An Energy Efficient Clustering In Multi-Hop Wireless Sensor Network with Multi-Objective Optimization

D. Rajendra Prasad,

Professor,

Dept. of ECE, St. Ann's College of Engineering & Technology, Chirala, AP-India.

Abstract

Wireless Sensor Networks (WSNs) are collection of nodes with each having its processor, sensor, transmitter and receiver. Sensors are low cost devices performing a specific sensing task. Sensors are small, with limited processing and computing resources used throughout an area to monitor a specific event. Data aggregation through efficient network organization helps nodes to be partitioned into small groups called clusters. This grouping of sensor nodes into clusters is called clustering. Every cluster has a leader, referred to as Cluster-Head (CH). Clustering based routing methods prolong WSNs life. Self-organization and energy efficiency are two characteristics of a large, deployed sensor network which control operation and network life. This paper presents a Hybrid Multi Objective Bee swam Optimization with Hill Climbing for efficient clustering.

Keywords: Wireless Sensor Network (WSN), Clustering, Low Energy Adaptive Clustering Protocol (LEACH), Bee Swarm Optimization (BSO), Hill Climbing.

1. INTRODUCTION

A WSN can be defined as a network of devices, denoted as nodes, which can sense the environment and communicate the information gathered from the monitored field (e.g., an area or volume) through wireless links. The data is forwarded, possibly via multiple hops, to a sink (sometimes denoted as controller or monitor) that can use it locally or is connected to other networks (e.g., the Internet) through a gateway. The nodes can be stationary or moving. They can be aware of their location or not. They can be homogeneous or not [1].The variety of possible applications of WSNs to the real world is practically unlimited, from environmental monitoring, health care, positioning and tracking, to logistic, localization ,and so on.

The important difficulty in the organization of sensor networks is energy efficiency. This requirement for energy efficiency occurs since the sensor node battery capability is strictly restricted and battery replacement is not practical. The sensor node battery restriction reduces the lifetime of the network. The lifetime of every single node differs according to the requirements positioned on its battery [2].Therefore, a main factor in the construction of sensor networks is their robustness to handle the falling life time of every sensor nodes. Different network architectures and routing protocols to reduce energy consumption and to expand sensor network lifetime has been analyzed. After analyzing those techniques, network construction dependent on clustering are regarded as the efficient technique in when energy consumption is considered.

Grouping sensor nodes into clusters has been widely adopted by the research community to satisfy the scalability objective and generally achieve high energy efficiency and prolong network lifetime in large-scale WSN environments. In the hierarchical network structure each cluster has a leader, which is also called the cluster head (CH) and usually performs the special tasks fusion and aggregation, and several common sensor nodes (SN) as members [3].

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 [4]. 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.

The cluster formation process eventually leads to a two-level hierarchy where the CH nodes form the higher level and the cluster-member nodes form the lower level. The sensor nodes periodically transmit their data to the corresponding CH nodes. The CH nodes aggregate the data and transmit them to the base station (BS) either directly or through the intermediate communication with other CH nodes. However, because the CH nodes send all the time data to higher distances than the common (member) nodes, they naturally spend energy at higher rates. A common solution in order balance the energy consumption among all the network nodes is to periodically re-elect new CHs in each cluster.

Many clustering algorithms in various contexts have been proposed. These algorithms are mostly heuristic in nature and aim at generating the minimum number of clusters such that any node in any cluster is at most d hops away from the cluster head [5]. Most of these algorithms have a time complexity of O (n), where n is the total number of nodes. Many of them also demand time synchronization among the nodes, which makes them suitable only for networks with a small number of sensors.

Compared with flat routing protocols in WSNs, clustering routing protocols have a variety of advantages. They are more scalability, Data Aggregation/Fusion, less load, less energy consumption and more robustness, Collision Avoidance, Latency Reduction, Load Balancing, Fault-Tolerance, Guarantee of Connectivity, Energy Hole Avoidance, Maximizing of the Network Lifetime, Quality of Service [6].

The main objective of hierarchical routing is to reduce energy consumption by classifying nodes into clusters. A clustering based protocol that minimizes energy dissipation in wireless sensor networks. In LEACH the role of the cluster head is periodically transferred among the nodes in the network in order to distribute the energy consumption. The performance of LEACH is based on rounds. Then, a cluster head is elected in each round. For this election, the number of nodes that have not been cluster heads and the percentage of cluster heads are used [7].

