A Review Study of Hierarchical Clustering Algorithms for Wireless Sensor Networks

Vinay Kumar[1], Sanjay B. Dhok[2], Rajeev Tripathi[3] and Sudarshan Tiwari[4]

[1]Assistant Professor, Department of Electronics Engineering, Visvesvaraya National Institute of Technology, Nagpur, Maharashtra, India

[2]Associate professor, Department of Electronics Engineering, Visvesvaraya National Institute of Technology, Nagpur, Maharashtra, India

[3] Professor, Department of Electronics & Communication Engineering, Motilal Nehru National Institute of Technology, Allahabad, Uttar Pradesh, India

[4] Professors & Director, National Institute of Technology, Raipur, Chhattisgarh, India

Abstract

The hierarchical clustering is an efficient way to reduce the overall energy consumption within the cluster by performing aggregation and fusion of data. Hence, the amount of transmitting information to the base station is decreased. Clusters create hierarchical Wireless Sensor Networks (WSNs) which facilitate efficient utilization of limited resources of sensor nodes and thus extend network lifetime, reduce energy consumption of the system and provide overall system scalability. The objective of this paper is to present a state of the art survey on hierarchical clustering in WSNs. Our paper also presents a comparison of different hierarchical clustering algorithms on the basis of cluster properties, cluster head selection, heterogeneity and clustering processes.

Keywords: Wireless Sensor Networks, hierarchical routing, Clustering, clustering algorithms**.**

1. Introduction

WSNs are made up of individual embedded systems that are competent of interacting with their environment through various sensors, processing information locally, and communicating this information wirelessly with their neighbors. A sensor node consists of three components: sensing, processing and communication components and can be either an individual board or embedded into a single unit [1, 2, 3, 4]. Deployment of a large number of nodes in WSNs is one of the main characteristics which makes a major difference between traditional networks & sensor networks. In a wireless medium, large number of nodes have advantages in term of connectivity and coverage but also have disadvantages in terms of increased collision and generated overheads. Grouping of sensor nodes is called a cluster [5]. Clustering is used in WSNs [6, 7, 8], as it provides overall network scalability, efficient use of constrained resources that gives network topology stability and energy saving characteristics. A large number of clusters will cover the area with small size clusters and a very small number of clusters will exhaust the cluster head with large amount of messages transmitted from cluster members. In this work, we have surveyed the state-of-art of different algorithms for hierarchical clustering reported in the literature of WSNs and have presented some of the clustering methodologies. We have also discussed the attributes, advantages and disadvantages of clustering and compared different clustering algorithms based on cluster count, heterogeneity, cluster overlapping, role of cluster heads, objective of sensor node grouping and methodology [9]. The rest of the paper is organized as follows: In Section 2, we provide energy efficient routing. Section 3 presents hierarchical routing in WSNs. Section 4 presents a survey on state-of-art algorithms for hierarchical clustering, reported in the literature with open issues and challenges and the final paper is concluded in section 5.

2. Energy Efficient Routing

Lifetime of the network is determined by residual energy of the system, hence main and most important challenge in WSNs is the efficient use of energy resources. The following are the routing challenges unique to WSNs [10]: fault tolerance, node deployment, and energy consumption without losing accuracy, link heterogeneity, and data reporting model, network dynamic, connectivity, security, transmission media, data aggregation, coverage, scalability and quality of services. There are mainly two different ways to achive energy efficient route selection: maximum network lifetime routing and minimum cost routing [53,54,55].

IJCSI International Journal of Computer Science Issues, Vol. 11, Issue 3, No 1, May 2014
ISSN (Print): 1694-0814 | ISSN (Online): 1694-0784
www.IJCSI.org

2.1 Taxonomy of Routing in WSNs

Routing in WSNs can be divided mainly into three types depending on, network structure, routing criteria and topology which are shown in figure 1. Network structure based routing can be further divided into hierarchical or cluster based routing [10, 11], location based routing [12, 13] and flat routing [14]. Hierarchical or cluster based routing methods, originally proposed in wired networks, with advantages related to efficient communication and scalability. In a hierarchical architecture, sensor nodes with higher energy can be used to process and send the information, while low-energy nodes can be used to perform the sensing in the proximity of the target. It employ some of the well known routing tactics to WSNs [15-18].

