Int. Res. Adv. 2016, 3(2), 56-61 Article

Integrated Science

Integrated Research Advances

Termite Colony Optimization Based Routing In Wireless Mesh Networks

Sharad Sharma,[1*] Asha Malik[2]

[1]Department of Electronics &Communication Engineering, Maharishi Markadeshwar University, Mullana, Ambala, Haryana, India. [2]Department of Electronics &Communication Engineering, Panipat Institute of Engineering and Technology, Panipat, Haryana, India

Received on: 1-June-2016 Accepted and Published on: 5-July-2016

ABSTRACT

With the advancement in wireless technologies WMN has become key component of the next generation wireless network technologies. Due to the dynamically changing network conditions finding paths in the networks have become a challenging issue for their implementation. In this paper we propose a nature inspire swarm intelligence based soft computing technique called Termite Colony Optimization, for solving network path optimization problems. TCO takes its inspiration from natural termite's mound building behaviour based on the pheromone gradient. It is a meta-heuristic technique. TCO is effective at calculating minimum cost path when run for definite iterations, thus optimizes network performance.

Keywords: Soft Computing, Stigmergy, Swarm Intelligence (SI), Termite Colony Optimization (TCO), Wireless Mesh Network (WMN.)

INTRODUCTION

Wireless Mesh Network is a multi-hop network incorporating features of rapidly deployable, self-organizing,self-configuring,self-balancing, healing and self-aware network. It is a superset of the existing wireless network topologies. The nodes are key structural and functional units of these networks. The nodes can be static or dynamic, individually have the capability to automatically establish connection to create network by sensing and connecting to nodes having similar capabilities within their radio range.

The nodes work both as a host as well as router and forward packets between any two nodes within their radio range. They comprise of both mesh routers and mesh clients. These features provide advantage of reliable service coverage with robustness, low upfront cost, easy network maintenance and help in providing connectivity anytime and anywhere to the internet. Based on the functionality of nodes the network is categorised in three types: (i) Client mesh, (ii) Infrastructure mesh and (iii) Hybrid mesh.[1]

Corresponding Author Dr. Sharad Sharma
Tel: +91-9416327989
Email: sharadpr123@rediffmail.com

Cite as: *Int. Res. Adv., 2016, 3(2), 56-61.*

The highly dynamic topology of WMN has made routing to be one of the most critical issue. To cope with these routing issues a large number of routing protocols and routing metrics are designed in literature by research fraternity. Also routing algorithms are designed which take these matrices in consideration for finding optimal path.

A routing metric is formed by assigning a value to each route or path. It is used by the routing algorithm to select one or more paths out of the subset of paths discovered by the routing protocol. Generally, the value reflect the cost of using a particular path with respect to some optimization objectives and account as indicator of network performance. A comparison of the existing routing metric and protocols in WMNs is done in.[2] In WMN high quality routes in due time are desired, Quality aware routing (QAR)[3] is one such approach another approach Interference Aware Routing using Ant Colony Optimization (AMIR) deals with interference issues.[4]

For the formulation of routing algorithm in changing environment, it is required to have complete knowledge of the traffic flow between each node. This pretends to be an extremely difficult task, so suboptimal routing solutions are calculated using policies based on heuristics. Heuristic approach is followed by stochastic algorithms and is effective at generating good solutions by taking computational efforts into consideration. Traditional approaches are well suited for generating paths in small sized networks. For solving the above mentioned problem in trend soft computing techniques especially nature inspired swarm intelligence (SI) based evolutionary algorithms are designed and implemented. These algorithmic approaches are gaining popularity for finding solutions to computationally hard problems.

In this paper, we propose a nature inspired swarm intelligence based soft computing technique, Termite Colony Optimization. It is a probabilistic, meta heuristic and hybrid algorithmic approach. TCO takes its inspiration from the natural eusocial termite's mound building behaviour. In colony an organism modulates directly or indirectly the availability of resources for other organisms, *stigmergy* is the name given to this term in engineering.[5] The SI principles are significantly applied by termites in WMN framework to find optimal path based on the cost function. The termites are artificial agents which iteratively build probabilistic solutions by taking into account pheromone trails and local heuristic information available at a node. TCO is applied to evaluate shortest path in configured client WMNs.