LEACH randomly selects some nodes as cluster heads, then those cluster heads broadcast a packet saying that they are the cluster head and depending upon the signal strength, other nodes joins one of those cluster heads making a cluster. After that cluster heads synchronize themselves with their respective nodes within the cluster with the help of a schedule message that describes the sleeping and waking up time of the node, ensuring TDMA like division of channel.

Once the cluster head is defined in the setup phase, it establishes a TDMA schedule for the transmissions in its cluster. This scheduling allows nodes to switch off their interfaces when they are not going to be employed. The cluster head is the router to the sink and it is also responsible for the data aggregation. As the cluster head controls the sensors located in a close area, the data aggregation performed by this leader permits to remove redundancy.

The operation of LEACH is divided into rounds. Each round begins with a set-up phase when the clusters are organized, followed by a steady-state phase where several frames of data are transferred from the nodes to the cluster-head and onto the base station.

Set up Phase

In LEACH, nodes take autonomous decisions to form clusters by using a distributed algorithm without any centralized control. Here no long-distance communication with the base station is required and distributed cluster formation can be done without knowing the exact location of any of the nodes in the network. In addition, no global communication is needed to set up the clusters. The cluster formation algorithm should be designed such that nodes are cluster-heads approximately the same number of time, assuming all the nodes start with the same amount of energy [8].

Finally, the cluster-head nodes should be spread throughout the network, as this will minimize the distance the non-cluster-head nodes need to send their data. A sensor node chooses a random number, r, between 0 and 1. Let a threshold value be T (n):

$$T(n) = p/1 - p \times \left(r \bmod p^{-1} \right)$$

If this random number is less than a threshold value, *T(n)*, the node becomes a cluster-head for the current round. The threshold value is calculated based on the above given equation that incorporates the desired percentage to become a cluster-head, the current round, and the set of nodes that have not been selected as a cluster-head in the last (1/P) rounds, p is cluster head probability.

Steady state

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 [9]. The steady state phase is longer than setup phase.

Low-power optimization techniques developed for conventional ad hoc networks are not sufficient as they do not properly address particular features of embedded and sensor networks. It is not enough to reduce overall energy consumption, it is also important to maximize the lifetime of the entire network, that is, maintain full network connectivity for as long as possible [10,11].

Energy efficiency, cost and application requirement are the challenges that are to be taken care while designing a WSN. This requires optimization of both hardware and software to make WSN efficient. Software addresses issue of Network Lifetime. There are several optimization algorithms to suit the different problems. Choosing a proper algorithm is very important in any optimization technique.

This work proposes a Hybrid Multi-objective Bee swam Optimization with Hill climbing for energy efficient clustering. Section 2 reviews related works conducted in literature. Section 3 explains methodology and Section 4 discusses experimental results. Section 5 concludes the proposed work.

2. RELATED WORK

Elhabyan& Yagoub [12] proposed a novel centralized PSO protocol for Hierarchical Clustering (PSO-HC) in WSNs. The objective of the proposed work is to maximize the network lifetime by minimizing the number of active CHs and to maximize the network scalability by using two-hop communication between the sensor nodes and their respective CHs. The effect of using a realistic network and energy consumption model in cluster-based communication for WSN was investigated. Extensive simulations showed that PSO-HC outperformed the well-known cluster-based sensor network protocols in terms of average consumed energy and throughput.

Ma et al., [13] presented and analyzed an Efficient Node Partition Clustering protocol using Niching Particle Swarm Optimization (ENPC-NPSO), a protocol that partitions the network field efficiently and the selection of cluster heads (CHs) considers the networks states information. The results of performance evaluation showed that ENPC-NPSO can improve system lifetime and data delivery by distributing energy dissipation evenly in the networks.

Huynh et al., [14] proposed a new approach by combining the stable cluster selection method with particle swarm optimization and intelligent searching to minimize the distance between the nodes in each cluster and reduce the number of dead nodes over time. The simulation results showed that the proposed protocols have the lower energy consumption and longer lifetime compared to other protocols.