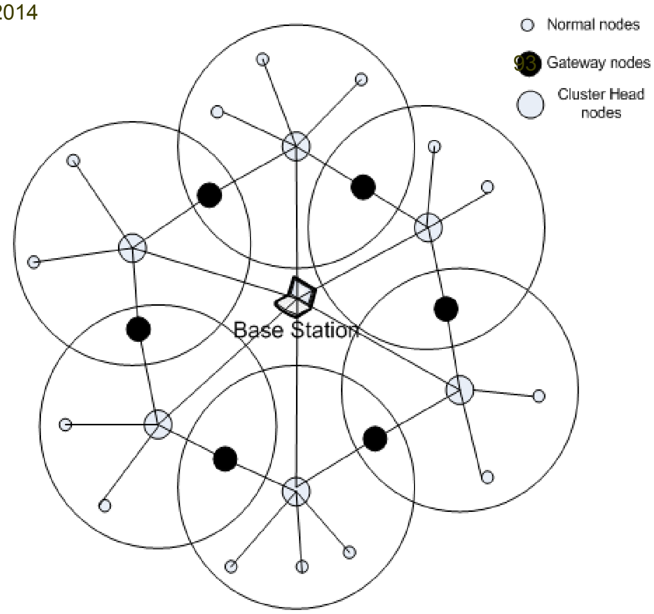

Figure 2: Clustering process in WSNs

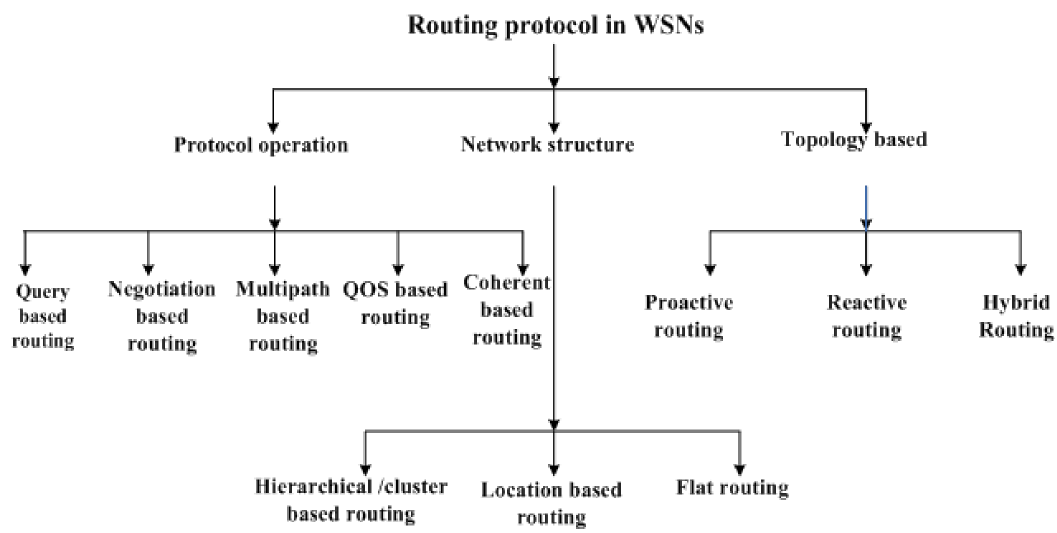

Figure 1. Taxonomy of routing protocol in WSNs.

3. Hierarchical Clustering in WSNs

To achieve network scalability, high energy efficieny and prolong network lifetime in large scale WSNs, sensor nodes are often grouped into non-overlapping clusters called clustering process in WSNs. Hierarchical based routing is a two level routing where first level involves selecting the cluster heads in WSNs[56]. The second level involves the data transmission from nodes to a base station via cluster heads. A large number of clusters will cover the area with small size clusters and a very small number of clusters will exhaust the cluster head with large amount of messages to be transmitted from cluster members [19]. Figure 2 shows the clustering in WSNs along with clusters, cluster heads and base station and figure 3 shows the classification of clustering in WSNs.

3.1 Why Clustering in WSN?

Clustering enables efficient resource distribution and thus helps in better designing of power control. It facilitates data aggression/data fusion and any changes in node behavior within a cluster affect only that cluster, but not the entire network, which will therefore be robust to changes. [20, 21, 22, 23].

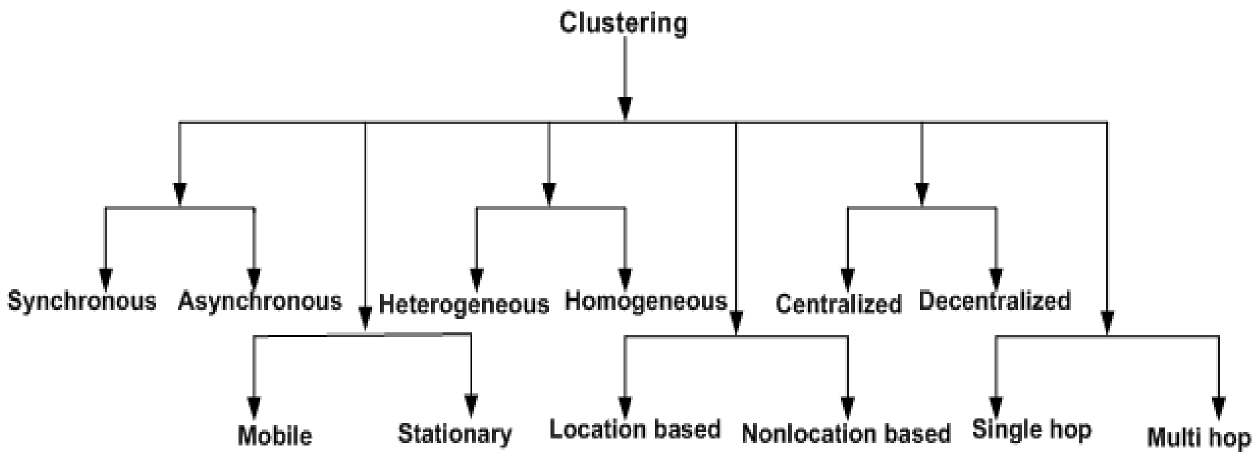

Figure 3. Taxonomy of clustering in WSN

3.2 Drawbacks of clustering

Some of the drawbacks of clustering are as follows[22, 23, 24, 25, 26]:

i. **Range for Clustering***:* In the selection of the cluster heads some algorithms select cluster heads only according to either ID number or residual energy of the sensor nodes. Yet both methods cannot guarantee that the cluster heads(CHs) to be always at the center of the cluster. If the CHs are at the edge of the cluster, extra RF range or number of hops to cover the whole cluster is needed.

