degree or density as a metric for cluster selection to achieve power balancing. It operates in multi-hop networks, using an adaptive transmission power in the inter-clustering communication. HEED was proposed with four primary goals namely (i) prolonging network lifetime by distributing energy consumption, (ii) terminating the clustering process within a constant number of iterations, (iii) minimizing control overhead, and (iv) producing well-distributed CHs and compact clusters. HEED periodically selects CHs according to a combination of two clustering parameters. The primary parameter is their residual energy of each sensor node (used in calculating probability of becoming a CH) and the secondary parameter is the intra-cluster communication cost as a function of cluster density or node degree (i.e. number of neighbors). The primary parameter is used to probabilistically select an initial set of CHs while the secondary parameter is used for breaking ties. The HEED clustering improves network lifetime over LEACH clustering because LEACH randomly selects CHs (and hence cluster size), which may result in faster death of some nodes. The final CHs selected in HEED are well distributed across the network and the communication cost is minimized. However, the cluster selection deals with only a subset of parameters, which can possibly impose constraints on the system. These methods are suitable for prolonging the network lifetime rather than for the entire needs of WSN.

G. SEP (Stable Election Protocol)

SEP [6] a heterogeneous-aware protocol to prolong the time interval before the death of the first node. That is crucial for many applications where the

feedback from the sensor network must be reliable. SEP is based on weighted election probabilities of each node to become cluster head according to the remaining energy in each node. The advanced node and normal node are the nodes with different residual energy. SEP attempts to maintain the constraint of well balanced energy consumption. Intuitively, advanced nodes have to become cluster heads more often than the normal nodes, which is equivalent to a fairness constraint on energy consumption. It performs poorly in multi-level heterogeneous WSNs.

H. EECDA (Energy Efficient Clustering and Data Aggregation Protocol)

EECDA [8] protocol efficiently maintains the energy consumption of sensor nodes by involving them in a single-hop communication within a cluster. The data aggregation and fusion technique is used to reduce the number of transmitted messages to the BS to save the energy and prevent the congestion. To make the protocol implementation, few assumptions are considered are: (i) n sensor nodes are uniformly dispersed within a square field. (ii) All sensor nodes and the BS are stationary after deployment. (iii) The WSN consists of heterogeneous nodes in terms of node energy. (iv) CHs perform data aggregation. (v) The BS is not energy limited in comparison with the energy of other nodes in the network. By using few heterogeneous nodes in the network brings three main benefits: (i) Extending network lifetime: the average energy consumption for forwarding a packet from the heterogeneous nodes to a BS will be much less than the energy consumed in homogeneous sensor networks. (ii) Improving reliability of data communication: the heterogeneous sensor network can get much higher end-to-end delivery rate than the homogeneous sensor network. (iii) Decreasing latency of data transmission: the heterogeneous nodes can decrease the forwarding latency by using fewer hops to the BS. In this clustering they have considered normal, advanced and super nodes for heterogeneous network. Different thresholds are used for these nodes. Three phases are considered in this algorithm, they are Cluster formation phase, Route selection phase and Data transmission phase. Due to the extended stability, the throughput of EECDA is

higher than that of M-LEACH. But this algorithm cannot be used for any network with mobility constraints.

I. Energy-saving cluster routing with mobile sink (ESCR-MS)

In wireless sensor networks with the mobile sink, the sink can join or leave the network at any time. Such mobility of the sink increases the flexibility, but also increases the energy consumption and shortens the network lifetime. To solve this energy-saving cluster routing algorithm can be used. This algorithm uses the clusters and multi-hop inter-clusters routing to save the energy of the whole network. The inter-clusters routing will be updated when the sink sends the signal according to its displacement. Here the sink node has no energy constraints. The network considered is homogeneous network. All sensor nodes can communicate with each other use single hop or multi-hop routing. Transmit power of the mobile sink is fixed. The sensor nodes can determine the distance between two nodes by power information of the received signal. The whole flow is divided into three parts. They are establishment process of clusters, inter-cluster routing process and continuously data transfer process. [6] The establishment process of clusters includes the cluster-heads selection and the cluster-members selection. The inter-cluster routing process can establish the multi hop routing between cluster-heads. In the continuously data transfer process, the sensor can transfer the data to sink along the routing which was built in the first two processes. And in this stage, the mobile sink calculates the displacement of itself to decide when to go to the second process to build the inter-cluster routing. For the mobile sink network with this algorithm the energy cost decreases evenly with living nodes decreases. The process of network dying is slow here.