Dandekar& Deshmukh [15] considered the problem of optimal deployment of k sink nodes in a wireless sensor network for minimizing average hop distance between sensors and its nearest sink with maximizing degree of each sink node which can solve hot spot problem which is another critical issue of WSN design. Given a wireless sensor network where the location of each sensor node is known, partition the whole sensor network into k disjoint clusters and place sink nodes optimally. The multi sink placement algorithm was proposed based on Particle swarm optimization. The simulation results showed that the proposed optimization based algorithm perform better over algorithm without optimization.

Ma et al., [16] proposed and analyzed an Adaptive Assistant-Aided Clustering Protocol using Niching Particle Swarm Optimization (AAAC-NPSO), a protocol scheme for wireless sensor networks that obeys the idea of energy efficient with application-specific to obtain good performance. The simulation results showed that AAAC-NPSO can improve system lifespan and data delivery by optimizing energy dissipation in the networks.

Particle swarm optimization (PSO)-based effective clustering in wireless sensor networks was proposed by Parvin& Vasanthanayaki [17].The proposed enhanced-OEERP (E-OEERP) reduces/eliminates such individual node formation and improves the overall network lifetime when compared with the existing protocols. It can be achieved by applying the concepts of PSO and gravitational search algorithm (GSA) for cluster formation and routing, respectively. The performance of the proposed work in terms of energy consumption, throughput, packet delivery ratio, and network lifetime are evaluated and compared with the existing OEERP, low energy adaptive clustering hierarchy, data routing for in-network aggregation, base-station controlled dynamic clustering protocols. The proposed system was simulated using NS-2 simulator. The results proved that, the proposed E-OEERP showed better performance in terms of lifetime.

Liu& Li [18] proposed a new type of routing protocol for WSN called power-efficient clustering routing protocol (PECRP), which is suitable to long-distance and complex data transmission, and for fixed sensor nodes of WSN. The proposed system proved the rationality that multi-hop transmission can prolong the lifetime of WSN in narrow sense situation based on mathematical proofs. The simulations showed that PECRP has better performances than LEACH in prolonging lifetime and transmitting data in the symmetrical distribution of nodes in WSN.

Habib& Marimuthu [19] proposed an energy optimization framework, where the clusters evolve overtime through Ant Colony Optimization (ACO) for selecting near-optimum number of clusters. During cluster evolution, the selection of gateways (clusters) varies the sensor-gateway membership dynamically, and thus changes the lifespan of WSN. The simulation results for a typical WSN with 100 sensors select WSN with three clusters possessing 500 days of lifespan as the best solution compared to the initial WSN with 147 days of lifespan. The fact observed that increasing the number of clusters beyond certain threshold, increased the distance between central server and gateways thereby decreased the lifespan of gateways.

Kulkarni et al., [20] proposed a novel multi-objective optimization method known as Green (Energy Efficient)-Multi-Objective Hybrid Routing Algorithm (G-MOHRA) in WSNs. G-MOHRA uses hierarchical clustering. The performance of G-MOHRA is evaluated through intensive simulation and equated with Simple Hybrid Routing Protocol (SHRP) and Dynamic Multi-objective Routing Algorithm (DyMORA). The metrics such as AEC, Residual Energy, Packet Delivery Ratio, Jitter, and Normalized Routing Load are used for comparison. Performance of G-MOHRA has been observed to outclass SHRP and DyMORA. It improved the Packet Delivery Ratio by 18.72% as compared to SHRP and 24.98 % as compared to DyMORA. G-MOHRA outperformed SHRP and DyMORA in terms of Average Energy Consumption by a factor of 19.79 % and 15.52 % as compared to SHRP and DyMORA respectively.

Sharma et al., [21] proposed a novel routing approach based on ACO algorithm in Wireless Sensor Networks on which LEACH protocol is applied, to route the data packets in sensor networks to maximize energy efficiency and to increase the network lifetime. The performance of the proposed algorithm has been compared with the LEACH protocol and the simulation results showed that the proposed approach provided optimized solutions in terms of efficient energy utilization and enhanced network lifetime.

An efficient energy cluster-based routing protocol (EECRP) for wireless sensor network was presented by Xi-Rong et al., [22] and its properties are investigated. Its core is that using an uneven clustering method to organize network topology and particle swarm optimization (PSO) algorithm to optimize the clusters, which can settle the problem of hot spot and blind nodes, separately. Simulation results showed that the consumption energy of each node is effectively balanced. At the meantime, network lifetime is greatly increased using EECRP.

