Recent Advances of Hierarchical Routing Protocols for Ad-Hoc and Wireless Sensor Networks: A Literature Survey*

Ibrihich OUAFAA [1]*, Krit SALAH-DDİNE [2], Laassiri JALAL [3], El Hajji SAİD [4]

[1]Laboratory of Mathematics, Computing and Applications, Faculty of Sciences, University of Mohammed-V, Rabat, Morocco
[2]Polydisciplinary Faculty of Ouarzazate, Department of Mathematics, Informatic and Management Ibn Zohr University Agadir, Morocco.
[3]Faculty of Sciences of Kenitra Department of Computer Sciences, Ibn Tofail University, Kenitra, Morocco
[4] Laboratory of Mathematics, Computing and Applications, Faculty of Sciences, University of Mohammed-V, Rabat, Morocco
wafaa.ibrihich@gmail.com, krit_salah@yahoo.fr, laassiri.jalal@gmail.com , elhajji.said@gmail.com
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Abstract— The hierarchical clustering is an efficient way to reduce the overall energy consumption within the cluster by performing aggregation and fusion of data. Clusters create hierarchical WSNs, which facilitate efficient utilization of the limited resources of sensor nodes, thereby extend the network lifetime, reduce energy consumption of the system and provide overall system scalability. The proposed work of the present paper is to provide an overview of hierarchical protocols and an overview of the protocol's performance. The study of different clustering routing protocols of WSN and Ad-Hoc are presented and the aim is to give the comparison of different hierarchical routing protocols between WSNs and Ad-Hoc on various parameters.

Keywords— WSNs, AD-Hoc, Energy Consumption, Scalability, Clusters, Lifetime Battery

1. INTRODUCTION

Hierarchical routing is the procedure of arranging routers in a hierarchical manner. A hierarchical protocols in WSNs allows an administrator to make best use of his fast powerful routers as backbone routers, and the slower, lower powered routers may be used for access purposes. Hierarchical protocols make an effort to keep local traffic local, that is, they will not forward traffic to the backbone if it is not necessary to reach a destination.

The Ad-Hoc Network is usually assumed homogeneous, where each mobile node shares the same radio capacity [1, 28, 29, 30, 31, 32]. However, a homogeneous Ad-Hoc network suffers from poor scalability. Building a physically hierarchical ad hoc network is a very promising way to achieve good scalability.

Generally a Wireless Sensor Networks (WSNs) is composed of a large number of wireless sensors with low processing power and energy consumption for monitoring a certain environment. The large number of nodes and their random placement in space offers great redundancy in data transmission.

There are many types of routing protocols in wireless sensor network, which are classified as follows: Flooding and gossiping, Rumour routing, Gradient based routing, Energy aware routing, Hierarchical protocols.

In this paper, we described different hierarchical protocols schemes. Furthermore, we examine and compare hierarchical clustering algorithms in WSNs and Ad-Hoc based on different parameters: cluster stability, delivery delay, scalability, algorithm complexity and energy efficiency.

2. HIERARCHICAL CLUSTERING IN WSNS

In "Hierarchical Networks" protocols, nodes are grouped into the clusters. Every cluster has a cluster head which election is based on different election algorithms. The cluster heads are used for higher-level communication reducing the traffic overhead. The use of routing hierarchy has many advantages. It reduces the size of routing tables providing better scalability. The main aim of this type of routing is to optimize energy consumption of sensor nodes by arranging the nodes into clusters. Data aggregation and fusion is performed within the cluster in order to decrease the number of transmitted messages [2]. As shown in Figure 1.

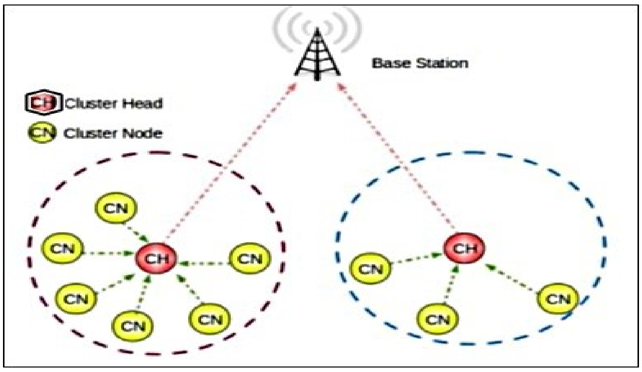

Figure 1. Clustering in WSNs

3. CLUSTERRING OBJECTIVES

Clustering algorithms in the literature varies in their objectives. In WSNs, clustering the nodes is performed with different Objectives and purposes. The energy conservation is the most important and common objective of all these objectives. We separate these objectives as primary and secondary. The primary objectives indicate the objectives that are the most important and substantial in the clustering process. On the other hand, the secondary objectives indicate the objectives that are not substantially important for the network and they are indirectly achieved by clustering the nodes. As shown in Figure 2 [3]:

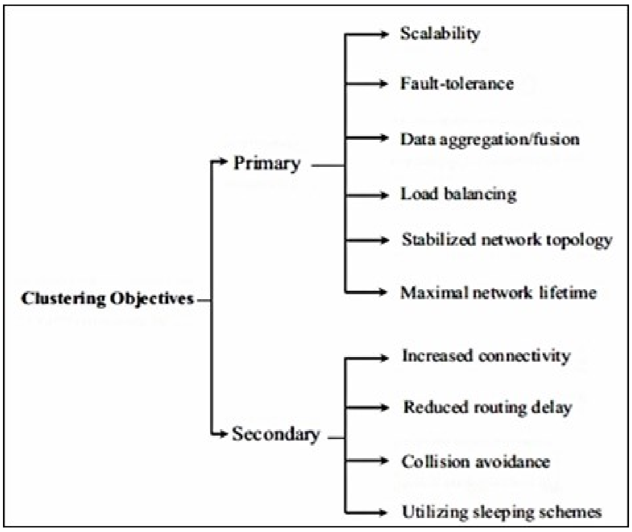

Figure 2. Clustering objectives in a general view

4. CLASSIFICATION OF HIERARCHICAL ROUTING PROTOCOLS IN WSN

Clustering plays an important role for energy saving in WSNs. With clustering in WSNs, energy consumption, lifetime of the network and scalability can be improved. Because only cluster head node per cluster is required to perform routing task and the other sensor nodes just forward their data to cluster head (Figure 3). Clustering has important applications in high-density sensor networks, because it is much easier to manage a set of cluster representatives (cluster head) from each cluster than to manage whole sensor nodes [4].

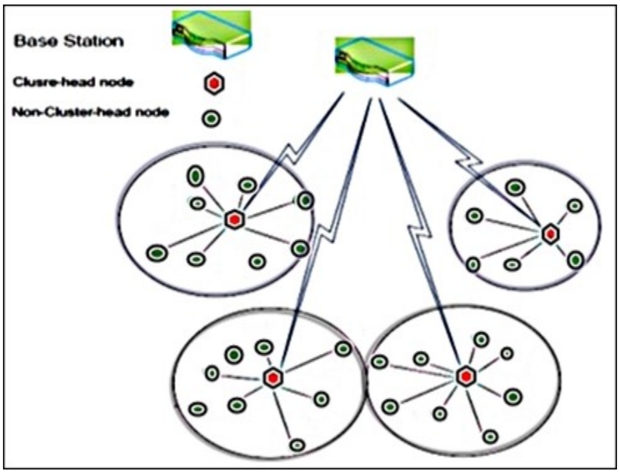

Figure 3. Clustering model hierarchical routing

In WSNs the sensor nodes are resource constrained which means they have limited energy, transmit power, memory, and computational capabilities. Energy consumed by the sensor nodes for communicating data from sensor nodes to the base station is the crucial cause of energy depletion in sensor nodes. [5] The main hierarchical protocols in WSN are:

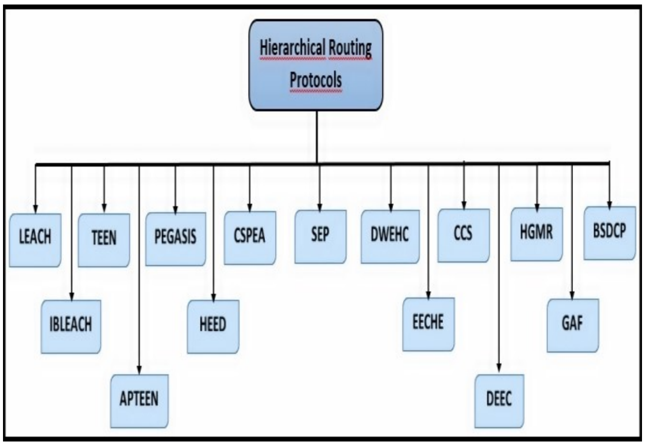

Figure 4. Clustering routing protocols in WSN

4.1. Low-Energy Adaptive Clustering Hierarchy (LEACH)

The one of the most popular hierarchical routing algorithms for wireless sensor networks is LEACH [6]. In LEACH, the nodes form themselves into local clusters, with one node acting as the local cluster-head. The idea is to form clusters of the sensor nodes based on the received signal strength and use local cluster heads as routers to the sink. This will save energy since the transmissions will only be done by such cluster heads rather than all sensor nodes. Optimal number of cluster heads is estimated to be 5% of the total number of nodes. All the data processing such as data fusion and aggregation are local to the cluster. Cluster heads change randomly over time in order to balance the energy dissipation of nodes. This decision is made by the node choosing a random number between 0 and 1. The node becomes a cluster head for the current round if the number is less than the following threshold:

$$T(n) = \begin{cases} \dfrac{p}{1 - p * \left(r mod 1/p\right)}, & if\ n \in G \\ 0, & otherwise \end{cases}$$

Where p is the desired percentage of cluster heads (e.g. 0.05), r is the current round, and G is the set of nodes that have not been cluster heads in the last 1/p rounds.

4.2. Improved and Balanced LEACH

It is improved version of LEACH. Some high energy nodes declare themselves to be gateway nodes and send ADVT (advertisement) messages to other non-gateway nodes. The other non-gateway nodes with maximum energy declare themselves to be cluster head and send ADVT messages to non-cluster nodes. The non-cluster nodes can receive two or more ADVT requests. A node sends Join-Request to that cluster head which require minimum communication energy. Each node starts their task after the construction of clusters [7].

