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Analysis of Routing Protocols in AD HOC and Sensor Wireless Networks Based on Swarm Intelligence

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Abstract There are various bio inspired and evolutionary approaches including genetic programming (GP), Neural Network, Evolutionary programming (EP) exploited for routing optimization in MANETs and WSNs. The Swarm Intelligence based algorithmic approaches; Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO) are more promising in providing loop free, energy-aware, and multi-path routing in mobile ad hoc and wireless sensor networks. There are various constraints involved in ad hoc and sensor networks protocols due to the mobility and non infrastructure nature of the system. We study in this research work a probabilistic performance evaluation frameworks and Swarm Intelligence approaches (PSO, ACO) for routing protocols. The performance evaluation metrics employed for wireless and ad hoc routing algorithms is , (a) routing overhead, (b) route optimality, and (c) energy consumption. This survey provides collection of Swarm Intelligence based algorithms for mobile ad hoc and sensor networks and their critical analysis. The study concludes that PSO and ACO based protocols are advantageous than other approaches applied for the routing optimization in ad hoc and wireless sensor networks.

Keywords Ant Colony Optimization (ACO), MANET, Honeybees, Swarm Intelligent, PSO, Wireless Sensor Network (WSN)

1. Introduction

The MANETs are a collection of wireless mobile nodes having no well established infrastructure and dynamically changing topology in nature. Due to the frequently changes in topology and infrastructure less nature, Ad hoc networks require a highly adaptive routing algebraic approaches. In ad hoc networks, component failure is caused by the multicast routing protocols. Multicast and the multipath structure for the routing have the redundancy. In mobile and ad hoc networks, power is constrained and topology changes repeatedly. The focus of this survey study is the collection of Swarm Intelligence based routing algorithms proposed for the routing optimization in Ad Hoc & Wireless Sensor Networks by considering various constraints i.e. mobility, energy awareness, overhead, end to end delay etc. The biological inspired routing protocols are more promising for routing optimization, with consideration of specific issues, due to the nature of Mobile Ad hoc Networks (MANETs) and Wireless Sensor Networks (WSNs) than early approaches like AODV[1], DSR[2], OLSR[3] and ZRP[4]. There are various protocol suits given in[5], used in computer networks. Some routing algorithms are more efficient at ad hoc & sensor networks while some are more promising on fixed infrastructure.

There are various evolutionary based (GA, GP, EP .etc) approaches are used in the wired networks as well as MANETs and WSNs for the routing optimization and Quality of Service but the survey study concluded that Swarm Intelligence based heuristic approaches Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO) and Honeybees are more promising for the ad hoc and wireless networks due to the nature of their working and design systems. Swarm Intelligence inspired, routing algorithms are more capable to tackle various issues associated with the routing in MANETs and WSNs due to their mobility and non infrastructure nature. It is desired very fast and exact location search of destination in ad hoc & wireless networks. For the optimum utilization of resources like, power consumptions, bandwidth and routing overhead reduction; in ad hoc sensor networks, routing approaches exploits the natural warm behavior mimicked in Swarm Intelligence.

In[6] Fatih Çelik, et al provided survey of routing protocols inspired by SI in WSNs and factors to consider during routing protocol design. M. Anupama and Bachala Sathyanarayana provided collection of cluster based routing protocols in MANETs in[7].

This survey provides more extensive study of routing algorithms based on Swarm Intelligence paradigms (PSO, ACO and Honeybees) with critically analysed features in

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MANETs and WSNs. The comparative study of emerging SI based routing algorithms, explores the suitability and effectiveness of bio inspired approaches. This critical comparative analysis of PSO and ACO with the state of art algorithms, provide new research directions.

The remaining paper organization is as; the Background section provides is introduction of MANETs and WSN. The second section, Swarm Intelligence, explains the sub-domains of SI like Particle Optimization, Ant Colony Optimization and Honeybees. The third section that is main part of the paper provides SI based routing algorithms proposed in Ad hoc and Wireless Sensor Networks with their pros and cons. Finally, the last section concludes the whole study work.