Mao et al., [23] proposed a novel energy efficient unequal clustering scheme for large scale wireless sensor networks(WSNs) which aimed to balance the node power consumption and prolong the network lifetime as long as possible. The proposed approach focused on energy efficient clustering scheme and inter-cluster routing protocol. The confirmation experiment results have indicated the proposed clustering scheme has more superior performance than other methods such as LEACH and EEUC.

3. METHODOLOGY

In this section, we discussed about hybrid Multi-objective Bee Swarm Optimization with hill climbing algorithm to improve the optimization process.

3.1 Multi-objective Bee Swarm Optimization (MOBSO)

The Multi-objective Bee Swarm Optimization (MOBSO) algorithm is composed taking into account the BSO strategy. The MOBSO separates a swarm to experienced forager, onlooker and scout bees, which fly in a D-dimensional search space $S \subset R^D$ to find an optimal Pareto front. Accept that an arrangement of bees in a swarm is spoken to as β. Bees are partitioned as $\beta = \vartheta \cup k \cup \xi$ in view of fitness, where $\xi, k \text{ and } \vartheta$, speak to sets of experienced forager, onlooker, and scout bees individually [24].

In MOBSO, the bee i is connected with a position vector $\vec{x}(\beta,i)$ which speak to an attainable arrangement in a D-dimensional search space S. Every position vector $\vec{x}(\beta,i)$ speaks to a food source with a related quality vector $f(\vec{x}(\beta,i))$.

MOBSO has three principle phases that are initialization, update and termination. The principal phase starts the algorithm. The second phase is the body of the algorithm and iteratively updates the swarm and the outside file. At last the third phase terminates the algorithm commercial returns the known Pareto front.

In the initialization phase, the quantity of scouts and the quantity of onlookers and experienced forager, $n(\xi \cup k)$, are individually decided as $n(\vartheta) \leftarrow ps \times n(\beta)$ and $n(\xi \cup k) \leftarrow n(\beta) - n(\vartheta)$.

After initiation, the bees of the swarm employ the accompanying processes to modify their positions all through cycles until the termination condition is met. At every cycle of the algorithm, a predefined rate of the swarm SW goes about as scouts while the remaining bees are dynamically partitioned as experienced foragers and onlookers. The non-mastery process is completed utilizing capacity select_non_dominated (SW_{iter-1}) to select experienced foragers. The entire swarm aside from scout is assessed and the non-dominated ones are selected as experienced foragers while the others selected as onlookers.

Classification of bees into the three classes furnishes a swarm with very dynamic behavior, which can utilize distinctive flying patterns [24]. The accomplished forager, onlooker, and scout bees utilize these flying patterns to probabilistically change their trajectories in the search space for finding new food sources with better nectars. The algorithm terminates after predefined number of emphases. After the termination, the outer file contains the known Pareto front.

3.2 Hill Climbing

Hill-climbing is a simple and viable heuristic search strategy in which it is expected that a sensible global optimum can be sensibly drawn closer if on every search step the algorithm picks the direction that maximizes the immediate gain. The quality of the system is in its simplicity [25,26]. It has been widely striven for optimum search in exponential domains in issues, for example, genetic algorithms, clustering, and so forth. When all is said in done, hill climbing has the inclination of getting stuck in local minimums or maximums;

Hill choosing to climb begins a random beginning location from a legitimate arrangement of parameters. It then processes five random locations that are inside of a predefined distance from this beginning location [27]. Every location is assessed in reenactment and the location with the smallest error is picked as the new location. The distance is then sliced down the middle and the process is rehashed until convergence.

function Hill-Climbing(*problem*) **returns** a solution state

inputs: *problem*, a problem

local variables: *current*, a node

next, a node

current ←Make-Node(Initial-State[*problem*])

loop do

next ←a highest-valued successor of *current*

if Value[next] <Value[current] **then return** *current*

current ←*next*

end

3.3 Proposed Hybrid Multi-objective Bee swam Optimization with Hill climbing for energy efficient clustering

Hybridization between evolutionary algorithms and local search is known as memetic algorithms. Memetic Algorithms have been ended up being requests of magnitude quicker and more accurate than evolutionary algorithms for distinctive classes of issues [28]. As reported in the literature, hybrid routines joining probabilistic techniques and deterministic strategies have discovered achievement in taking care of complex optimization issues.