4.3. Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN)

TEEN (Threshold sensitive Energy Efficient sensor Network protocol) is a hierarchical clustering protocol, which groups sensors into clusters with each led by a CH. The sensors within a cluster report their sensed data to their CH. The CH sends aggregated data to higher level CH until the data reaches the sink. In this scheme, at every cluster change time, in addition to the attributes, the CH broadcasts to its members the following:

- Hard Threshold: This is a threshold value for the sensed attribute. It is the absolute value of the attribute beyond which, the node sensing this value must switch on its transmitter and report to its cluster head.
- Soft Threshold: This is a small change in the value of the sensed attribute which triggers the node to switch on its transmitter and transmit. [8]

4.4. Adaptive TEEN (APTEEN)

APTEEN is Adaptive Periodic Threshold-sensitive Energy Efficient Sensor Network Protocol. In APTEEN once the CHs are decided, in each cluster period, the CH first broadcasts the following parameters:

- Attributes (A): This is a set of physical parameters which the user is interested in obtaining data about.
- Thresholds: This parameter consists of a hard threshold (HT) and a soft threshold (ST). HT is a particular value of an attribute beyond which a node can be triggered to transmit data. ST is a small change in the value of an attribute which can trigger a node to transmit data again.
- Schedule: This is a TDMA schedule assigning a slot to each node.
- Count Time (TC): It is the maximum time period between two successive reports sent by a node. It can be a multiple of the TDMA schedule length and it accounts for the proactive component. [9]

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

PEGASIS stands for Power-Efficient Gathering in Sensor Information Systems. This is a chain based protocol that provide improvement over LEACH algorithms. So PEGASIS is an extension of the LEACH protocol. PEGASIS has two main objectives: first, improving the network longevity and uniform energy consumption among the nodes, and second, using a chain-based multi-hop path, which tries to reduce the delay between the source and the BS. PEGASIS protocol requires formation of chain which is achieved in two steps: 1).Chain construction, 2). Gathering data. [10]

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

HEED 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. [11]

4.7. Constrained Shortest Path Energy Aware Routing (CSPEA)

Network is divided into clusters where each cluster has a cluster head and a gateway node is used to connect them. Estimation of energy consumption can be made by calculating distance from source to destination. Energy efficiency can be achieved by choosing best path for data routing. It is the best approach because it entails less control packet overhead.[12]

4.8. Stable Election Protocol (SEP)

It is improved version of LEACH. It operates like LEACH but the difference in SEP that there are two types of nodes; 1.Normal nodes, 2.Advance nodes which has different level of energy. In SEP, weighted election probabilities are used to select the cluster head from all the sensor nodes according to their energy [13].

4.9.Distributed Weight-based Energy-Efficient Hierarchical Clustering Protocol (DWEHC)

Ding et al. [14] have proposed DWEHC to achieve more aggressive goals than those of HEED. Basically, generating balanced cluster sizes and optimizing the intra-cluster topology.
Both DWEHC also consider residual energy in the process of CH election. It creates a multi-level structure for intra-cluster communication and limits a parent node's number of children. Each node calculates its weight according to:

$$W_{weight}(s) = \frac{E_{residual}(s)}{E_{initial}(s)} \times \sum_{u} \frac{R-d}{6R}$$

Where Eresidual (s) and Einitial (s) are respectively residual and initial energy at node s, R is the cluster range that indicate how far a node is from the CH inside a cluster, and d is the distance between node s and the neighboring node u. [15]

4.10. Energy-Efficient Cluster Head Election Protocol (EECHE)

In this algorithm, some sensor nodes use additional energy resources. The CH broadcast the TDMA schedule to all sensor nodes and based on that TDMA schedule the sensor nodes participate in the network operations. Otherwise, they will turn off their radio when they are not participating. This process minimizes the energy consumption. This protocol reduces energy consumption of those nodes which are far away from the sink and balance the energy consumption which are near to the sink. Routing is done based on the residual energy of the cluster heads. [12]

4.11. Concentric Clustering Scheme (CCS)

CCS (Jung et al., 2007), the main idea of which is to consider the location of the BS to enhance the performance and to prolong the lifetime of the network, the network is divided into a variety of concentric circular tracks. Each circular track is assigned with a level. The track nearest to the BS is assigned with level-1 and the level number increases with the increase of the distance to the BS. Each node in the network is assigned with its own level. [16]

4.12. Distributed Energy-Efficient Clustering (DEEC)

In terms of selecting CH which is based on the residual energy level of the nodes with respect to the average energy of the network. However, DEEC is based on two types of nodes; normal and advance nodes. The network is divided into clusters and each cluster head is chosen by a probability of ratio between residual energy of each node and average energy of the network. DEEC is better than LEACH, SEP because it has longer lifetime [17].

4.13. Hierarchical Geographic Multicast Routing (HGMR)

Hierarchical Geographic Multicast Routing (HGMR) [18], proposed is a location-based multicast protocol. This protocol seamlessly incorporates the key aim concepts of the Geographic Multicast Routing (GMR) and Hierarchical Rendezvous Point Multicast (HRPM) protocols, and optimizes them by providing forwarding energy efficiency as well as scalability to large-scale WSNs. In HGMR, the multicast group is divided into subgroups using the mobile geographic hashing: the deployment area is partitioned into a number of equal-sized square sub-domains called cells and each cell comprises a manageably sized subgroup of members. In each cell, there is an Access Point (AP) responsible for all members in that cell, and a Rendezvous Point (RP) [19] manages all Aps.

