Swarm Intelligence Inspired Energy Efficient Routing Protocols for Sensor Networks: An Investigation

Priyanka chhillar[1], Kirti Bhatia[2], Rohini sharma[3]

[1]*Student, CSE,Sat Kabir Institute of Technology & Management, Bahadurgarh,India*
[2]*A.P,CSE, Sat Kabir Institute of Technology & Management, Bahadurgarh,India*
[3]*Research Scholar, School of Computer & Systems Sciences, Jawaharlal Nehru University New Delhi*

Abstract - *Wireless Sensor Networks suffers from energy exhaustion problem. A large share of energy in wireless sensor network is consumed in routing the data and control packets as compare to other operations like sensing and sleep state. There are various protocols that use optimal path for data routing to conserve energy. An optimal path for routing can be obtained by using Swarm intelligence (SI) techniques. Consequently, in the last period, various routing protocols for sensor networks have been established bestowing to the ideologies of swarm intelligence. Swarm intelligence is the cooperative behavior of distributed, self-established systems, simulated or natural. In this article, we bestow a broad survey of the swarm intelligence based energy efficient routing protocols. We discuss different variants of swarm intelligence and its relevance to the energy efficient routing.*

1.INTRODUCTION

Wireless sensor networks [1] entail a big quantity of self-governing nodes that are furnished with sensing capacities, wireless interfaces, and restricted memory and energy sources. Sensor networks are useful in dispersed and supportive sensing of different types of corporeal events and happenings of interesting incidence. Generally, the sensors are statically arranged over enormous zones. Though, they can be portable also and proficient in working with the atmosphere. The sensor networks can be utilized in a comprehensive continuum of applications in both military and civilian situations, ecological monitoring, investigation for protection, computerized health care, intellectual building automation, automatic traffic mechanism and object tracing [2-3].

In the sensor networks different sensors convey their data towards a global observing data collecting node usually known as a sink that accomplishes complete data aggregation and analysis. Nodes can also transmit data to the intermediate relay nodes that can independently or jointly manage the data before transmitting it to the global sink or towards a global sink, and perform incomplete data aggregation on the route. This is known as in-network data aggregation that is used for energy optimization.

Sensors have short communication span and these form an infrastructure less network across a common wireless channel. Both data and control packets are directed through single hop or through multi-hop. Sensors communicate with each other in the network so as to complete distinctive activities. During communication and other activities, sensors consume a lot of energy.

The planning and execution of routing methods that can use energy efficiently and maintenance information interchange is highly desirable in the sensor networks. There are various theoretical and practical issues during the design of routing protocols. Therefore, in order to improve network's lifespan, the methods embraced for route detection and knowledge routing should be energy balanced. Moreover, as the sensors normally work in an unescorted manner, the network is estimated to show autonomic features [4], i.e. the protocols in practice must be self-established and vigorous to breakdowns. Also, the routing protocol should be capable to manage huge networks, and the related issues like radio interference, use of long multi-hop routes, limited energy.

The necessities of routing protocols are similar in sensor networks as well as in MANETs [5-6]. Though, as equated to the MANETs, sensor networks are more energy confined networks. Here the nodes are generally static and deployed in a remote area that makes it hard to recharge the sensor nodes. The sensor networks are normally used in data-centric applications.

So far, various different routing methods have been suggested for the sensor networks and these protocols are built on a range of different procedures and optimization criteria [7-12]. In this work, we emphasize on routing protocols for sensor networks and these are planned bestowing to the ideologies of swarm intelligence and investigate the best important ones.

The Swarm intelligence (SI) [13, 14] is a comparatively fresh topic that was formerly expressed as ''Every effort which plan new methods or disseminated issue-solving strategies stimulated by the cooperative actions of insects and other animal cultures'' [13]. The SI system forms an autonomous disseminated system that can exhibit flexible, vigorous, and scalable conducts. The SI frameworks incorporate other standard structures such as Ant Colony Optimization (ACO) [14,16,17], Particle Swarm Optimization (PSO) [18,19], Bee Colony organization [20-26], intelligent water drop method [27], cuckoo search method [28,29], the glow-worm (GSO) [30], Bat algorithm [31, 32] and schools of fishes.