ii. **Hot spot in Clustering:** All the data in sensor network are sent to the base station, the traffic near the base station is higher. The sensor nodes in these areas will therefore run out energy earlier. The base station will then be isolated and as a result, the residual energy stored in the other sensor nodes will be wasted.

iii. **Ripple Effect of Re-Clustering***:* In ripple effect of re-clustering, re-election of one cluster head may affect the structure of many clusters.

iv. **Stationary node assumptions for cluster formation:** For moving sensor node networks, sensor node must be assume to be stationary for cluster formation phase so that mobile sensor nodes are able to obtain neighboring information.

v. **Constant Computation Round for Clustering:** The number of rounds that are required for a cluster formation procedure is called computation rounds. Unbounded time complexity represents a non computation round of clustering schemes.

vi. **Message Complexity***:* Message complexity is the total amount of clustering-related message exchanged for the cluster formation. For ripple effect, message complexities for the re-clustering are same for both cluster formation and cluster maintained. But for no ripple message complexity is much lower for re-clustering.

vii. **Flooding in Clustering***:* Energy is wasted by flooding in route discovery and duplicated transmission of data by multiple routes from the source to the destination

4. Different Algorithms for clustering in WSNS

Some of the state of art algorithms for clustering are reviewed below. Figure 4 shows the taxonomy of various algorithms for clustering in WSNs.

LEACH: Low Energy Adaptive Clustering Hierarchy (LEACH) protocol is the oldest clustering algorithm in WSNs. LEACH builds on the work described in [23]. It has following design goals: random placement of nodes, self-configuring and adaptive cluster formation, local control for data transfers and low-energy MAC and application specific data processing. LEACH protocol has different rounds and each round has two phases, a setup phase and steady state phase. In the steady state phase transfer of data takes place and in set up phase it provides cluster formation in an adaptive manner [23].

HEED (Hybrid, Energy-Efficient, and Distributed Clustering Approach) this algorithm [28] uses an iterative clustering process for selection of cluster head. In this approach two features are added to the LEACH protocol first, the routing protocol is assumed to propagate sensor nodes residual energy throughout the network which selects better cluster heads than the original LEACH and Second, sensor nodes select a cluster head in its cluster range proximity which convert LEACH into the multi hop network. HEED approach improves network lifetime over

LEACH for all cost types. This is because of the fact that LEACH randomly selects cluster heads. This may result in faster death of some nodes. This is avoided in HEED as the final cluster heads are selected such that they are well distributed across the network. HEED require less energy in clusters than LEACH because LEACH propagate residual energy information.

GICR (Global Information based Clustering Routing Mechanism) In this paper [28] the authors have proposed a theoretical method for finding clusters in WSNs. LEACH protocol uses a dynamic cluster head election method for election of cluster heads. The number of cluster heads, elected in each round is not always optimal due to dynamic self elected probability per round, this problem is sorted by new algorithm called GICR. This algorithm uses the cooperation of the node in the phase of cluster head election to collect global information and this done through cluster interaction algorithm. The total contribution of this algorithm divided into two parts, first one, it eliminates the blindness of the dynamic cluster head election algorithm in LEACH. Second, it enhances the DCEA (Dynamic Cluster Head Election Algorithms). GICR provide improvement over LEACH protocol in term of system life time and effective data delivery to the base station and this happens because of cluster heads, elected in every round is closer to the optimal value of the number of cluster heads which will consume energy more efficiently.

TSCHS (Two Step Cluster Head Selection Routing Protocol) In LEACH protocol, chosen number of cluster heads in each round varies around the optimal value which reduces the lifetime of the network. The cluster head number variability problem is sorted out by the new protocol TSCHS. In TSCHS [29], cluster head selection is divided into two parts: temporary cluster heads selected on initial selection stage with the number larger than optimal value and after computing first part, number of clusters chosen out of temporary cluster heads which is a based on distance from cluster head to base station and residual energy. Distribution of cluster heads is more evenly and in TSCHS than in LEACH. Thus the author found that TSCHS achieves about 50 percent improvement over LEACH under different network condition. As a result the network works with optimal number of clusters. Thus TSCHS has enhanced the network lifetime by balancing the energy load in the network.

Table I & II shows the comparison of different clustering algorithms.

4.1 Open Issues and Challenges

- ✓ Interesting issues for routing protocols is the consideration of mobility of the node. More recent protocols assume that the sensor node and the base station are stationary. However, there might be situations in some application such as battle environments where the base station and possibly sensor nodes required to mobile. In such cases, information processing and frequent update of the position of the sensor nodes may drain the energy of the nodes. Therefore new routing techniques are needed to maintain
- ✓ Hierarchical routing is an old technique to improve energy efficiency and scalability of networks. However, new techniques of network clustering that maximize network lifetime are growing research area in WSNs.
- ✓ In cluster based routing protocols, a group of sensor nodes efficiently transfer the sensed data to the base station. The cluster heads (CHs) are sometimes chosen as specialized nodes that are less energy-constrained. A cluster-head performs aggregation of data and sends it to the base station on behalf of the sensor nodes within its cluster. The research issues regarding such protocols are how to form the clusters so that the energy consumption and latency are optimized. The factors affecting cluster formation and cluster-head communication are future research areas.