4.14. Geographic Adaptive Fidelity (GAF)

In this algorithm, nodes will elect one sensor node to stay awake for a certain period and then they go to sleep. This node is responsible for monitoring and reporting data to the BS on behalf of the nodes in the zone. Hence, GAF conserves energy by turning off unnecessary nodes in the network without affecting the level of routing fidelity. Each node uses its GPS-indicated location to associate itself with a point in the virtual grid. Nodes associated with the same point on the grid are considered equivalent in terms of the cost of packet routing. Thus, GAF can substantially increase the network lifetime as the number of nodes increases. [20]

4.15. Base-Station Controlled Dynamic Clustering Protocol (BCDCP)

This is a centralized clustering routing protocol. Is proposed in Muruganathan et al. (2005) which uses a high energy BS in Order to form the clusters. The main ideas in BCDCP are the Formation of balanced clusters where each CH serves an approximately equal number of member nodes to avoid CH overload, uniform placement of CHs throughout the whole sensor field, and utilization of CH-to-CH routing to transfer the data to the BS. [21]

5. HIERARCHICAL CLUSTERING IN AD-HOC NETWORKS

Due to mobility of ad hoc networks and the lack of fixed infrastructure, routing protocols have to be very flexible in order to deal with this dynamically changing environment. However, because of the small size of these networks, ad hoc protocols can be categorized based on the routing topology. One class of these protocols is the flat and the hierarchical protocols. Unlike flat protocols where each node has its unique global address and all the nodes are peers, in hierarchical protocols nodes are grouped into clusters. Every cluster has a CH which election is based on different election algorithms. The cluster heads are used for higher-level communication reducing the traffic overhead. Clustering may be extended to more than just two levels having the same concepts of communication in every level. The use of routing hierarchy has a lot of advantages. It reduces the size of routing tables providing better scalability. The main hierarchical protocols in Ad-Hoc are:

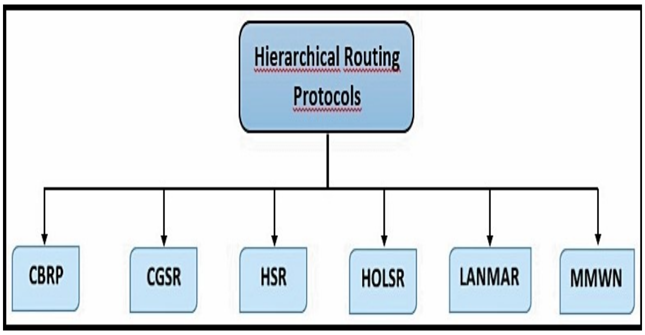

Figure 5. Clustering Routing Protocols in Ad-Hoc

5.1. Cluster-Based Routing Protocol (CBRP)

In CBRP [22], the nodes are organized in a hierarchy. As most hierarchical protocols, the nodes in CBRP or grouped into clusters. Each cluster has a cluster-head, which coordinates the data transmission within the cluster and to other clusters. The advantage of CBRP is that only cluster heads exchange routing information, therefore the number of control overhead transmitted through the network is far less than the traditional flooding methods. However, as in any other hierarchical routing protocol, there are overheads associated with cluster formation and maintenance. The protocol also suffers from temporary routing loops.

5.2. Cluster Head Gateway Switch Routing (CGSR)

CGSR (Chiang, Wu, Liu, & Gerla, 1997) [23] is a hierarchical routing protocol. CGSR uses similar proactive routing mechanism as DSDV. The cluster structure improves performance of the routing protocol because it provides effective membership and traffic management. Besides routing information collection, update and distribution, cluster construction and cluster head selection algorithms are important components of cluster based routing protocols.

5.3. Hierarchical State Routing Protocol HSR

The Hierarchical State Routing (HSR) protocol [24] is a distributed multi-level hierarchical routing protocol, which provides nodes clustering in multiple levels. HSR employs clustering in different levels. Here, every cluster has its leader, which is elected through different algorithms. However, besides physical clustering, HSR defines also the concept of logical clustering. Here the links between the nodes are not physical. The links are based on certain relations.

5.4. Hierarchical Optimized Link-State Routing (HOLSR)

HOLSR (Gonzalez, Ge, & Lamont, 2005) is a routing mechanism derived from the OLSR protocol. The main improvement realized by HOLSR over OLSR is a reduction in routing control overhead, for example, topology control information, in large heterogeneous mobile ad-hoc networks. A heterogeneous mobile ad-hoc network is defined as a network of mobile nodes where different mobile nodes have different communication capabilities, for example, multiple radio interfaces with varying transmission powers. To reduce routing control overhead, HOLSR organizes mobile nodes into multiple topology levels based on their varying communication capabilities.

5.5. Landmark Ad-Hoc Routing (LANMAR)

LANMAR (Gerla, Hong, & Guangyu, 2000; Guangyu, Geria, & Hong, 2000), The Landmark Ad hoc Routing (LANMAR) [25] is proposed as a modification of FSR and aims to gain better scalability. In LANMAR, mobile nodes are divided into predefined logical subnets according to their mobility patterns, i.e., all nodes in a subnet are prone to move as a group. A landmark node is pre-specified for every logic subset to keep track of the subnet.

5.6. Multimedia Support in Mobile Wireless Networks (MMWN)

In MMWN (Kasera & Ramanathan, 1997), routing protocol [26] maintains an Ad-Hoc network using a clustering hierarchy in order to reduce routing control overheads where node mobility is high or nodes do not communicate frequently. Each cluster has two types of mobile nodes: switches and endpoints. Each cluster also has location manager (LM), which performs the location management for each cluster. All information in MMWN is stored in a dynamically distributed database.

The advantage of MMWN is that only LMs perform location updating and location finding, which means that routing overhead is significantly reduced when compared to the traditional table driven algorithms (such as DSDV and WRP). However, location management is closely related to the hierarchical structure of the network, making the location finding and updating very complex. This is because in the location finding and updating process, messages have to travel through the hierarchical tree of the LMs [27].