The basic processes of these biological organizations have been amended to design novel distributed optimization algorithms for the elaboration of the SI-inspired routing techniques for the sensor networks. The insect societies work as a cooperative unit and essentially resolve routing problems. Insects determine and create paths that can be followed by other insects to successfully move backwards and forwards from their colony to sources of food.

The similarity among the SI systems and routing in sensor networks is very high. These biological systems can be realized as a dispersed flexible system of insolent control packets that use the energy and computational sources to discover the paths in the network or in the environment. Owing to these resemblances between searching behaviours of SI colonies and network routing, a comparatively great number of SI-inspired routing protocols have been projected for wireless sensor networks, in the recent years.

The main purpose of this survey is to summarize the operation of SI-based sensor network routing protocols, and to highlight the advantages and shortcomings of the proposed techniques for the restrictions and goals of routing in sensor networks.

The remaining part of the paper is constituted as follows: section 2 refer to the related work. Section 3 presents the analysis of existing swarm intelligence inspired routing techniques for sensor networks. Section 4 concludes the investigation work and provides future direction.

2. RELATED WORK

In [2] authors used average residual battery level of the entire network and it was calculated by adding two fields to the RREQ packet header of a on-demand routing algorithm i) average residual battery energy of the nodes on the path ii) number of hops that the RREQ packet has passed through.According to their equation retransmission time is proportional to residual battery energy. Those nodes having more battery energy than the average energy will be selected because its retransmission time will be less. Small hop count is selected at the stage when most of the nodes have same retransmission time. Individual battery power of a node is considered as a metric to prolong the network lifetime in [3]. Authors used an optimization function which considers nature of the packet, size of the packet and distance between the nodes, number of hops and transmission time are also considered for optimization. In [4] initial population for Genetic Algorithm has been computed from the multicast group which has a set of paths from source to destination and the calculated lifetime of each path. Lifetime of the path is used as a fitness function. Fitness function will select the highest chromosomes which is having highest lifetime. Cross over and mutation operators are used to enhance the selection. In [5] authors improved AODV protocol by implementing a balanced energy consumption idea into route discovery process. RREQ message will be forwarded when the nodes have sufficient amount of energy to transmit the message otherwise message will be dropped. This condition will be checked with threshold value which is dynamically changing. It allows a node with over used battery to refuse to route the traffic in order to prolong the network life. In [6] Authors had modified the route table of AODV adding power factor field. Only active nodes can take part in rout selection and remaining nodes can be idle. The lifetime of a node is calculated and transmitted along with Hello packets. In [7] authors considered the individual battery power of the node and number of hops, as the large number of hops will help in reducing the range of the transmission power. Route discovery has been done in the same way as being done in on-demand routing algorithms. After packet has been reached to the destination, destination will wait for time δt and collects all the packets. After time δt it calls the optimization function to select the path and send RREP. Optimization function uses the individual node's battery energy; if node is having low energy level then optimization function will not use that node.

3.ANALYSIS OF EXISITING SWARM BASED ENERGY EFFICIENT ROUTING PROTOCOLS

Swarm Intelligence nature in routing protocols

Maximum of the SI inspired routing protocols that are developed for sensor networks are inspired by activities perceived in ant and, bee colonies. Additionally, the searching patterns of the insect colonies have assisted a chief source of motivation to design a variety of new routing techniques. The intention rests in the point that, throughout of searching, the entities of the colony mutually investigate the surroundings to determine sources of food and, once located them, they set up routes among the roost and the sources of food. The insects follow the same route to go and to come back, as to successfully transfer the food back to the roost (nest). Hence, the cooperative searching progression contains dispersing exploration, detection, establishing, and practice of optimized routing paths in lively atmospheres. This procedure is much similar to the route establishing process by sensor nodes in the sensor networks. Here, sensor nodes collectively establish multi-hop routes towards the sink node. The sensors exchange the control packets, establish routes and then select an optimal path towards the sink for data transmission. The swarm intelligence can be summarized as follows:

(a) It is de-centralized; control is completely distributed among a number of entities.
(b) The communication process is completely localized among the entities.
(c) All the entities exhibit similar behavior without consulting each other.