Related Work

A large number of nature inspired soft computing techniques are present in literature to mention a few, Big bang and big crunch (BB-BC),[9] Biogeography based optimization (BBO),[7] Artificial bee colony,[8] Ant colony optimization (ACO),[9] firefly algorithm[10] etc. The best features of the nature are incorporated in these algorithms which have evolved over decades.

BeeAdHoc is a hybrid algorithm inspired by the foraging behavior of honey bees and applied to Ad Hoc networks,[11] AntHocNet another hybrid routing algorithm based on the self organising behaviour of ant colonies for finding shortest path is related to optimize the performance of the network.[12] Another efficient probabilistic reactive algorithm is *Termite* uses the concept of stigmergy to maximize throughput of network.[13] A survey of various routing algorithm Ad Hoc networks and mesh network is mentioned in literature.[14]

In field of WMNs novel work is done by applying hybrid routing approaches using soft computing based techniques AntMeshNet, ACO, BBO, Firefly algorithm and BB-BC.[15-18]

Termite Colony Optimization

TCO is inspired by the intelligent behaviour shown by eventual discovery of the shortest path during the termites mound structure building process. Initially the termites arbitrarily search for soil pallets and after finding it they deposit it on the destined mound. This behaviour shown as a result of depositing chemical trail *pheromone* on the path returning after depositing soil pallets on the termite mound. The pheromone acts as attractive stimulus to other members of the colony to follow paths with higher intensities. This is a volatile chemical and evaporates eventually leading to higher intensities at smaller path, marked as the path followed by majority of termites upon independent quest and experience of each termite locally modifying the environment. This act is called *stigmergy*[5] and is observed in ants and termites colonies. In case study termites (isoptera) with genus *macrotermes* this act is called ecosystem engineering. The benefit of this behaviour facilitates acquiring of resources, habitats heterogeneity, population dynamics of organisms thus results in emergent properties at the community level and stability.[19] These properties are incorporated in the wireless networks for sharing information, connecting, configuring nodes, dynamically self organising and stabilising network.

A. Termite Colony Optimization Algorithm

In this section we formulate the network model and apply the TCO algorithm on it. We consider a client mesh network *G(N,L)*operating in a fixed geographical region. *N* is a set of wireless nodes i.e. randomly arranged routers and *L* being the set of communication links.

These links are established in such a way thatN_i, the neighbouring nodes automatically senses the similar capability nodes within its radio range and connects with them. on a link *L*, the transfer of information to the neighboring nodes is only possible when they have a common channel interface. The assignment of channels is beyond the scope of this paper.

More formally, *G(N,L)*is an absolutely connected and directed graph topology formed by randomly generated nodes. Using Cartesian coordinate distance formula the distance *d(i, j)* between the every i^{th} and j^{th} nodes with coordinates (x_i, y_i) and (x_j, y_j) is calculated, given as,

$$d(i,j) = \sqrt{\left((x_i - x_j\right)^2 + (y_i - y_j)^2)} \quad (1)$$

A connectivity matrix is formulated assigning unity elements on the links to the neighbouring nodes within the predefined radio range *R.* A random link cost matrix is generated which appends the connected links with a random weight called the cost. The TCO algorithm for selecting the shortest path between source and destination node in a network is as follows:

Initially a constant amount of pheromone τ_{ij} is deposited between the all the nodes on the link /edge from node *i*to node *j* on the graph. At a node *i*, for each termite *k*the probability of selecting *j* with pheromone trail τ_{ij} is computed by,

$$p_{ij}^k = \begin{cases} \frac{(\tau_{ij} + K)^F}{\sum_{l \in N_i^k} (\tau_{il} + K)^F}, & if\ j \in N_i^k \\ 0, & if\ j \notin N_i^k \end{cases} \quad (2)$$

K is the threshold factor, determines the sensitivity of probability calculation to small amounts of pheromone. Its value can be taken $K \geq 0$, many values are given in literature.[20] F is sensitivity factor modulates the differences in the pheromone amounts, its value ranges from $0 \leq F \leq 2$.N_i^k, are the nodes in the neighbourhood of termite k at node i. The parameters K and F help in regulation of adaptation to new routing information.

Each termite k randomly hops from node to node by checking the stochastic decision criteria until the terminal node is reached and drops a soil pallet to the destination node, this termite is called forward termite. After reaching the terminal node the forward termite is converted into a backward termite to retrace the traversed path. On way it updates the information table at each node by eliminating the loops on the path and increments the pheromone deposited on the edge *(i, j)* as

$$\tau_{ij} \leftarrow \tau_{ij} + \gamma \quad (3)$$

γ is pheromone deposition factor.