6.COMPARISON OF HIERARCHICAL ROUTING PROTOCOLS IN AD-HOC AND WSN

Many different hierarchical routing protocols have been proposed for WSN and Ad-Hoc. (Chiang, Wu, Liu, & Gerla, 1997, Muruganathan et al., 2005, Gonzalez, Ge, &

Lamont, 2005, Ramesh and Somasundaram, 2011; Younis et al., 2006; Arboleda and Nasser, 2006; Jiang et al., 2009; Xu and Gao, 2011; Maimour et al., 2010; Joshi and Lakshmi Priya, 2011; Kumarawadu et al., 2008; Deosarkar et al., 2008; Lotf et al., 2010; Wei et al., 2011; Aslam et al., 2012; Kumar et al., 2013; Subhai et al., 2013; Jindal and Gupta, 2013; Arora et al. 2013; Naveen Sharma and Anand Nayyar, 2014).

One of the most important surveys on clustering algorithms has been presented in Abbasi and Younis (2007). In this work, the authors describe some important clustering approaches in WSNs and wireless networks. Naveen Sharma and Anand Nayyar provides a Review of Cluster Based Energy Efficient Routing Protocols for Wireless Sensor Networks, in which they compare and classify the clustering approaches based on different parameters such as scalability, stability clustering and energy efficiency, etc.

Another survey is presented in Younis et al. in witch they describe the clustering approaches based on the parameters of the CH election and the execution nature of a clustering algorithm (probabilistic or iterative). These protocols can be classified based on different parameters; therefore, there is a need to compare different routing protocols to judge the performance and their usage over different networks. The comparison done here is based on a given set of parameters such as Scalability, mobility, network lifetime, algorithm complexity, energy efficiency and cluster stability. Shown in Table1.

Table1: Hierarchical Routing Schemes Comparison for Ad-Hoc and WSN

		Cluster Stability	Scalability	Energy Efficiency	Algorithm Complexity	Network lifetime	Mobility	Delivery Delay
Ad-Hoc	HSR	Medium	Low	High	Low	better	Stationary	Medium
	CBRP	High	High	High	Medium	Very good	Stationary	Medium
	HOLSR	Medium	Very Poor	Medium	Very High	Good	Fixed BS	Small
	MMWN	Low	High	Very Good	High	Very good	Stationary	Medium
	CGSR	Medium	Medium	Poor	Low	Good	Stationary	Large
	LAMNAR	Very Low	Very Low	Very Poor	Very Low	Very good	Stationary	Poor
WSN	LEACH	Medium	Very Low	Very Poor	Low	Good	Fixed BS	Very Small
	IBLEACH	High	High	Very High	Medium	Good	Fixed BS	Very Small
	PEGASIS	Very Low	Very Low	Poor	Very High	Very good	Fixed BS	Very Large
	CSPEA	Medium	Very Low	High	High	Better	Stationary	Medium
	TEEN	High	Low	Very High	High	Very good	Fixed BS	Very Small
	SEP	Medium	Medium	Medium	Very Low	Better	Stationary	Very Small
	APTEEN	Very Low	Low	Medium	Very High	Better	Fixed BS	Very Small
	EECHE	Medium	Medium	Very Good	Low	Good	Stationary	Small
	HEED	High	Medium	Medium	Medium	Very good	Stationary	Medium
	GAF	Medium	High	Medium	Medium	Very good	Limited	Poor
	DWEHC	High	Medium	Very High	Medium	Very good	Stationary	Medium
	BCDCP	High	Very Poor	Very Poor	Very High	Good	Fixed BS	Small
	CCS	Low	Very Poor	Poor	Medium	Very good	Stationary	Large
	HGMR	High	Very High	Medium	Low	Better	Fixed BS	Medium
	DEEC	High	High	High	Very Low	Good	Stationary	Very Small

The objectives of this study was to determine which of these protocols behave better in clustering objectives such as scalability, energy efficiency, as shown in Figures 6, 7 and 10. There is a lot more to do research work.