5. Conclusion

Hierarchical routing plays an important role in the performance of WSNs, and research associated with routing is always a focus. One major requirement in WSNs is energy efficiency. We have surveyed the state-of-art of different hierarchical clustering algorithms reported in the literature of WSNs and presented the methodologies utilized by different authors in WSNs from an energy efficiency point of view. We have discussed the fundamental concepts of clustering, clustering attributes, advantages and disadvantages of clustering, different clustering algorithms with its taxonomy. We have also compared the clustering algorithms based on cluster count, heterogeneity, cluster overlapping, role of cluster heads, objective of sensor node grouping and methodology. We have also provided the open issues and challenges in hierarchical routing or clustering

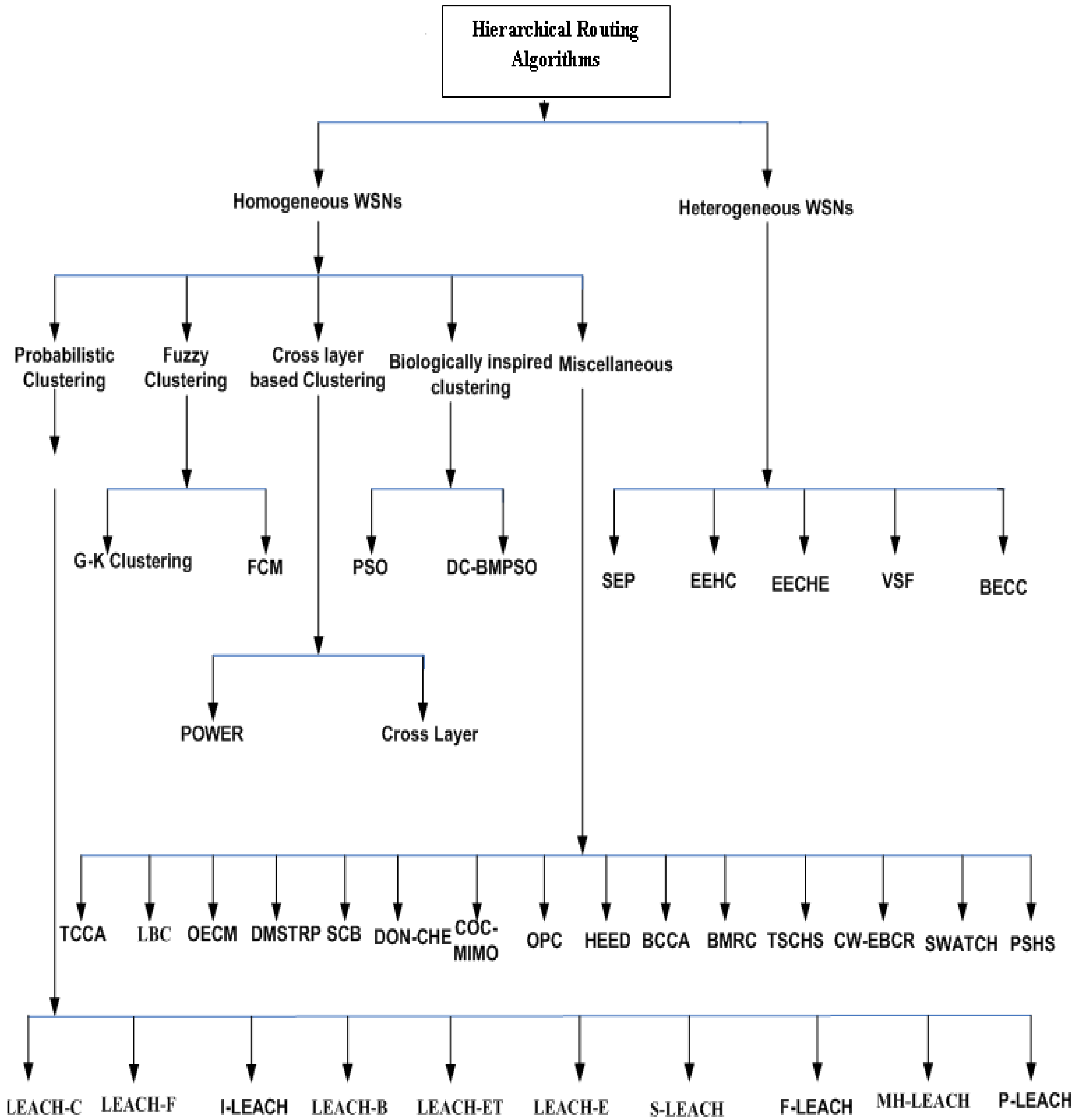

Figure 4: Taxonomy for clustering Algorithms in WSNs

Table 1: Comparison of Clustering Algorithms based on Cluster count, Inter and Intra cluster communication, and the Role of CH