2. Background

2.1. MANET'S

The subtype of networks that is self-configured, infrastructure less, network of mobile devices connected by wireless links, is named Mobile Ad hoc Network (MANET)[8]. MANET can also be defined as, a collection of mobile wireless nodes that intercommunicate on share wireless channels. Individual devices in a mobile ad hoc network are free to move in any direction and frequently devices links changes occur. The MANETs are differentiated with other wireless networks due to their characteristics like dynamic topology configuration, mobility of nodes, infrastructure less, frequently node failure, distrusted multi-hop forwarding and limited energy power. The stated features causes more challenging routing in MANETs. Multicast routing approaches are efficient emerging protocol class in Mobile Ah-hoc Networks. Wireless group communication protocols are required for multipoint data dissemination and multiparty conferencing. The more promising ,efficient and effective routing protocol for MANETs is one that needs relatively low control overhead,, effectively adaptation to dramatic topological changes, low packet delays , provides high throughput, and optimized battery power utilization. These golden aspects of protocol in MANETs improve the efficiency and productivity of the wireless system. So these characteristics let the users and their mobile devices participate as long as possible to the network activities. The balance of all these conflicting objectives is very hard. For the optimization of the stated objectives, Swarm Intelligence based meta-heuristics approaches (PSO and ACO) are more promising than other algorithms in MANETs. There are various flavours of routing algorithms proposed in literature for MANETs based on SI which are discussed in the section IV.

2.2. Wireless Sensor Networks

Wireless Sensor Networks (WSNs)[9] is a paradigm of networks that contains sensing, computation, and wireless communications capabilities with small nodes. A wireless sensor network consists of autonomously and spatially distributed sensors to monitor physically environmental conditions. The development of WSNs was initiated by military applications and importance such as battlefield surveillance but now their application is introduce in industrial process monitoring and control, and machine health monitoring. In WSNs, sensors collect information about the area within their detection ranges and share their data and information with neighbour sensor node as well as base station. There is no any infrastructure in wireless sensor networks and individual node can change its position simultaneously. There is lot of routing issues associated with protocols in WSNs due to the frequent mobility of nodes. There are desired optimizations in routing, data dissemination and power management in WSNs. The main and prominent, one of the design issues in wireless sensor networks is energy awareness. The new protocols focus on the power optimization which leads to the long lifetime of the sensor nodes in WSNs. In this survey we present a critical analysis of the state-of-the-art routing techniques in WSNs. We discuss the design issues and challenges for routing protocols in wireless sensor networks particularly and MANETs generally.

In the "Figgure.1" there is shown the architecture of WSN and the structure of the node in the wireless sensor networks[9]. Each node consists on Sensing Unit, Position Finding, System Mobilizer, Processing Unit, Transmission Unit and Power Unit as shown in the diagram.

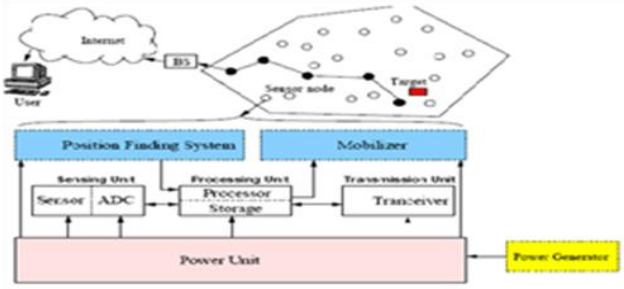

Figure 1. Node Architecture in WSN[9]