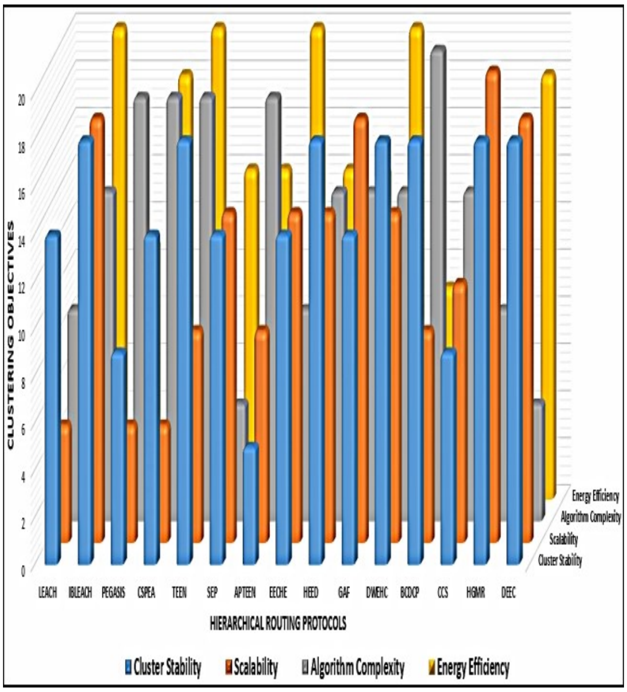

Figure 6. Comparison of the clustering based routing protocols for WSN

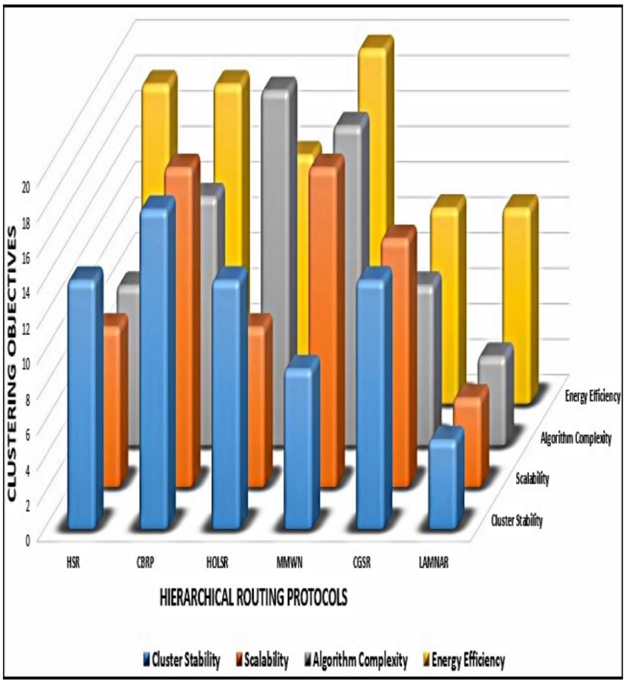

Figure 7. Comparison of the clustering based routing protocols for Ad-Hoc

From the Chart 1, we can see that all hierarchical schemes for Ad-Hoc can achieve clustering objectives (energy efficiency, scalability and network lifetime). The performance improvement of the algorithms can be explained by the fact that these schemes achieve a reduction of control overhead, as the mobile nodes are grouped into distinct hierarchical clusters.

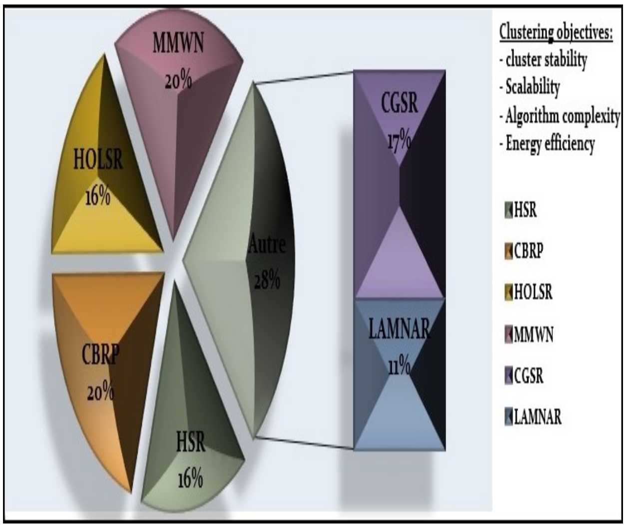

Chart 1. The hierarchical routing protocols can achieve clustering objectives for ad-hoc (in percentage)

From Figure 8 shown below, we notice that PEGASIS, TEEN, APTEEN, HGMR, HEED and GAF are better in terms of network lifetime. Besides, if we talk WSN, the scalability criteria is applied by IBLEACH, GAF, HGMR and DEEC algorithms.

On the other side, the algorithm based on clustering for Ad-Hoc (MMWN, CBRP and CGSR), are most scalable as shown in figure 9, one because it they use location management (updating and finding).