The termites are guided by updation of the pheromone and plays essential role in the convergence of the algorithm to a suboptimal route. On the edge *(i, j)* the updation of the pheromone trail is governed by the equation as

$$\tau_{ij} \leftarrow \tau_{ij} . e^{-\rho} \quad (4)$$

ρ is decay factor, decides the rate of evaporation of the pheromone and value is taken $\rho \geq 0$. The forward termites explore for new paths and the backward termites are responsible for exploitation of the obtained paths. The best shortest path can be obtained if and only if time permits the search to be continued till the termination criterion is satisfied.

As a metaphor to the networks the amount of pheromone ϱ, is deposited on a path conveyed by equation,

$$\varrho = \frac{1}{C_{(Total\ link\ cost)}} \quad (5)$$

For simple computation in our paper the link cost is computed by cumulative link cost of the path between the source and destination node and is given as,

$$C_{(Total\ link\ cost)} = \sum_{i=1}^{destination\ node} \sum_{j=1}^{destination\ node} C_{(i,j)} \quad (6)$$

And the objective function includes the minimization of the total link cost mentioned as

$$Objective\ function = minimum[C_{(Total\ link\ cost)}] \quad (7)$$

The values of parameters used in algorithm are K=0.4, F=2, ρ=0.03 and γ=1.In this way optimal route based upon the link cost is obtained using TCO.

Pseudo Code for TCO Algorithm in WMN

begin
/TCO Parameter Initialization/
Define source node, Terminal node, Number of Termites, Initial pheromone bound, Number of paths, Number of Iterations, Number and location of nodes.
/end of TCO Parameter Initialization/
while(*t< Max Generation or Termination criteria not met*)
For *i*=1: *n*
For *j*=1: *n*
If *distance (i, j) <= R (radio range of node)*
Connectivity_matrix (i, j) =1 /*routing table maintenance*/
Integrated_link_cost (i, j) = cost metric
end*if*
endfor *j*
endfor*i*
/Build paths between source and terminal node/
Random generation of initial termite population of k paths
Compute cost of all candidate solutions
Compute the shortest path using S-TCO
Update pheromone trails
end while
Postprocess results and visualization;
end

Figure 1. Pseudo code of the TCO based routing algorithm applied in WMN

B. Steps of the TCO Algorithm

Step1: Initialize parameters: source node terminal node, no. of termites, and initial pheromone on edges.
Step2:Build paths from source to terminal node using connectivity matrix and assigning link cost to each edge.
Step 3: Randomly generate population of 'k' forward termites on paths starting from source node, stochastically choose next hop using transition probability.
Step 4: Evaluate summation of pheromone strength on each path.
Step 5: Backward termite, while backtracking from terminal to source node: deposit pheromone, remove paths with loops and update pheromone.
Step 6: Obtain loop free viable paths.

If,

Step7: Termination criterion is satisfied;
Step 8: Sort and store the no. Of paths mentioned during initialization with total cost in elapsed time, the best shortest path is computed if and only if time permits.

Else,

Go to: Step 3.

End.

SYSTEM MODEL

Simulation of the network is done in artificial environment using MATLAB for analysis and optimization of the routing algorithm. The system model gives description of the architectural and simulation parameters of the network. We consider 10, 30, 50 and 100 node network for client WMNs. The networks are placed within a 500m X 500m, 1000m X 1000m and 2000m X 2000m area. The nodes in the network area are randomly distributed. A two ray ground reflection propagation model isused with log normal shadow fading. The radio transmission range of the nodes is varied from 200 meters to 400 meters. In all the network models node number 1 acts as the source node and transmits data packets to the last node which acts as the destination node. Random wave point mobility model is considered with the nodes having Omni directional antenna and can transmit data at a constant bit rate for e.g. 1 packet/sec, resulting in CBR traffic model. Table.1 depicts the architectural details of the used client WMNs.