Randomized optimization algorithms are called as "multi-objective" on the off chance that they allow the detail of more than one optimization objective. A few fitness capacities can be characterized, permitting to improve programs for usefulness as well as for nonfunctional necessities such as energy consumption and communication frequency [29]. Besides, diverse search algorithms like randomized Hill Climbing and Genetic Algorithms can be consolidated to accelerate the optimization process.

Hill Climbing strategy has dependably been caught in local optimal arrangement, a heuristic utilizing dominant part voting instrument between neighbor sensor nodes was acquainted with give it a superior opportunity to escape from local optimal arrangements [30]. Clustering procedures are utilized to compose sensor nodes with one selected CH in every cluster.

Hill climbing methodology is utilized to enhance determined arrangements of the MOBSO. In this hybrid algorithm, MOBSO perform global search and hill climbing is utilized to local search. At the point when the beginning answer was acquired by the MOBSO, local search begins with Hill climbing [31]. The task is considered as a neighborhood structure for the issue.

4. EXPERIMENTAL RESULTS

The evaluation setup consists of varying number of sensor nodes (75 to 450) and one sink spread over an area of 4 sq. Km. The simulations are run for 300 sec. The proposed hybrid MOBSO-Hill climbing is compared with BSO. Parameters like end to end delay, packet delivery ratio and lifetime of the network is evaluated during the simulations. Table 1 shows the simulation parameters used in this work.

Table 1 Simulation Parameters

Parameter	Value
Initial number of bees	10
Number of worker bees	5
Number of onlooker bee	5
Number of scout bee	5
initial energy in each node	0.5 J
Crossover rate	0.2
Mutation rate	0.1
Number of iterations	500

Table 2 End to End delay

Number of nodes	BSO	Hybrid BSO-Hill climbing
75	0.001324	0.001305
150	0.001674	0.001459
225	0.015721	0.014095
300	0.01906	0.019849
375	0.042302	0.044328
450	0.04678	0.047712

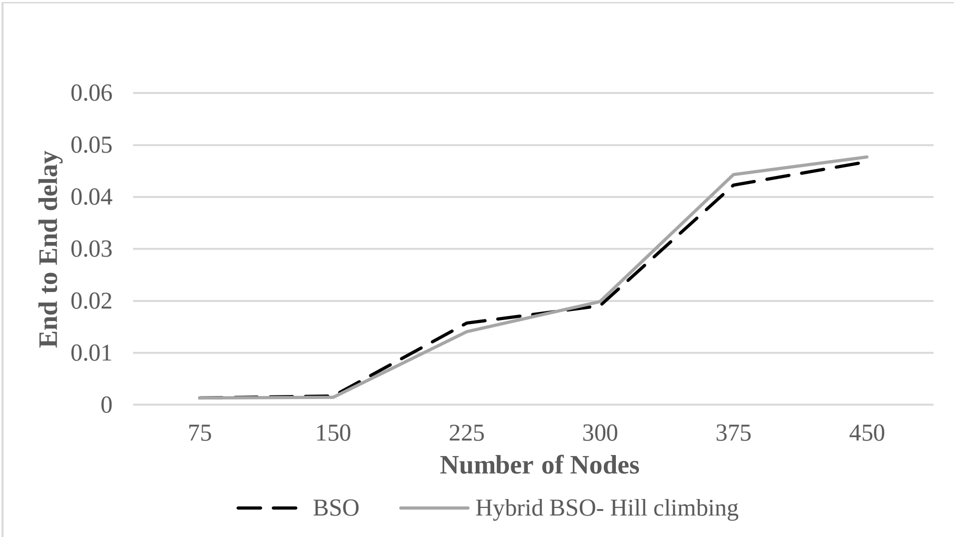

Figure 1 End to End delay

It is observed from the figure 1 and table 2; the proposed hybrid BSO-Hill climbing algorithm reduced the end to end delay when compared with BSO by 13.72% with 150 nodes and by 1.45% with 75 nodes.