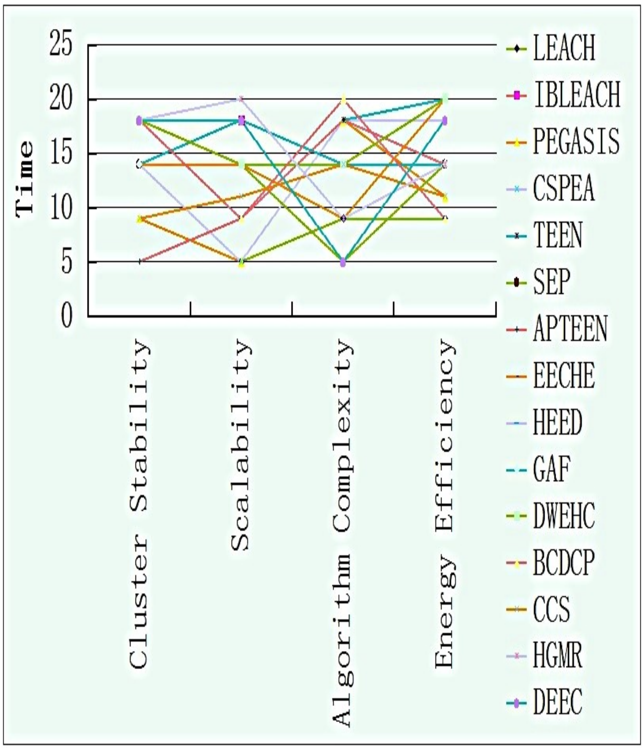

Figure 8. Hierarchical routing protocols for WSN Vs lifetime

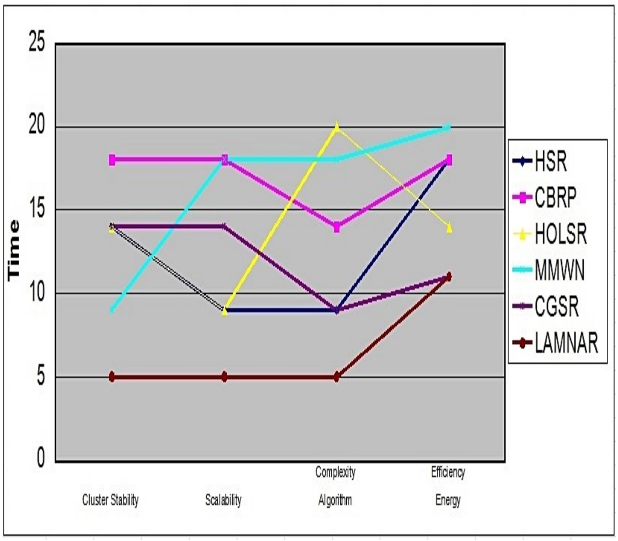

Figure 9. Hierarchical routing protocols for Ad-Hoc Vs lifetime

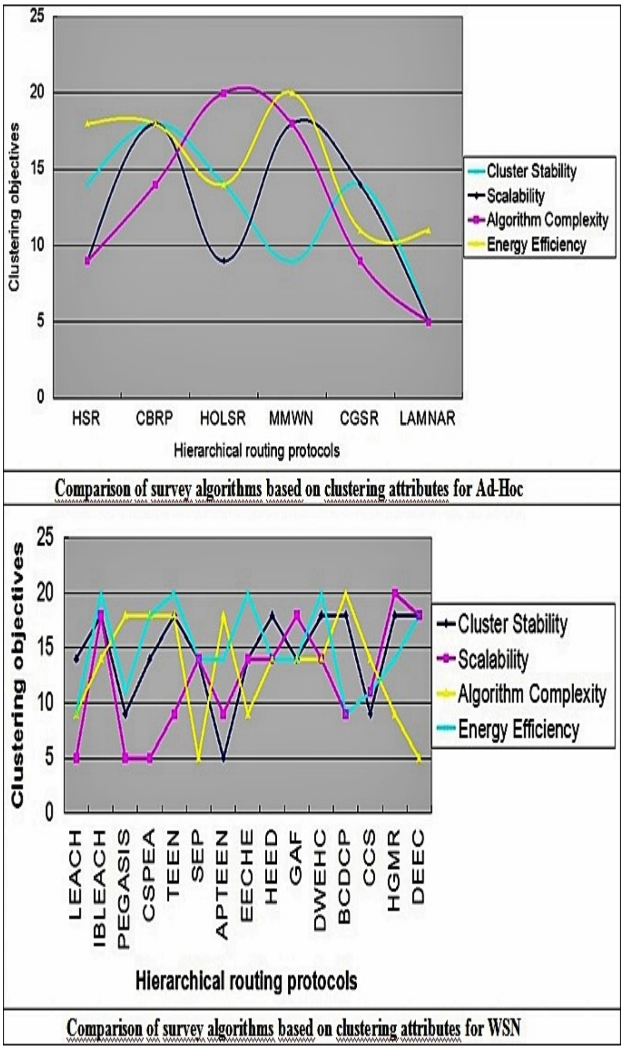

Figure 10. Comparison of survey algorithms based on clustering attributes for WSN and Ad-Hoc

We can see in Figure 10, that IBLEACH, TEEN, APTEEN, and DWEHC have showed better performance than other hierarchical protocols for WSN if we select the energy efficiency and cluster stability are taken as criteria.

7. CONCLUSION

To adapt to the constraints of WSNs, many hierarchical routing protocols have been proposed with different design goals, clustering criteria and basic assumptions.
Hierarchical routing plays an important role in the performance of wireless and ad-hoc network, and research associated with routing is always a focus. In this paper, our focus was on the hierarchical protocols that have been developed for wireless and ad-hoc networks. Thus, we can conclude that the hierarchical protocols are appropriate for sensor networks with the heavy load and wide coverage area. So in order to develop a scheme that will prolong the lifetime of the wireless and ad-hoc networks is needed to increase the energy consumption of the sensors with in the network. The main aim of the routing protocol is to enhance lifetime of the wireless sensor network. So routing protocols designed for wireless sensor network should be as energy efficient as possible to prolong the lifetime of individual sensor nodes, and hence the network lifetime.
This study will helpful to design new clustering approach which will reduce energy so as to improve network lifetime.

REFERENCES

[1] C. Perkins, E. Belding-Royer, and S. Das. “Ad hoc On-Demand Distance Vector Routing Protocol”, Feb2007. http://www.ietf.org/rfc/rfc3561.txt.

[2] Arora et al., “A review on Hierarchical Protocols in Wireless Sensor Networks“, *International Journal of Advanced Research in Computer Science and Software Engineering* Volume 3, Issue 8, pp. 804-809, August – 2013.

[3] M. MehdiAfsar , Mohammad-H and Tayarani-N, “Clustering in sensor networks: A literature survey”, *Journal of Network and Computer Applications* 46, pp 198–226, 2014.

[4] Vinay Kumar, Sanjeev Jain and Sudarshan Tiwari, “Energy Efficient Clustering Algorithms in Wireless Sensor Networks: A Survey*”, IJCSI International Journal of Computer Science* Issues, Vol. 8, Issue 5, No 2, September 2011.

[5] W.Heinzelman, A. Chandrakasan, H. Balakrishnan, “Energy-efficient communication protocol for wireless sensor networks”, in: Proceeding of the Hawaii International Conference System Sciences, Hawaii, January 2000.

[6] Ben Alla Said and EZZATI Abdellah, “Improved and Balanced LEACH for Heterogeneous Wireless Sensor Networks,” 2010.

[7] S. Lindsey and C.S. Raghavendra, “PEGASIS: Power-efficient Gathering in Sensor Information System”, Proceedings IEEE Aerospace Conference, vol. 3, Big Sky, MT, pp. 1125-1130, Mar. 2002.