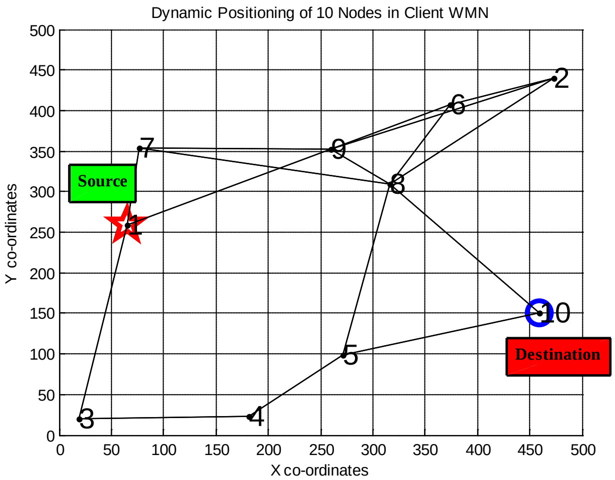
Table 1. Architectural details of Client WMNs

Client WMNs		
No. of Nodes	Area(m × m)	Radio Range of a node (meters)
10	500 × 500	200
30	1000 × 1000	300
50	1000 × 1000	300
100	2000 × 2000	400

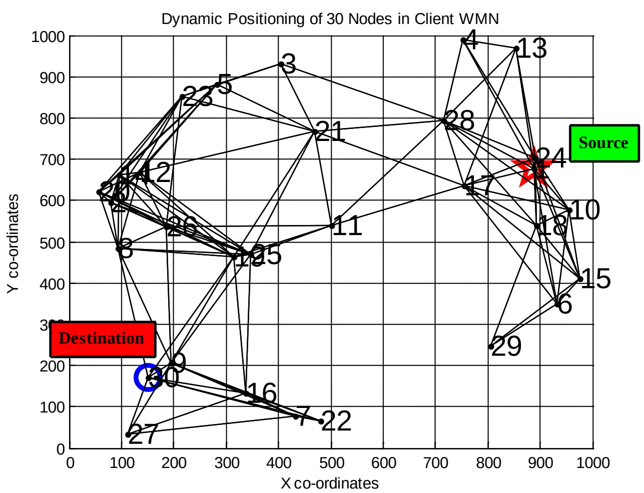
The network architecture for 10, 30, 50 and 100 nodes are shown in figure 2 (a-d) respectively; clearly displaying the source and destination nodes. 50, 100, 150, 200 and 500 iterations were executed for each set for difference client WMN configurations.

Table 2: demonstrates the results for 10, 30, 50 and 100 node client WMNs. The link costs are obtained by performing 50,100, 150, 200 and 500 iterations of TCO. The runtime for cited

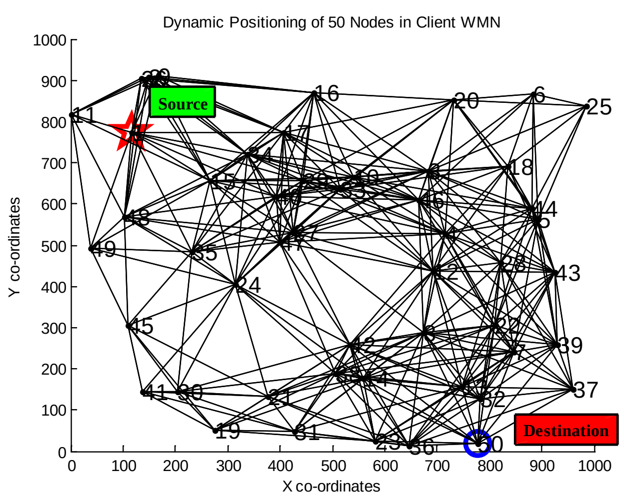
iterations and is documented along with the link cost of the best path computed.



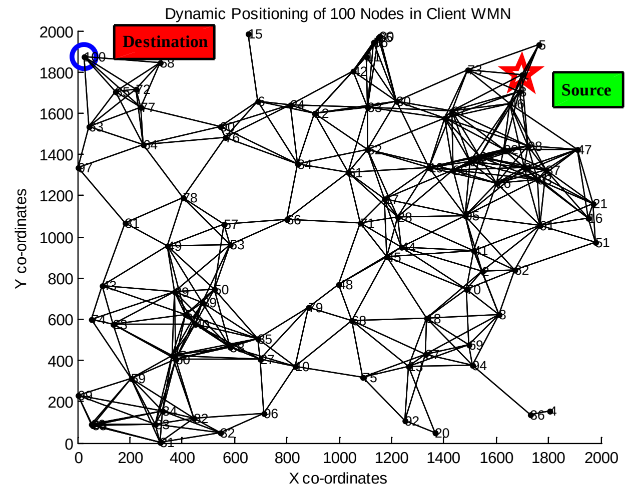
(a)