Table 3 Packet Delivery Ratio

Number of nodes	BSO	Hybrid BSO-Hill climbing
75	0.8183	0.8554
150	0.79053	0.8283
225	0.772	0.8167
300	0.7351	0.7694
375	0.6846	0.7296
450	0.6	0.6634

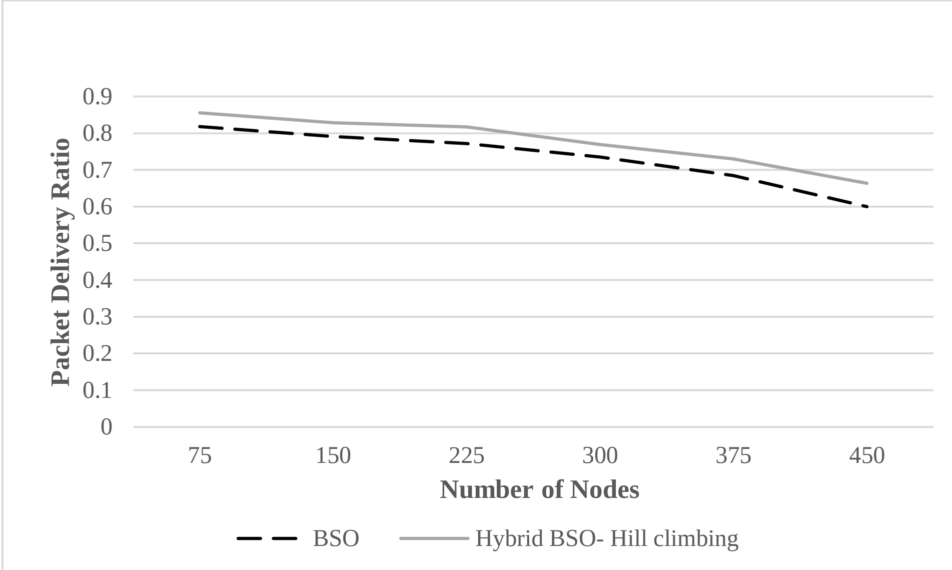

Figure 2 Packet Delivery Ratio

It is observed from the figure 2and table 3, the proposed hybrid BSO-Hill climbing algorithm improved packet delivery ratio when compared with BSO by 10.04% for 450 nodes and by 4.43% for 75 nodes.

Table 4 Lifetime Computation

Number of rounds	BSO	Hybrid BSO- Hill climbing
0	100	100
100	96	97
200	84	89
300	76	79
400	35	56
500	11	34
600	0	9
700	0	0
800	0	0

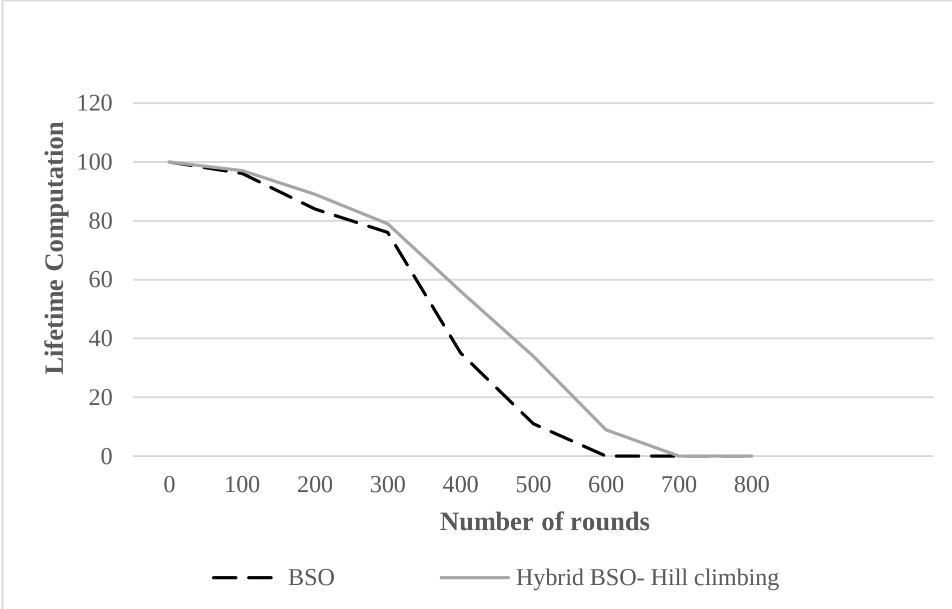

Figure 3 Lifetime Computation

From the table 4 and figure 3, it is observed that with the proposed hybrid BSO with Hill climbing, the network lasts for 600 rounds by then all the nodes in the network die whereas BSO lasts for 500 rounds.