The table 1 shows the comparison of above described hierarchical routing protocols on the basis of parameters like cluster stability, location awareness, energy efficiency, hop count, type of network and mobility.

Table 1: Comparison of various hierarchical routing protocols

Clustering Routing protocol	Mobility	Location Awareness	Cluster Stability	Energy efficiency	Hop count	Homogeneous/ Heterogeneous
LEACH	Stationary	No	Moderate	High	Single	Homogeneous
LEACH-C	Stationary	Yes	Moderate	High	Single	Homogeneous
Multi-hop LEACH	Stationary	Yes	Moderate	Very High	Multi	Homogeneous
Angled LEACH	Stationary	Yes	Moderate	High	Single	Homogeneous

PEGASIS	Stationary	Yes	N/A	Good	Multi	Homogeneous
HEED	Stationary	Yes	Good	High	Multi	Homogeneous
SEP	Stationary	No	Good	Very high	Single	Heterogeneous
EECDA	Stationary	No	Good	Very high	Single	Heterogeneous
ESCR-MS	Sink is mobile	Yes	Moderate	High	Multi	Homogeneous

III. CONCLUSION

In this survey paper various hierarchical routing protocols like LEACH, Multi hop LEACH, PEGASIS, HEED, SEP for wireless sensor network are discussed. The main concern of this survey is to examine the energy efficiency, mobility, location

awareness, stability of cluster and hop count for these routing protocols. The future work is to create a new routing protocol using EECDA clustering concept with mobile sink to increase the life time of the network.

REFERENCES

- [1] Shio Kumar Singh, M P Singh, and D K Singh, "Routing Protocols in Wireless Sensor Networks –A Survey", in International Journal of Computer Science & Engineering Survey, Vol.1, No.2, November 2010.
- [2] Deepti Garg, Roopali Garg, "Angled-Leach in Wireless Sensor Networks", in International Journal of Advances In Computing And Information Technology, April 2012.
- [3] Sabarish B A, Guru Moorthy S M, Dhivya M A, Sakthi Naveen K, Vaishnavi S, "A survey on clustering protocols in Wireless Sensor Networks", in International Journal Of Advances In Computing And Information Technology, April 2012.
- [4] Geetha. V.a, Pranesh.V. Kallapur, Sushma Tellajeerac, "Clustering in Wireless Sensor Networks: Performance Comparison of LEACH & LEACH-C Protocols Using NS2", in Elsevier journal, 2012.
- [5] Feng Zhao, Chenglin Zhao, Yongxing Wang, Xuebin Sun, Ting Jiang, "An energy-saving cluster routing for Wireless sensor networks With mobile sink", in AIAI2010.
- [6] G. Smaragdakis, I. Matta, A. Bestavros, "SEP: A Stable Election Protocol For Clustered Heterogeneous Wireless Sensor Networks", Proceedings of 2nd International Workshop on Sensor and Actor Network Protocols and Applications (SANPA'04), Boston, MA, 660-670, 2004.
- [7] D. Kumar, T.C. Aseri, R.B. Patel, "EECDA: Energy Efficient Clustering and Data Aggregation Protocol for Heterogeneous Wireless Sensor Networks", in Int. J. of Computers, Communications & Control, ISSN 1841-9836, E-ISSN 1841-9844 Vol. VI 2011.
- [8] W.B. Heinzelman, A.P. Chandrakasan, H. Balakrishnan, "An Application-Specific Protocol Architecture for Wireless Microsensor Networks", in IEEE Transactions on Wireless Communications, 1(4):660-669, 2002.
- [9] S. Lindesy, C. Raghavendra, "PEGASIS: Power-Efficient Gathering in Sensor Information System", in Proceedings of IEEE Aerospace Conference, 1-6, 2002.
- [10] W.R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-efficient Communication Protocol for Wireless Microsensor Networks", in IEEE Computer Society Proceedings of the Thirty Third Hawaii International Conference on System Sciences (HICSS '00), Washington, DC, USA, Jan. 2000, vol. 8, pp. 8020.
- [11] Rupesh Mehta, Abhishek Pandey & Pratik Kapadia, "Reforming Clusters Using C-LEACH in Wireless Sensor Networks", in International Conference on Computer Communication and Informatics, 2012.
- [12] Jia Xu, Ning Jin, Xizhong Lou, Ting Peng, Qian Zhou, Yanmin Chen, "Improvement of LEACH protocol for WSN", in International Conference on Fuzzy Systems and Knowledge Discovery, 2012.