(b)



(c)

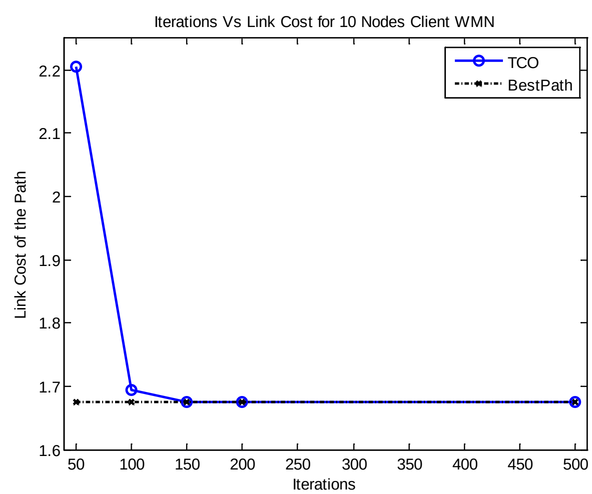


(d)

Figure 2. Network architecture (a, b, c, d) for 10, 30, 50 and 100 node client WMN.

The link cost versus number of iterations is plotted in figure 3 (a-d) for 10, 30, 50 and 100 node client WMNs correspondingly. It is clearly observed that for a 10 node network the TCO based approach started with a link cost of 2.2045 in 50 iterations and selected best path within a link cost of 1.6750 in 150 iterations and continued to the same cost and path till 500 iterations. It started at a time of 0.075446 seconds and found the shortest path 1-9-6-8-10 in 0.080658 second in 150 iterations. Similarly for 30, 50 and 100 node client WMN configurations the details are mentioned in table 2.

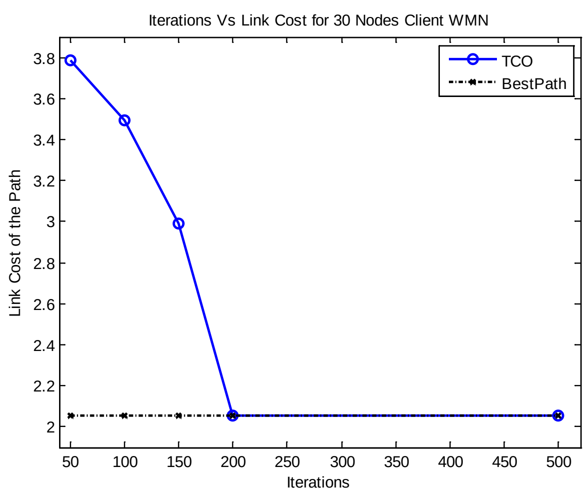
The TCO based approach successfully enumerated the minimal cost path within 200 iterations for 10, 30, 50 nodes and for 100 nodes networks it is able to compute best path in 500 iteration. This is because 100 node clientWMN has more number of possible paths.



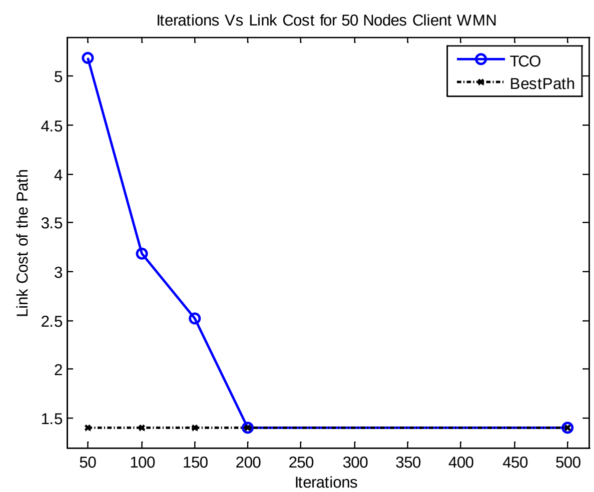
3(a)

Table 2. Results for Client WMNs (20 trails for each set is conducted)