Algorithm	Abbreviation	Cluster count	Intra-cluster topology	Inter-cluster communication	Role of the CHs
Low Energy Adaptive Clustering Hierarchy	**LEACH[23]**	Fixed	Fixed (1- hop)	Direct Link	Relaying
Varying Sensing Field	**VSF[31]**	Variable	Fixed	Multi-hop	Relaying and Aggregation
Level Based Clustering algorithm	**LBC[32]**	Fixed	Fixed (1 2 3… K)	Direct link	Relaying and Aggregation
Systemic Cost Based algorithm	**SCB[33]**	Variable	Adaptive	Multi-hop	Relaying and Aggregation
Power On With Elected Rotation	**POWER[34]**	Variable	Fixed	Multi-hop	Relaying and Aggregation
Stable Election Protocol	**SEP[35]**	Variable	Fixed	Direct Link	Relaying
Hybrid, Energy-Efficient, and Distributed Clustering Approach	**HEED[27]**	Variable	Fixed (1-Hop)	Direct, Multi-hop	Relaying and Aggregation
Base station Controlled Dynamic Clustering protocol	**BCDCP[36]**	Variable	Fixed (1-Hop)	Multi-hop	Relaying and Aggregation
Step Wise Adaptive Clustering Hierarchy	**SWATCH[37]**	Variable	Fixed	Direct Link	Multi-hop and Aggregation
Cluster optimized cooperative MIMO transmission scheme	**COC-MIMO[38]**	Variable	Fixed	Multi-hop	Relaying
Time Controlled Clustering Algorithms	**TCCA[39]**	Variable	Fixed	Multi-hop	Relaying and Aggregation
BC-Clustering Algorithm	**BCCA[41]**	Variable	Fixed	Multi-hop	Relaying and Aggregation
Improved LEACH	**I-LEACH[40]**	Variable	Fixed (1-Hop)	Direct Link	Relaying
Proper Size Hot Spot algorithm	**PSHS[42]**	Variable	Fixed (1-Hop)	Multi-hop	Relaying and Aggregation
Optimal Placement of Cluster heads algorithms	**OPC[43]**	Variable	Adaptive	Multi-hop	Relaying and Aggregation
Dynamic optimum number of CH election method	**DONCHE[44]**	Variable	Fixed	Direct Link	Relaying
Dynamic Clustering-binary Multi PSO algorithm	**DCBMPSO[45]**	Variable	Fixed	Multi-hop	Relaying
Energy Efficient Heterogeneous Clustered Scheme	**EEHC[47]**	Variable	Adaptive	Multi-hop, Direct Link	Relaying and Aggregation
Energy Efficient Cluster Head Election Method	**EECHE[46]**	Variable	Adaptive	Multi-hop, Direct Link	Relaying and Aggregation
Cross layer approach	**CROSS[48]**	Variable	Single hop	Multi-hop	Relaying
Particle Swarm Optimization algorithm	**PSO[49]**	Variable	Single hop	Multi-hop	Relaying, Aggregation
Virtual Grid Based Clustering Routing protocol	**VGCR[50]**	Variable	Single hop	Direct Link	Relaying, Aggregation
Distributed Source Coding based algorithm	**DSCB[51]**	Variable	Fixed (1-hop)	Multi-hop	Aggregation
Gustafson- Kessel clustering	**GK-Clustering[52]**	Fixed	Fixed (1-hop)	Direct Link	N/A

Table 2: Clustering Algorithms comparison based on clustering Method, Heterogeneity, Advantages and CH selection parameters

Algorithm	Abbreviation	Heterogeneity	Advantages	CH selection parameters	Clustering Method
Low Energy Adaptive Clustering Hierarchy	**LEACH[23]**	No	Energy Saving	Residual Energy	Analytical
Varying Sensing Field	**VSF[31]**	Yes	Energy Saving, Network Lifetime	Heterogeneous Sensor	Analytical
Level Based Clustering algorithm	**LBC[32]**	Yes	Energy Saving	Residual Energy	Analytical
Systemic Cost Based algorithm	**SCB[33]**	Yes	Energy Saving	Initial Energy	Analytical
Power On With Elected Rotation	**POWER[34]**	Yes	Power Efficiency, Improvement in Coverage	Residual Energy	Analytical
Stable Election Protocol	**SEP[35]**	Yes	Provide Network Stable Region	Residual Energy	Analytical
Hybrid, Energy-Efficient, and Distributed Clustering Approach	**HEED[27]**	No	Energy Saving	Residual Energy	Iterative
Base station Controlled Dynamic Clustering protocol	**BCDCP[36]**	No	Energy Saving, Network Lifetime	Initial Energy	Iterative
Step Wise Adaptive Clustering Hierarchy	**SWATCH[37]**	No	Energy Saving	Residual Energy	Analytical
Cluster optimized cooperative MIMO transmission scheme	**COC-MIMO[38]**	No	Energy Saving	Residual Energy	Analytical
Time Controlled Clustering Algorithms	**TCCA[39]**	No	Energy Saving	Residual Energy	Analytical
BC-Clustering Algorithm	**BCCA[41]**	No	Network Lifetime	Node ID	Analytical
Improved LEACH	**I-LEACH[40]**	No	Energy Saving	Residual Energy	Experimental
Proper Size Hot Spot algorithm	**PSHS[42]**	No	Enhance Network Life Time	Residual Energy	Analytical
Optimal Placement of Cluster heads algorithms	**OPC[43]**	No	Network Lifetime	Initial Energy	Analytical
Dynamic optimum number of CH election method	**DONCHE[44]**	No	Energy Saving	Residual Energy	Experimental
Dynamic Clustering-binary Multi PSO algorithm	**DCBMPSO[45]**	No	Energy Saving	Residual Energy	Analytical
Energy Efficient Heterogeneous Clustered Scheme	**EEHC[47]**	Yes	Energy Saving	Residual Energy	Analytical
Energy Efficient Cluster Head Election Method	**EECHE[46]**	Yes	Energy Saving	Residual Energy	Analytical
Cross layer approach	**CROSS[48]**	No	Energy Saving, Network Lifetime	N/A	Analytical
Particle Swarm Optimization algorithm	**PSO[49]**	No	Energy Saving	Residual Energy	Theoretical
Virtual Grid Based Clustering Routing protocol	**VGCR[50]**	No	Energy Saving, Network Lifetime	Residual Energy	Analytical
Distributed Source Coding based algorithm	**DSCB[51]**	No	Efficient Data Correlation	Max-Min Hop Number	Analytical
Gustafson- Kessel clustering	**GK-Clustering[52]**	No	Energy Saving	N/A	Fuzzy Clustering

REFERENCES

[1]. F. Akyildiz and M. C. Vuran "Wireless Sensor Networks" *A John Wiley and Sons, Ltd, Publication, 2010*

[2]. G. Pottie and W. Kaiser, "Wireless integrated network a survey" *ACM Communications, Vol.43, No.5, pp. 51–58, 2000*.