Ant Colony Optimization based approaches

It has been observed that ants deposit a chemical like material (pheromone) while moving over a path. The communication between the ants is based on the amount of pheromones, produced by the ants. More is the quantity of the pheromone on a path, more it will be followed by other ants. Figure 1 illustrates the complete process of ACO approach in searching food from the nest to the source. While moving towards the food, an ant lays some amount of pheromone on the path, the following ants attract towards the pheromone and also lays some pheromone on the same path. While returning back to the nest, an ant follows the path that has the highest amount of the pheromone. Figure 1 also shows that there is an obstacle in the path that creates two paths towards the food source. Now some ants can follow longer path. Over time, amount of pheromone evaporates. In a short route, amount of pheromone will be more as compared to amount of pheromone in the longer path, as a result when the ants come back from food source, they will detect more amount of pheromone on a short path, now all the ants will follow the shortest path.This path is known as an optimal path for routing. The transition probability of an ant in moving from a point i to j is given by:

$$p_{ij}(t) = \frac{[\tau_{ij}(t)]^{\alpha} * [\eta_{ij}(t)]^{\beta}}{\sum_{S_l \in Next\ candidate)} [\delta\tau_{il}(t)]^{\alpha} * [\eta_{ij}(t)]^{\beta}} \quad (1)$$

Where, t_{ij} is the pheromone concentration on the path between (i, j) and η_{ij} is the heuristic estimate of the path from position i to j. The α and β are the constant factors that regulate the effect of the pheromone and the heuristic on the choice of the ant. Here next candidate is an ant that follows the path between point i and j through some intermediate point (l).

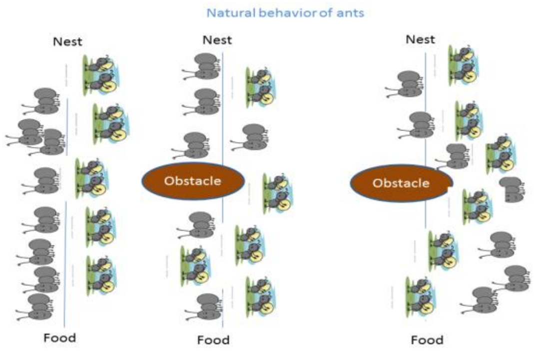

Fig 1: Natural Behavior of Ants

Sharma et al. [17] have proposed an ACO inspired lifespan maximization protocol for sensor networks. The authors have searched an optimal path between the non-cluster nodes and the sink. Other than ACO, they have used different transmission levels for transmission within the cluster and for transmission on the ACO path.

Liu et al. [38] have proposed ACO-greedy approach which improves network's lifetime by eliminating energy holes problem [11]. They have used ACO for accurate node deployment in the area, and this provides full coverage in the network with low deployment cost.

The Authors in [39] have used parallel ACO approach and k-mean clustering techniques to diminish power consumption and expand lifetime of the network. The authors in [40] have proposed IC-ACO that select an optimal radius around the cluster head and the node with highest residual energy transmits to the cluster head while rest of the nodes goes to sleep mode. Nodes which are in the cluster head and not in the sleep mode discover an optimal path towards the sink and transmit the data through the optimal path. This approach improves the lifetime of the network. The authors in [41] have presented ant transitions (ACO-TCAT) to diminish poorer results and constricted the exploring scope of the algorithms.

Bee Colony Optimization

The Bee Colony Optimization (BCO) is another Swarm Intelligence (SI) optimization method and it is based on well-organized labour employment and power depletion. It is a multi-agent disseminated paradigm. In the BCO paradigm, there are three types of bees; Queen, drones and Workers [20]. There are three types of bees in the workers' group, The food is collected by the group of workers. Some are the employed bees that hunt for the food and convey its information (fitness value) to the onlooker bees that select the finest quality food. The scout bee search for a fresh food source. Dancing bees attract the onlookers bees towards the food source. A fitness value is estimated for every fresh food resource and the employed bee remembers the one which has higher fitness value that is transmitted to the onlooker bees. For every employed bee, a candidate food resource or the solution is calculated from the previous one by:

$$V_{ij} = x_{ij} + rand(-1,1) * (x_{ij} - x_{kj}) \quad (2)$$

Where j is the problem domain and k is the number of employed bees. Figure 2 describes BCO method.