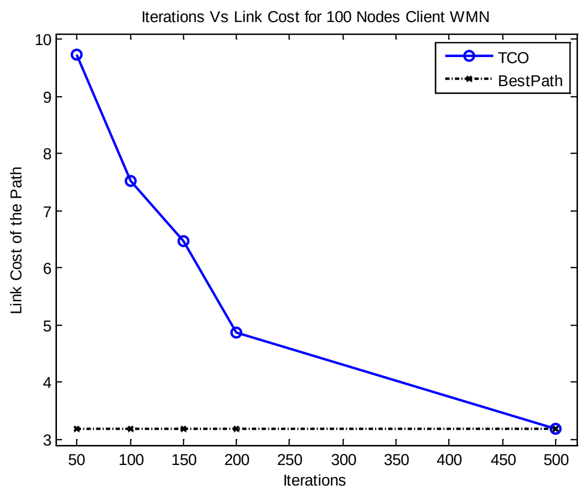
No. Of Nodes	Iterations	Client WMN Parameters			Link Cost of Best Path
		Link Cost	Time (Seconds)	Path	
10	50	2.2045	0.075446	1-7-9-8-10	1.6750 (Best Path: 1- 9- 6- 8- 10)
	100	1.6945	0.078511	1-9-8-10	
	150	1.6750	0.080658	1-9-6-8-10	
	200	1.6750	0.081852	1-9-6-8-10	
	500	1.6750	0.0852314	1-9-6-8-10	
30	50	3.7837	0.076880	1-17-11-25-9-30	2.0531 (Best Path: 1-28-21-19-30)
	100	3.4925	0.078344	1-4-28-11-19-30	
	150	2.9890	0.080817	1-18-28-11-19-30	
	200	2.0531	0.083589	1-28-21-19-30	
	500	2.0531	0.089495	1-28-21-19-30	
50	50	5.1856	0.085290	1-40-4-7-5-39-32-8-21-38-50	1.4038 (Best Path: 1-29-27-42-50)
	100	3.1877	0.088758	1-17-34-47-38-50	
	150	2.5260	0.089331	1-34-46-8-50	
	200	1.4038	0.090103	1-29-27-42-50	
	500	1.4038	0.092689	1-29-27-42-50	
100	50	9.7259	0.090458	1-46-22-14-9-88-19-41-26-95-28-61-84-6-90-77-100	3.1760 (Best Path: 1-98-86-52-84-90-77-100)
	100	7.5310	0.092745	1-67-98-14-7-52-84-66-53-78-64-77-58-72-100	
	150	6.4756	0.094328	1-67-7-19-61-66-57-78-81-97-63-100	
	200	5.8772	0.096217	1-3-67-33-52-84-24-90-64-85-100	
	500	3.1760	0.099189	1-98-86-52-84-90-77-100	



3b)



3(c)



2(d)

Figure 3. Iteration v/s Link cost of path (a, b, c, d) for 10, 30, 50 and 100 node client WMN.

Results And Conclusion

A novel routing approach is proposed based on termite's intelligence. The performance of termite colony optimization based approach is computed. The link cost of the route is the criteria of performance evaluation of this nature inspired routing approach. The link cost of the route is considered to be the distance between the source and the destination nodes. The objective of the approach is to find the shortest path between a source and a destination node in terms of link cost.

The approach is applied to 10, 30, 50 and 100 node client WMNs. For each scenario the approach was simulated for 50, 100, 150, 200 and 500 iterations and corresponding link cost was computed for 20 trials of each set. After comprehensive rounds of simulation it has been witnessed that the proposed termite's intelligence based approach for routing in WMN was capable to converge to the best path in all the network scenarios for different iterations. TCO based routing approach is a competent solution to find the shortest /best source and destination nodes in dynamic WMNs. Future improvements with respect to TCO can be done to improve the protocol to make it suitable for IOT (Internet of things).

References

.