[3]. S. Kushwaha, V. Kumar, S. Jain "Node architectures and its deployment in wireless sensor networks: a survey" *High Performance Architecture and Grid Computing, published Springer Berlin Heidelberg pp. 515-526, 2010.*

[4]. V. Kumar and S. Tiwari "Routing in IPv6 over low-power wireless personal networks (6LowPAN): A survey" Journal of computer Networks and Communication 2012.

[5]. J. Y. Yu, and P. H. J. Chong "A survey of clustering schemes for mobile ad hoc networks" *IEEE Communications Surveys Tutorials*, Vol.7, pp. 32–48, 2005.

[6]. A. A. Abbasi, and M. Younis "A survey on clustering algorithms for wireless sensor networks" *Elsevier Science direct Computer Communications*, Vol. 30, pp. 2826–2841, 2007.

[7]. V. Kumar, S. Jain, S. Tiwari "Energy efficient clustering algorithms in wireless sensor networks: A survey" *IJCSI International Journal of Computer Science Issues PP. 1694-0814, vol.8, issue.5 2011.*

[8]. V. Kumar and S. Tiwari "Energy Efficient Mechanisms in Wireless Sensor Networks: A survey" *International Journal of Advanced Research in Computer Science pp.595-604, vol.2, issue.5, 2011*

[9]. B. P. Deosarkar, N. S. Yadav, and R. Yadav, "Cluster head selection in clustering algorithms for wireless sensor networks: A survey" Proceedings *of International Conference on Computing, Communication and Networking* pp. 1–8, 2008.

[10]. J. N. Al-Karaki, R.U. Mustafa and A.E. Kamal "Data Aggregation in Wireless Sensor Networks - Exact and Approximate Algorithms" *Proc. IEEE Wksp. High Perf. Switching and Routing*, pp.18–21, 2004.

[11]. S. Dulman, T. Nieberg, J. Wu, and P. Havinga "Trade-off between traffic overhead and reliability in multipath routing for wireless sensor networks" *Proceedings of IEEE on Wireless Communications and Networking*, Vol.3, pp.1918–1922, 2003.

[12]. Z. Lei, Z. Hongsong, X. Yongjun, and L. Xiaowei "LEGR: A load-balanced and energy-efficient geographic routing for lossy wireless sensor network' *Proceedings of 3rd International Conference on Intelligent Sensors, Sensor Networks and Information*, pp.119–124, 2007.

[13]. V. Kumar, A.S.Raghuvansi and S.Tiwari "Performance study of beacon- enabled IEEE 802.15.4 standards in WSNs with Clustering" International conference on power control and embedded system pp. 1-5, 2010.

[14]. I. F. Akyildiz, S. Weilian, Y. Sankarasubramaniam, and E. Cayirci, "A survey on sensor networks' IEEE *Communications Magazine*" Vol.40, No. 8, pp.102–114, 2002.

[15]. R. Kravets and P. Krishnam, "Application-driven power management for mobile communication" *Journal of Wireless Networks*, Vol.6, No. 4, pp.263–277, 2000.

[16]. L. Subramanian, and R. H. Katz, "An architecture for building self-configurable systems" In *Proceedings of the 1st ACM international symposium on Mobile ad hoc networking and computing*, pp.63–73, 2000.

[17]. L. Hong, J. Luo, Y. Liu and S. Das "daptive data fusion for energy efficient routing in wireless sensor networks" *IEEE Transactions on Computers*, Vol.55, No.10, pp.1286–1299, 2006.

[18]. V.Kumar, S.Tiwari, "Performance of Routing Protocols for Beacon-Enabled IEEE 802.15.4 WSNs with Different Duty Cycle", International Conference on Devices and Communications, pp.1-5, 2011.

[19]. L. Hou, W. Muqing and Y. Zhang "Energy efficiency of self-organization proposals in wireless sensor network" Proceeding of IEEE 70th Conference on Vehicular Technology, pp.1–5, 2009.

[20]. W. Dali, and H. Chan "A survey on cluster schemes in ad hoc wireless networks" *Proceedings of 2nd International Conference on Mobile Technology, application and systems*, pp.1-8, 2005.

[21]. U. C. Kozat, G. Kondylis, B. Ryu, and M. Marina, "Virtual dynamic backbone for mobile ad hoc networks" *IEEE International Conference on Communication*,Vol.1, pp.250-255, 2002.

[22]. B. Chen, K. Jamieson, H. Balakrishnan and R. Morris "SPAN: An energy-efficient coordination algorithm for topology maintenance in ad hoc wireless networks' *In Wireless Networks*, Vol. 8, pp. 481–494, 2002.

[23]. W. Heinzelman, A. Chandrakasan and H. Balakrishnan, " Application-specific protocol architecture for wireless microsensor networks" *IEEE Transaction of Wireless Communications*, Vol. 1, No. 4, pp.660–670, 2002.