5. CONCLUSION

Energy-efficiency is a core challenge in WSN as energy is limited, valuable and hard to find. Many clustering algorithms are proposed to reduce energy consumption and extend sensor network life. Data aggregation through efficient network organization helps nodes to be partitioned into small groups called clusters. The grouping of sensor nodes into clusters is called clustering. Clustering a network to minimize the total distance is an NP-hard problem. This work presents a Hybrid Multi-objective Bee swam Optimization and Hill climbing for efficient clustering. CH selection process is based on remaining energy, intra cluster and inter cluster distance between nodes. Simulation show that the new MOBSO with Hill climbing method outperformed BSO for packet delivery ratio and network lifetime.

REFERENCES

1. Buratti, C., Conti, A., Dardari, D., & Verdone, R. (2009). An overview on wireless sensor networks technology and evolution. Sensors, 9(9), 6869-6896.
2. Dawood, M. S., Sadasivam, S., & Athisha, G. (2011). Energy efficient wireless sensor networks based on QoS enhanced base station controlled dynamic clustering protocol. International Journal of Computer Applications (0975–8887), 13(4).
3. Mamalis, B., Gavalas, D., Konstantopoulos, C., & Pantziou, G. (2009). Clustering in wireless sensor networks. RFID and Sensor Networks: Architectures, Protocols, Security and Integrations, Y. Zhang, LT Yang, J. Chen, eds, 324-353.
4. Kumar, V., Jain, S., & Tiwari, S. (2011). Energy efficient clustering algorithms in wireless sensor networks: A survey. IJCSI International Journal of Computer Science Issues, 8(5).
5. Bandyopadhyay, S., & Coyle, E. J. (2003, April). An energy efficient hierarchical clustering algorithm for wireless sensor networks. In INFOCOM 2003. Twenty-Second Annual Joint Conference of the IEEE Computer and Communications. IEEE Societies (Vol. 3, pp. 1713-1723). IEEE.
6. Liu, X. (2012). A survey on clustering routing protocols in wireless sensor networks. Sensors, 12(8), 11113-11153.
7. García Villalba, L. J., Sandoval Orozco, A. L., Triviño Cabrera, A., & Barenco Abbas, C. J. (2009). Routing protocols in wireless sensor networks. Sensors, 9(11), 8399-8421.
8. Malik, M., Singh, D. Y., & Arora, A. (2013). Analysis of LEACH protocol in wireless sensor networks. International Journal of Advanced Research in Computer Science and Software Engineering, 3(2), 178-184.
9. Aslam, M., Javaid, N., Rahim, A., Nazir, U., Bibi, A., & Khan, Z. A. (2012, June). Survey of extended LEACH-Based clustering routing protocols for wireless sensor networks. In High Performance Computing and Communication & 2012 IEEE 9th International Conference on Embedded Software and Systems (HPCC-ICESS), 2012 IEEE 14th International Conference on (pp. 1232-1238). IEEE.
10. Bilouhan, S., & Gupta, R. (2011). Optimization of power consumption in wireless sensor networks. International Journal of Scientific and Engineering Research, 2(5), 32-36.
11. Tang, G. Y., Zhou, M. Z., & Yang, D. (2012, October). Adaptive design of wireless sensor networks based on hybrid immune particle swarm optimization. In System Science, Engineering

Design and Manufacturing Informatization (ICSEM), 2012 3rd International Conference on (Vol. 2, pp. 292-295). IEEE.