[8] Georgios Smaragdakis and Ibrahim Matta, “SEP: A Stable Election Protocol for Clustered Hetrogeneous Wireless Sensor Networks,” 2004.

[9] Ya Xu, John Heidemann, Deborah Estrin, “Geography informed Energy Conservation for Ad Hoc Routing,” Proceedings of the Seventh Annual ACM/IEEE International Conference on Mobile Computing and Networking (ACM Mobicom), 2001.

[10] A. Manjeshwar and D. P. Agrawal, “TEEN: A Protocol for Enhanced Efficiency in Wireless Sensor Networks”, in the Proceedings of the 1st International Workshop on Parallel and Distributed Computing Issues in Wireless Networks and Mobile Computing, San Francisco, CA, April 2001.

[11] Navdeep Kaur, Deepika Sharma and Prabhdeep Singh, “Classification of Hierarchical Routing Protocols in Wireless Sensor Network: A Survey*“, International*

Journal of P2P Network Trends and Technology- Volume 3,Issue 1, pp 56-6, 2013.

[12] Naveen Sharma and Anand Nayyar, "A Comprehensive Review of Cluster Based Energy Efficient Routing Protocols for Wireless Sensor Networks", *International Journal of Application or Innovation in Engineering & Management (IJAIEM*), Volume 3, Issue 1, pp 441-453, January 2014.

[13] Arati Manjeshwar and Dharma P. Agrawal, "APTEEN: A Hybrid Protocol for Efficient Routing and Comprehensive Information Retrieval in Wireless Sensor Networks" Proceedings of the International Parallel and Distributed Processing Symposium (IPDPS.02) 2002 IEEE.

[14] P. Ding, J. Holliday, A. Celik, "Distributed energy efficient hierarchical clustering for wireless sensor networks", in: Proceedings of the IEEE International Conference on Distributed Computing in Sensor Systems(DCOSS'05), Marina Del Rey, CA, June 2005.

[15] A.O Murugunathan, S.D. Ma, D.C.F. Bhasin, R.I. Fapajuwo, "A Centralized Energy-Efficient Routing Protocol for Wireless Sensor Networks," *IEEE Radio Communication*, S8–S13, 2005.

[16] I. Koutsonikola, D. Das, S. Charlie, H.Y. Stojmenovic, "Hierarchical geographic multicast routing for wireless sensor networks," Wireless. Network, 449–466, 2010.

[17] C. Siva Ram Murthy and B.S. Manoj. "Ad Hoc Wireless Networks: Architectures and Protocols".

[18] D. Koutsonikola., "Hierarchical geographic multicast routing for wireless sensor networks", Wirel. Netw., pp. 449–466, Oct-2010.

[19] L. Qing, Q. Zhu, M. Wang, "Design of a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks," In ELSEVIER, *Computer Communications*, 2006.

[20] Y. Xu, J. Heidemann, D. Estrin, "Geography-informed Energy Conservation for Ad-hoc Routing", In Proceedings of the Seventh Annual ACM/IEEE International Conference on Mobile Computing and Networking 2001, pp. 70-84.

[21] T. Jung, S. Han, Y. Chung, "The Concentric Clustering Scheme for Efficient Energy Consumption in the PEGASIS", In Proceedings of the 9th International Conference on Advanced Communication Technology, Gangwon-Do, Korea, pp. 260–265, 12–14 February 2007.

[22] M. Jiang, J. Ji, Y.C. Tay, "Cluster based routing protocol", Internet Draft, draft-ietf-manet-cbrp-spec-01.txt, work in progress, 1999.

[23] C. C. Chiang, T. C. Tsai, W. Liu and M. Gerla, "Routing in clustered multi-hop, mobile wireless networks with fading channel", The Next Millennium, The IEEE SICON, 1997.

[24] Guangyu Pei Mario Gerla Tsu-Wei Chen. "Fisheye State Routing in Mobile Ad Hoc Networks".

[25] G. Pei, M. Gerla, and X. Hong, "LANMAR: Landmark routing for large scale wireless ad hoc networks with group mobility". In Proceedings of the ACM Symposium on Mobile Ad Hoc Networking and Computing (MOBIHOC), pages 11-18, 2000.

[26] K.K. Kasera, R. Ramanathan, "A location management protocol for hierarchically organised multihop mobile wireless networks", in: Proceedings of the IEEE ICUPC'97, San Diego, CA, October 1997, pp. 158–162.

[27] Muhammad Mahmudul Islam, Ronald Pose and Carlo Kopp, "Routing Protocols for Ad-Hoc Networks".

[28] Kalyani Wankhede, Prof. Sumedha Sirsikar, "Review of Clustering Algorithms in Wireless Sensor Networks", *International Journal of Advance Foundation and Research in Computer (IJAFRC)* Volume 1, Issue 11, November 2014.

[29] Jine Tang, ZhangBing Zhou, Jianwei Niu, Qun Wang, "An energy efficient hierarchical clustering index tree for facilitating time-correlated region queries in the Internet of Things", *Journal of Network and Computer Applications*, 2014.

[30] K. Pister, "On the limits and applications of MEMS sensor networks", Defense Science Study Group report, Institute for Defense Analysis, Alexandria, VA.

[31] J. M. Rabaey, M. J. Ammer, J. L. da Silva, D. Patel, S. Roundy, "PicoRadio supports ad hoc ultra-low power wireless networking, IEEE Computer, July 2000, pp. 42-48.

[33] D. Timmermann, "Smart environments", Invited Paper, Ladenburger Diskurs, Ladenburg, January 2001.