[24]. V.Kumar, A.S.Raghuvansi and S.Tiwari "LEACH and Its Derivatives in WSN: A Survey" International Conference on Communication and computational intelligence pp.81-86, 2010/11.

[25]. B. Zarei1, M. Zeynali and V. M. Nezhad, "Novel Cluster Based Routing Protocol in Wireless Sensor Networks" IJCSI International Journal of Computer Science Issues, Vol. 7, Issue 4, No 1, July 2010.

[26]. M. F. K. Abad, M. Ali J. Jamali "Modify LEACH Algorithm for Wireless Sensor Network" IJCSI

International Journal of Computer Science Issues, Vol. 8, Issue 5, No 1, September 2011.

[27]. O. Younis, and S. Fahmy "HEED: A hybrid, energy-efficient, distributed clustering approach for ad hoc sensor networks" *IEEE Transaction on Mobile Computing,Vol. 3, No.4, pp.366–379, 2004.*

[28]. Y. Geng, X. Jinsong, C. Shengshou, and Z. Yingzhou, "GICR: Global information based clustering routing mechanism for wireless sensor network" *Proceedings of 18th International Conference on Computer Communications and Networks*, pp. 1–6, 2009.

[29]. Z. Sun, Z. Zheng, and S. Xu, "An Efficient Routing Protocol Based on two Step Cluster Head Selection for Wireless Sensor Networks" *5th international Conference on Wireless communications, Networking and Mobile Computing*, pp. 1 -5, 2009.

[30]. A.S. Raghuvansi, S. Tiwari, R.Tripathi, and N. Kishor, "Optimal number of clusters in wireless sensor networks: An FCM approach" Proceeding *of IEEE international conference on computer and communication technology*, pp. 817-823, 2010.

[31]. E.J. Duarte-Melo, and L. Mingyan "Analysis of energy consumption and lifetime of heterogeneous wireless sensor networks" Proceedings of IEEE on Global Telecommunications Conference, vol. 1, pp. 21–25, 2002.

[32]. X. Han, X. Cao, E. Lloyd and C. Shen, "Fault-tolerant relay node placement in heterogeneous wireless sensor networks" *26th IEEE international conference on computer communication (INFOCOMM-07)*, Vol. 9, pp.643–656, 2010·

[33]. V. Mhatrea and C. Rosenberg "Design guidelines for wireless sensor networks: communication, clustering and aggregation" *On Ad-hoc networks*, Vol. 2, pp.45–63, 2004.

[34]. W. Li-Chun and W. Chung-WEI "A cross-layer design of clustering architecture for wireless sensor networks" *Proceedings of the IEEE International Conference on Networking, Sensing and Control*, Vol.1, pp. 547–552, 2004.

[35]. G. Smaragdakis, I. Matta and A. Bestavros "SEP: A stable election protocol for clustered heterogeneous wireless sensor networks" 2nd *International Workshop on Sensor and Actor Network Protocols and Applications, 2004.*

[36]. S. D. Muruganathan, D. C. F. Ma, R.I. Bhasin and A. O Fapojuwo "A centralized energy-efficient routing protocol for wireless sensor networks" IEEE Communications Magazine, vol. 43, No. 3, pp. S8–S13, 2005.

[37]. L. C. Wang, C. W. Wang, and C. M. Liu "Optimal number of Clusters in Dense Wireless Sensor Networks: A Cross-Layer Approach" *IEEE Transactions on Vehicular Technology*, Vol. 58, No.2, pp. 966-976, 2009.

[38]. V. K. L.S. Pillutla "Joint rate and cluster optimization in cooperative MIMO sensor networks" Proceedings *of IEEE 6th Workshop on Signal Processing Advances in Wireless Communications*, pp.265–269, 2005.

[39]. S.Selvakennedy and S. Sinnappan "The time-controlled clustering algorithm for optimized data dissemination in wireless sensor network" *Proceedings of 11th International Conference on Parallel and Distributed Systems*, pp. 368–372, 2005.

[40]. H. Liu, L. Li and S. Jin "Cluster number variability problem in LEACH" *Lecture Notes in Computer Science, Vol. 4159, pp. 429–437, 2006*.

[41]. H. Su, and X. Zhang "Energy-Efficient Clustering System Model and Reconfiguration schemes for Wireless Sensor Networks" *Information Sciences and Systems, 40th annual Conference*, pp. 99 – 104, 2006.

[42]. Y. Mao, L. Chengfa, C. Guihai and J. Wu "EECS: An energy efficient clustering scheme in wireless sensor networks"*24th international Proceedings IPCCC*, pp. 535–540, 2005.

[43]. M. Dhanaraj and C.R. Murthy "On achieving maximum network lifetime through optimal placement of cluster-heads in wireless sensor networks, " *Proceedings of IEEE International Conference on Communications*, pp. 3142–3147, 2007.

[44]. W. Huibin, Y. Xian, K. Deli, Y. Xijun, and M. Xiaoping "Route protocol of wireless sensor networks based on dynamic setting cluster" *Proceeding of IEEE International Information acquisition*, pp.112–117, 2007.

[45]. A. Latiff, N.M. Tsimenidis, C. C. Sharif and B. S. Ladha "Dynamic clustering using binary multi-objective Particle Swarm Optimization for wireless sensor networks" *19th international Symposium, pp.* 1 – 5, 2008.

[46]. D. Kumar, T. C. Aseri, and R. B. Patel "EECHE: energy-efficient cluster head election protocol for heterogeneous wireless sensor networks" *International Conference on Advances in Computing, Communication and Control*, pp. 75-80, 2009.