12. Elhabyan, R. S., & Yagoub, M. C. (2014, October). PSO-HC: Particle swarm optimization protocol for hierarchical clustering in Wireless Sensor Networks. In Collaborative Computing: Networking, Applications and Worksharing (CollaborateCom), 2014 International Conference on (pp. 417-424). IEEE.
13. Ma, D., Xu, P., & Ma, J. (2013, May). An efficient node partition clustering protocol using Niching Particle Swarm Optimization. In Software Engineering and Service Science (ICSESS), 2013 4th IEEE International Conference on (pp. 644-647). IEEE.
14. Huynh, T. T., Phan-Thi, H. N., Dinh-Duc, A. V., & Tran, C. H. (2014, October). Prolong the network lifetime by optimal clustering based on intelligent search algorithms in wireless sensor networks. In Advanced Technologies for Communications (ATC), 2014 International Conference on (pp. 251-255). IEEE.
15. Dandekar, D. R., & Deshmukh, P. R. (2013, February). Energy balancing multiple sink optimal deployment in multi-hop Wireless Sensor Networks. In Advance Computing Conference (IACC), 2013 IEEE 3rd International (pp. 408-412). IEEE.
16. Ma, D., Ma, J., & Xu, P. (2013, May). An adaptive assistant-aided clustering protocol for WSNs using niching particle swarm optimization. In Software Engineering and Service Science (ICSESS), 2013 4th IEEE International Conference on (pp. 648-651). IEEE.
17. Parvin, R., & Vasanthanayaki, C. (2015). Particle Swarm Optimization based Clustering by Preventing Residual Nodes in Wireless Sensor Networks.
18. Liu, T., & Li, F. (2009, September). Power-efficient clustering routing protocol based on applications in wireless sensor network. In Wireless Communications, Networking and Mobile Computing, 2009. WiCom'09. 5th International Conference on (pp. 1-6). IEEE.
19. Habib, S. J., & Marimuthu, P. N. (2014, October). Energy optimization in data communications through cluster evolution. In Information and Communication Technology Convergence (ICTC), 2014 International Conference on (pp. 161-166). IEEE.
20. Kulkarni, N., Prasad, N. R., & Prasad, R. (2014, September). G-MOHRA: Green Multi-Objective Hybrid Routing Algorithm for Wireless Sensor Networks. In Advances in Computing, Communications and Informatics (ICACCI, 2014 International Conference on (pp. 2185-2190). IEEE.
21. Sharma, T., Kumar, B., Berry, K., Dhawan, A., Rathore, R. S., & Gupta, V. (2014, April). Ant Based Cluster Head Election Algorithm in Wireless Sensor Network to Avoid Redundancy. In

Communication Systems and Network Technologies (CSNT), 2014 Fourth International Conference on (pp. 83-88). IEEE.

22. Xi-Rong, B., Zhi-Tao, Q., Xue-Feng, Z., & Shi, Z. (2009, June). An efficient energy cluster-based routing protocol for wireless sensor networks. In Control and Decision Conference, 2009. CCDC'09. Chinese (pp. 4716-4721). IEEE.
23. Mao, S., Zhao, C., Zhou, Z., & Ye, Y. (2011, August). An improved fuzzy unequal clustering algorithm for wireless sensor network. In Communications and Networking in China (CHINACOM), 2011 6th International ICST Conference on (pp. 245-250). IEEE.
24. Akbari, R., & Ziarati, K. (2012). Multi-objective bee swarm optimization. International Journal of Innovative Computing Information and Control, 8(1B), 715-726.
25. Akbari, R., Mohammadi, A., &Ziarati, K. (2010). A novel bee swarm optimization algorithm for numerical function optimization. Communications in Nonlinear Science and Numerical Simulation, 15(10), 3142-3155.
26. Krivitski, D., Schuster, A., & Wolff, R. (2005, April). Local hill climbing in sensor networks. In Proceedings of DMSN workshop, in conjunction with SDM'05.
27. Hnat, T. W., & Whitehouse, K. (2010, June). A relaxed synchronization primitive for macroprogramming systems. In Networked Sensing Systems (INSS), 2010 Seventh International Conference on (pp. 219-226). IEEE.
28. Grosan, C., & Abraham, A. (2007). Hybrid evolutionary algorithms: methodologies, architectures, and reviews. In Hybrid evolutionary algorithms (pp. 1-17). Springer Berlin Heidelberg.
29. Weise, T., & Geihs, K. (2006, July). Genetic programming techniques for sensor networks. In Proceedings of (Vol. 5, pp. 21-25).
30. Li, I. H., Wu, F. N., & Liao, I. E. (2006). An Energy-efficient Three-layer Clustering Hierarchy for Wireless Sensor Networks. In 2nd Workshop on Wireless, Ad Hoc, and Sensor Networks (pp. 27-34).
31. Nagamani, M., Chandrasekaran, E., & Saravanan, D. (2013). Pareto-based Hybrid Multi-Objective Evolutionary Algorithm for Flexible Job-shop Scheduling Problem.