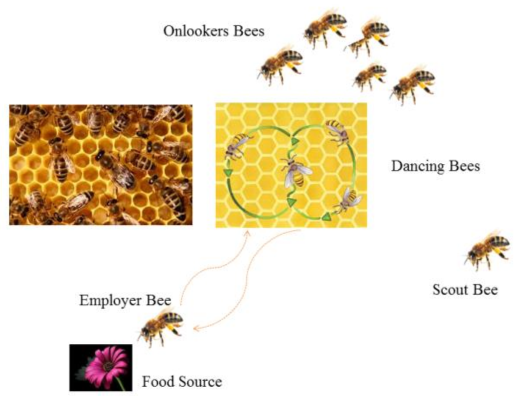

Fig 2: Bee Colony Optimization

The authors in [41] have proposed the "The PEEBR" routing algorithms. It considers energy conversion and development during routing. It is based on the BCO approach. Here, the scout bee collects delay parameters and energy depletion during flying from one node to another. Onlookers bees allocates the routing path according to the goodness of the routing path. It has two phases; first phase is Node-level for energy saving and second phase for selecting the path with energy depletion called network level. The network level provides two main information's about the energy consumption of the path. First is the residual power of the all nodes and second is the quantity of power consumed in transporting the data through given routing path.

Saleem et al. [42] have introduced a power aware routing protocol Bee Sensor. There are two categories of scouts in the Bee Sensor; forward and backward scouts. A source node initiates a forward scout in the direction of sink and the same scout come back at the source sensor, a dance number is computed through the least residual power of the route that specifies the figure of foragers to be emulated from this scout. The foragers transmit data from the source sensor to the sink.

Particle Swarm Optimization

It is a famous SI-inspired technique which is stimulated by the social deeds of the species, e.g. swarm of birds, fish school [19]. Figure 3 depicts a pattern of particle swarm based bird optimization.

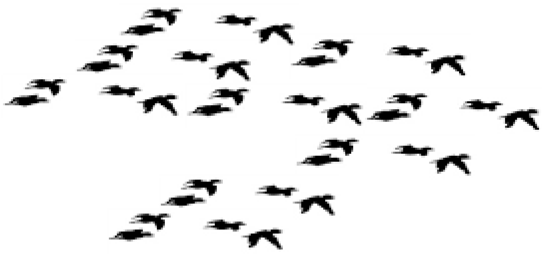

Fig 3: particle swarm based bird optimization

The population based optimizes a fitness function. It exercises the swarm of particles (search point) and follow the fitness of every point. Every particle is linked with some velocity that helps a particle to travel to a better position. Singh et al. [43] projected a power aware PSO inspired clustering method. It finds the optimal position (at centre of mass) for the cluster head. This optimization of the cluster head position reduces the average distance of all cluster members to the cluster head. The reduced distance assists in reducing the power consumed during the transmission. It considers N particles around the centre of mass and the velocity of the particles is depended on the residual power and the quantity of sensor nodes near it.

The authors in [44] have improved network lifetime by reducing power depletion in the sensor systems. They have expended the PSO method to detesct the optimal sink position in the network. The sink position has been used to for relay nodes, which reduce energy consumption in the network. Sudarmani et al. in [45] have used PSO based method for energy aware heterogeneous sensor networks and mobile sink. Table gives analysis of the protocols.