[47]. D. Kumar, C. Aseri and R.B. Patel "EEHC: Energy efficient heterogeneous clustered scheme for wireless sensor networks" *Computer communication*, Vol. 32, Issue 4, pp. 662-667, 2009.

[48]. Q.Wang, K. Xu, H. Hassanein and G. Takahara "Swatch: A stepwise adaptive clustering hierarchy in wireless sensor networks" *4th international IFIP-TC6 Networking Conference, Waterloo, pp. 1422–1425, 2005.*

[49]. C. Hongbin, C.K. Tse, and F. Jiuchao "Minimizing effective energy consumption in multi-cluster sensor networks for source extraction Wireless Communications" *IEEE transactions on mobile computing* Vol. 8, Issue, pp.1480-1489, 2009.

[50]. L. Hong, X. Shunjie, G. Wang and J. Zhe "Uneven virtual grid-based clustering routing protocol for wireless sensor networks" *International Conference on Information and Automation*, pp. 397 – 402, 2009.

[51]. C. Hao and S. Megerian "Cluster sizing and head selection for efficient data aggregation and routing in sensor networks" *Proceedings of IEEE on Wireless*

Communications and Networking,Vol. 4, pp. 2318–2323, 2006.

[52]. A.S.Raghuvansi, S. Tiwari, R. Tripathi and N. Kishor, "G K clustering approach to determine optimal number of clusters for Wireless Sensor Networks" *Proceeding of IEEE international conference on wireless communication and sensor networks*, pp. 1-6, 2009.

[53]. E. Zeydan, D. Kivanc, C. Comaniciu, U. Tureli "Energy-efficient routing for correlated data in wireless sensor networks" *Ad Hoc Networks, Volume 10, Issue 6, August 2012, Pages 962-975*

[54]. V. Kumar, S. Jain and S. Tiwari "Impact of Node Density and Mobility on Scalable Routing Protocols in Mobile AdHoc Networks"Special Issue of International Journal of Computer Applications (0975 8887) on Communication Security, No.5 Mar.2012

[55]. V. Kumar, S. Jain and S. Tiwari " Performance of Routing Protocols in MANETs with Node Density and Mobility using Omni and Directional Antenna"Special Issue of International Journal of Computer Applications (0975 -8887) on Wireless Communication and Mobile Networks, No.11., ww.ijcaonline.org, pp.51-55, Jan.2012.

[56]. A. M. Zungeru, L.Ang, K. P. Seng "Classical and swarm intelligence based routing protocols for wireless sensor networks: A survey and comparison" *Journal of Network and Computer Applications, Volume 35, Issue 5, September 2012, Pages 1508-1536.*

Mr.Vinay Kumar

Working as Assistant Professor in department of Electronics Engineering, Visvesvaraya National Institute of Technology, Nagpur India. He has received the Bachelor's Degree in Electronics and Communication Engineering from Uttar Pradesh Technical University Lucknow India in 2006 and the Master's Degree in Digital system from MNNIT (Motilal Nehru National Institute of Technology) Allahabad, India in 2010 and currently pursuing Ph.D.from MNNIT, Allahabad. His fields of interest are WSNs, MANETs, and WMNs. He is author of more than 17 Journals and conference papers.

Dr. Sanajy B. Dhok

Dr. S. B. Dhok, is Associate Professor in Electronics Engineering Department at Visvesvaraya National Institute of Technology, Nagpur (INDIA). He has done his Ph.D. from VNIT Nagpur. He is a member of IEEE society. He has published many research papers in national and international journals and conferences. His area of interest includes Signal Processing, Image Processing, Data Compression, Wireless Sensor Networks and VLSI Design.

Dr. Rajeev Tripathi

Dr. Rajeev Tripathi is a professor in the Department of Electronics & Communication Engineering at Motilal Nehru National Institute of Technology, Allahabad, India. He has several important administrative and academic positions namely, Head of the Department of Electronics & Communication Engineering, Dean academic, and In-charge Placement Cell. Prof. Rajeev Tripathi obtained his UG degree in Electronics and Telecommunication and PG degree in communication systems and PhD degree from from Allahabad University. He has supervised large number of M.Tech and PhD thesis. He has published number of research papers in the reputed International/National journals and conference proceedings. He has served in the programme committee of the several seminars, workshops and conferences and also worked as reviewer of several conferences and journals both nationally and internationally. He has successfully completed many research projects sponsored by various government agencies. He has been active member of several academic committees at the institute level as well as the member of Board of studies of several technical institutes in India. His areas of current research interest are wireless communication, wireless sensor networks, and next generation networks etc.

Dr. Sudarshan Tiwari

Dr. Sudarshan Tiwari joined as a Director of National Institute of Technology, Raipur on 25th July 2012. Prior to his present assignment, he was professor in the Department of Electronics & Communication Engineering at MNNIT, Allahabad, where he has held several important administrative and academic positions namely, Head of the Department of Electronics & Communication Engineering, Dean Research & consultancy, Dean Resource generation and International affairs, Chairman, GIS Cell, Head of the Mathematics Department, Deputy Project Coordinator INDO-UK REC Project. Prof. Sudarshan Tiwari obtained his UG and PG degree in Electronics Engineering from I.T., B. H. U. and PhD degree from IIT Roorkee. He has more than 32 years of teaching and research experience in the area of Communication Engineering and Networking. He has supervised large number of M.Tech and PhD thesis. He has published over 127 research papers in the reputed International/National journals and conference proceedings.