1. I.F Akylidiz, X Wang. A Survey on Wireless Mesh Networks. *IEEE Radio Communications*, **2005**, 523–530.
2. M.E Campista, P.M Esposito, M Moraes, M.K Cosla, M.B Duarte, D.G Passos, N. De Albuquerque, D.C.M Saade, M.G Rubinstein. Routing Metrics and Protocols for Wireless Mesh Networks. *IEEE Network*, Jan-Feb **2008**, 6–12.
3. C.E Koksal, H. Balakrishnan. Quality Aware Routing Metrics for Time Varying Wireless Mesh Networks. *IEEE Journal on selected areas in communications*. **2006**, 24(11), 1984–1994.
4. F. Bokhari, G. Zaruba. AMIRA: Interference Aware Routing using Ant Colony Optimization in Wireless Mesh Networks. *IEEE Conference on WCNC*, **2009** proceeding.
5. M. Dorigo, E. Bonabeau, G. Theraulaz. Ant Algorithms and Stigmergy. *Elsevier, Future Generation Computer Systems (FGCS)*, **2000**, 851–871.
6. O.K. Erol, I. Eksin. A new optimization method: Big Bang-Big Crunch. *Advances in Engineering Software*, **2006,** 37, 106–111.
7. D. Simon. Biogeography-Based Optimization. *IEEE Transactions on Evolutionary Computation*, **2008**, 12(6), 702–713.
8. M. Dorigo, V. Maniezzo, A. Colorni. The Ant System: Optimization by a Colony of Cooperating Agents. *IEEE Transactions on Systems, Man and Cybernetics- Part B*, **1996,** 26(1), 1–13.
9. D. Karaboga, B. Basturk. Artificial Bee Colony (ABC) Optimization Algorithm for solving Constrained Optimization Problem. *Springer- Verlag Berlin Heidelberg*, **2007**, 789–798.
10. X.S. Yang. Nature- Inspired Meta- heuristic Algorithms. University of Cambridge, United Kingdom, Luniver Press, **2010**.
11. H.F. Wedde, M. Farooq, T. Pannenbaecker, B. Vogel, C Mueller, J Meth, R. Jeruschkat. BeeAdHoc: An Energy Efficient Routing Algorithm for Mobile Ad Hoc Networks Inspired by Bee Behaviour. *Genetic and Evolutionary Computation Conference (GECCO' 05)*, Washington DC, 25-29 June **2005**, 153–160.
12. G. Dicaro, F. Ducatelle, L. M Gambardella. AntHocNet: An Adaptive Nature Inspired Algorithm for Routing in Mobile Ad Hoc Networks. Technical Report No. IDSIA-27-04-2004, Sep **2004,** 1–17.
13. M. Roth, S. Wicker. Termite: ad-hoc networking with stigmergy. *IEEE Trans. Global Telecommunications Conference, (GLOBECOM '03)*, **2003**, 5, 2937–2941.
14. E. Alotaibi, B. Mukherjee. A survey on routing algorithms for wireless ad-hoc and mesh networks. *J. Computer Networks*, **2012**, 56, 940–965.
15. S. Sharma, S. Kumar, B. Singh. Routing in Wireless Mesh Networks: Two Soft Computing based Approaches. *Int. J. Mobile Network Commun. Telematics (IJMNCT)*, **2013**, 3(3).
16. S. Sharma, S. Kumar, B. Singh. Hybrid Intelligent Routing in Wireless Mesh Networks: Soft Computing based Approaches. *I.J Intelligent Systems and Applications (IJISA)*, in Modern Education and Computer Science Press (MECS), **2014**, 01, 45–57.
17. S. Sharma, S. Kumar, B. Singh. AntMeshNet: An Ant Colony Optimization based Routing Approach to wireless Mesh Networks. *International Journal of Applied Meta-heuristic Computing (IJAMC)*, **2014,** 5(1), 20–45.
18. S. Sharma, S. Kumar, B. Singh. Routing in Wireless Mesh Networks: Three New Nature Inspired Approaches. *Springer Science*, Business Media New York in Wireless Press Communication **2015,** 83, 3157–3179.
19. J.M Dangerfield, T.S. Mccarthy, W.N. Ellery. The Mound-Building Termite Macrotermes michaelseni as an Ecosystem Engineer. *Journal of Tropical Ecology*, **1998,** 507–502.
20. M. Roth, S. Wicker. A Framework and Model for Soft Routing: The Markovian Termite and other Curious Creatures. *Fifth International Workshop on Ant Colony Optimization and Swarm Intelligence, Springer* Verlag Berlin Heidelberg, Vol. 4150, **2006.**

Dr. Sharad Sharma
Department Electronics and Communication Engineering
Maharishi Markandeshwar University, Ambala (Haryana), India.
Email ID: sharadpr123@rediffmail.com

Asha Malik
Department Electronics and Communication Engineering
Panipat Institute of Engineering and Technology, Panipat (Haryana), India.
Email ID: asha1407@gmail.com