Table: Comparative Analysis of the Swarm Intelligence Inspired Routing Protocols

Routing Protocols	**Energy Efficiency**	**Scalability**	**Network Lifetime**	**Simulator**	**Swarm Technique**
DTP-ACO	High	High	High	MATLAB	ACO
ACO-Greedy	High	High	High	Visual C++ 6.0.	ACO
ACO-TCAT	Moderate	Weak	Moderate	Visual C++ 6.0.	ACO
Parallel Ant Colony Optimization	Low	Weak	Low	JAVA	ACO
IC-ACO	Low	Weak	Low	MATLAB	ACO
Ant-Chain	High	Weak	Very High	Ns-2	ACO
PEEBR	High	Weak	High	Visual C++	BCO
BeeSensor	Very High	Weak	High	Ns-2	BCO
Energy aware clustering [43]	Very High	Weak	High	Ns-2	PSO
Optimal Sink Location [44]	Moderate	Weak	Low	MATLAB	PSO
Mobile Sink [45]	Low	Weak	Low	Ns-2	PSO

4. CONCLUSION AND FUTURE WORK

WSNs are highly energy constrained networks, new routing methodologies are required for these networks. The existing swarm intelligence based routing protocols can lessen the problem of energy consumption in the network. Our survey of the protocols illustrates that, substantial attempts have been made in projecting the techniques to resolve the issue of energy consumption in the sensor networks. The outcomes of the analytical comparison have been reported in the Table. There are also some drawbacks in the routing protocols like more delay, absence of information about the throughput of the network. However, most of the protocols efficiently use the swarm based intelligence method to resolve the energy issue of the sensor network. In future we will develop some SI inspired energy efficient technique for sensor networks.

REFERENCES

[1] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci, A survey on sensor networks, IEEE Communications Magazine Vol. 40, Issue 8, pp. 102–114, 2002.

[2] C. Raghavendra, K. Krishna, T. Znati (Eds.), Wireless Sensor Networks, Springer-Verlag, 2004.

[3] K. Sohraby, D. Minoli, T. Znati, Wireless Sensor Networks: Technology, Protocols, and Applications, Wiley, 2007.

[4] J. Kephart, D. Chess, The vision of autonomic computing, IEEE Computer Magazine Vol. 36, Issue 1, pp. 41–50, 2003.

[5] R. Sharma, D.K. Lobiyal, Proficiency Analysis of AODV, DSR and TORA Ad-hoc Routing Protocols for Energy Holes Problem in Wireless Sensor Networks, Procedia Computer Science, Elsevier, Vol. 57, pp.1057-1066, 2015.

[6] R. Sharma, D.K. Lobiyal, Energy Based Proficiency Analysis of Ad-hoc Routing Protocols in Wireless Sensor Networks, in IEEE Conference Proceedings (ICACEA), pp. 882-886, March 2015.

[7] K. Akkaya, M. Younis, A survey on routing protocols for wireless sensor networks, Ad Hoc Networks Vol. 3, Issue 3, pp. 325–349, 2005.

[8] J. Al-Karaki, A. Kamal, Routing techniques in wireless sensor networks: a survey, IEEE Wireless Communications, Vol. 11, Issue 6, pp.6–28, 2004.

[9] A. Boukerche, M. Ahmad, B. Turgut, D. Turgut, A taxonomy of routing protocols in sensor networks, in: A. Boukerche (Ed.), Algorithms and Protocols for Wireless Sensor Networks, Wiley, pp. 129–160, 2008.

[10] Z. Jin, Y. Jian-Ping, Z. Si-Wang, L. Ya-Ping, L. Guang, A survey on position-based routing algorithms in wireless sensor networks, Algorithms Vol. 2, Issue 1, pp.158–182, 2009.

[11] R. Sharma, D.K. Lobiyal, Energy Holes Avoiding Techniques in Sensor Networks: A survey, International Journal of Engineering Trends and Technologies. Vol. 24, No.4, pp. 204-208, 2015.

[12] R. Sharma, D.K. Lobiyal, Region Based Energy Balanced Inter-cluster communication Protocol for Sensor networks, in NCCCIP Conference Proceedings, pp. 184-195, 2-3 May 2015.

[13] E. Bonabeau, M. Dorigo, G. Theraulaz, Swarm Intelligence: From Natural to Artificial Systems, Oxford University Press, New York, USA, 1999.

[14] M. Dorigo, G.A. Di Caro, The ant colony optimization metaheuristic, in: D. Corne, M. Dorigo (Eds.), New Ideas in Optimization, McGraw-Hill, pp.11–32, 1999.

[15] J. Kennedy, R.C. Eberhart, Y. Shi, Swarm Intelligence, Morgan Kaufman, San Francisco, USA, 2001.

[16] M. Dorigo, T. Stützle (Eds.), Ant Colony Optimization, MIT press, 2004.

[17] R. Sharma, D.K. Lobiyal, Dual Transmission Power and Ant Colony Optimization Based Lifespan Maximization Protocol for Sensor Networks, International Journal of Business Data Communications and Networking (IJBDCN), Vol.11, Issue 1, pp. 1-14, 2015.

[18] F.V.D. Bergh, A. Engelbrecht, A study of particle swarm optimization particle trajectories, Information Sciences 176 (8) (2006) 937–971.

[19] J. Kennedy, R.C. Eberhart, Y. Shi, Swarm Intelligence, Morgan Kaufman, San Francisco, USA, 2001.

[20] C. Ozturk, D. Karaboga, and B. Gorkemli, Artificial bee colony algorithm for dynamic deployment of wireless sensor networks, Turkish Journal of Electrical Engineering&Computer

Sciences, Vol. 20, no. 2, pp. 255–262, 2012.

[21] C. Ozturk, D. Karaboga, and B. Gorkemli, Probabilistic dynamic deployment of wireless sensor networks by artificial bee colony algorithm, Sensors, Vol. 11, no. 6, pp. 6056–6065, 2011.

[22] D. Karaboga, B. Gorkemli, C. Ozturk, and N. Karaboga, A comprehensive survey: artificial bee colony (ABC) algorithm and applications, Artificial Intelligence Review, 2012.

[23] W. Gao, S. Liu, and L.Huang, A global best artificial bee colony algorithm for global optimization, Journal of Computational and Applied Mathematics, Vol. 236, no. 11, pp. 2741–2753, 2012.

[24] A. Rajasekhar, A. Abraham, and M. Pant, Levy mutated artificial bee colony algorithm for global optimization, in Proceedings of IEEE International Conference on Systems, Man, and Cybernetics (SMC '11), pp. 655–662, Anchorage, Alaska, USA, October 2011.

[25] X, Yu, J. Zhang, J. Fan, and T. Zhang, A Faster Convergence Artificial Bee Colony Algorithm in Sensor Deployment for Wireless Sensor Networks, International Journal of Distributed Sensor Networks, Vol. 2013, Article ID 497264, 9 pages.

[26] A. Dubey, D.Meena, Artificial Bee Colony Based Energy Efficient Routing Protocols in MANET: A Survey, International Journal of Engineering Research & Technology (IJERT), Vol. 3, Issue 2, pp. 1271- ,1276, 2014.

[27] H. Shah-Hosseini, "The intelligent water drops algorithm: a nature-inspired swarm-based optimization algorithm," International Journal of Bio-Inspired Computation, Vol. 1, pp. 71-79, 2009.

[28] M. Dhivya and M. Sundarambal, "Cuckoo Search for data gathering in Wireless Sensor Networks," International Journal of Mobile Communications, Vol. 9, Issue 6, pp. 642-656, 2011.

[29] M Dhivya, M.Sundarambal, and L. N. Anand, Energy efficient computation of data fusion in wireless sensor networks using cuckoo based particle approach (CBPA), International Journal of Communications, Network and System Sciences, Vol. 4, No. 4, 2011, pp. 249-255.

[30] W. H. Liao, Y. Kao, and Y. S. Li, A sensor deployment approach using glowworm swarm optimization algorithm in wireless sensor networks, Expert Systems with Applications, Vol. 38, no. 10, pp. 12180–12188, 2011.

[31] M. Sharawi, E. Emary, I. A. Saroit, H.El-Mahdy, Bat Swarm Algorithm for Wireless Sensor

Networks Lifetime Optimization, International Journal of Science and Research (IJSR), Vol. 3, Issue 5, pp. 654- 664, 2014.

[32] S. Sendra, L. Parra, J. Lloret, and S. Khan, Systems and Algorithms for Wireless Sensor Networks Based on Animal and Natural Behavior, International Journal of Distributed Sensor Networks Vol. 2015, Article ID 625972, 19 pages.

[33] M. Saleem ,G. A. D. Caro, M. Farooq, Swarm intelligence based routing protocol for wireless sensor networks: Survey and future directions, Information Sciences, Vol. 181, pp. 4597–4624, 2011.

[34] S. P. Kaur, A. Kaur, Review of Power-Efficient Gathering in Sensor Information System (PEGASIS) for Network Optimization in WSN, International Journal of Advanced Research in Computer Science and Software Engineering, Vol. 4, Issue 6, pp. 872- 877, 2014.

[35] M. Jindal, P. Khandnor, Routing Protocols for Wireless Sensor Networks Based on Swarm Intelligence: A Review, International Journal of Advanced Research in Computer Science and Software Engineering, Vol. 5, Issue 4, pp. 1129-1136, 2015.

[36] A. M. Zungeru, Li-MinnAng, K. P. Seng, Classical and swarm intelligence based routing protocols for wireless sensor networks: A survey and comparison, Journal of Network and Computer Applications, Vol. 35, pp. 1508-1536, 2012.

[37] F. Çelik, A. Zengin and S. Tuncel, A survey on swarm intelligence based routing protocols in wireless sensor networks, International Journal of the Physical Sciences Vol. 5, Issue 14, pp. 2118-2126, 2010.

[38] X. Liu, D. He, Ant colony optimization with greedy migration mechanism for node deployment in wireless sensor networks, Journal of Network and Computer Applications, Vol. 39, pp. 310–318, 2014.

[39] K. V. Janaki Raam and K. Rajkumar, A Novel Approach using Parallel Ant Colony Optimization Algorithm for Detecting Routing Path based on Cluster Head in Wireless Sensor Network, Indian Journal of Science and Technology, Vol. 8, Issue 16,pp.1-7, 2015.

[40] J. Kim, T. Sharma, B. Kumar, G. S. Tomar, K. Berry, and W. Lee, Intercluster Ant Colony Optimization Algorithm for Wireless Sensor Network in Dense Environment, International Journal of Distributed Sensor Networks. Vol. 2014, Article ID 457402, 10 pages, 2014.

[41] X. Liu, Sensor Deployment of Wireless Sensor Networks Based on Ant Colony Optimization with Three Classes of Ant Transitions, IEEE Communications Letters, Vol. 16, Issue 10, pp. 1604-1607, 2012.

[41] I. M. A. Fahrnv, H.A. Hefny, L. Nassef, PEEBR:Predictive Energy Efficient Bee Routing Algorithm for Ad-hoc Wireless Mobile Networks, in 8th International Conference on INFOrmatics and Systems (INFOS2012) - 14-16 May, Computer Networks Track, Faculty of Computers and Information - Cairo University, 2012.

[42] M. Saleem, M. Farooq, Beesensor: a bee-inspired power aware routing protocol for wireless sensor networks, in:Proceedings of EvoWorkshops (EvoCOMNET), Vol. 4448, pp.81–90, 2007.

[43] B. Singh, D.K. Lobiyal, A Novel Energy-Aware Cluster Head Selection based on Particle warm Optimization for Wireless Sensor Networks, Human-centric Computing and Information Sciences Journal, SpringerOpen, Vol. 2, pp. 1-28, 2012.

[44] Md. N. Rahman, M. A, Matin, Efficient Algorithm for Prolonging Network Lifetime of

Wireless Sensor Networks, Tsinghua Science and Technology, Vol. 16, no. 6, 2011.

[45] Sudarmani, R., K.R. S. Kumar, Particle Swarm Optimization-Based Routing Protocol for Clustered Heterogeneous Sensor Networks with Mobile Sink, American Journal of Applied Sciences, Vol. 10, Issue 3, pp. 259-269, 2013.