3. Swarm Intelligence

Swarm Intelligence (SI) is subfield of Computational Intelligence which provides solution for complex optimization problems which are not easily tackled by other approaches. Swarm Intelligence mainly consists on Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO) and Honeybees paradigms. Swarm Intelligence based approaches are nature and bio inspired. A swarm is defined as a set of (mobile) agents that collectively solve problems. Swarm Intelligence is the property of a system whereby the collective behaviours of (unsophisticated) agents cause sophisticated global patterns to emerge. Swarms are abundantly found in nature. In the nature animals form into swarms to search food, build nests, to hunt and avoid being hunted etc. Each individual of the swarm has simple rule of

action and access to a limited amount of information via its immediate neighbours or local environment. However, despite of limited information and simple actions of members, the swarm, as a whole, is capable to accomplish very hard problems of the computation and optimization. Theses paradigms mimic the behaviour of real insects for food searching, organized living and defensive styles for computational problems. The application of the SI paradigms is mostly dependent on the nature of the computational problems. Mostly real hard problems can be simulated by exploitation of SI based algorithmic approaches. The SI based approaches are more promising from other conventional techniques for optimization problems. Due to the nature, architecture, topology and functionality of ad hoc and wireless networks, Swarm Intelligence approaches are most suitable for the routing and energy resources optimization related issues in MANETs and WSNs. Bio inspired, Swarm Intelligence approaches are more promising for ad hoc and wireless sensor networks due to the following prominent aspects i.e.[10].

i) Locality of interactions
ii) Availability of multiple paths,
iii) Self-organizing behaviours
iv) Failure backup,
v)Ability to adapt in a quick and robust way to topological and traffic changes and component failures,
vi) Scalable performance robustness to failures,
vii) Losses internal to the protocol,
viii) Easiness of design and tuning.

The prominent Swarm Intelligence based paradigms are shown in "Figure 2" The basic architecture and working principle of SI based algorithmic approaches is given in the following sections.

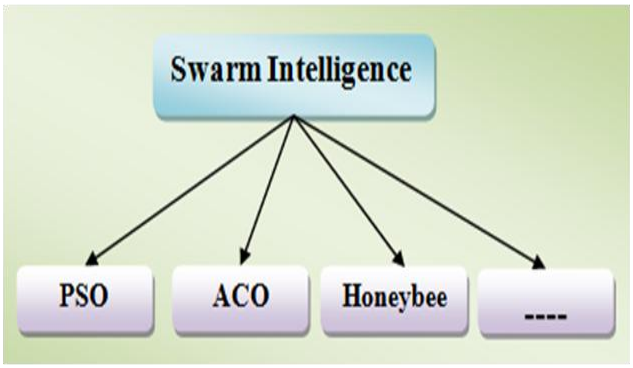

Figure 2. Sub-Domains of Swarm Intelligence

3.1. Particle Swarm Optimization

Particle Swarm Optimization is subfield of Swarm Intelligence which exploits the behaviour of swarms for the solution of complex problems. The particle swarm optimization natured algorithm maintains a swarm of particles. Particle Swarm Optimization approach exploit the mutual intelligence and information sharing ability of swarms. PSO applies the concept of social interaction for the solutions of hard and optimization problems. It was developed[11] in 1995 by James Kennedy and Russell Eberhart. In PSO each particle individually emerges a potential solution for the hard problem to be solved. In the PSO domain based approaches particles are flown through the multi-dimensional search space and the next position of each particle is determined as a factor of its own experience and that of other particles. The basic working mechanism of PSO based algorithm bases on fundamentally on the position of particle and velocity of the particle at given time. The searching process depends on the previous position and velocity of the particles locally as well as globally. The particles will mainly search the space between the global best and their personal bests for the better solutions. The algorithm iteratively runs for the solution optimization.

At the start of algorithm (PSO), particle position, personal best position and velocities of particles are initialized randomly within the constraints of the search space and after that the parameters updated accordingly given strategies. As bio inspired approaches are iterative, some termination mechanism is applied. For PSO algorithmic approaches mainly, stopping condition can be implied are maximum number of iterations, acceptable solution achievement or no improvement observed over a number iterations. There are various flavours of PSO algorithms proposed for the solution of problems, like Network security, Optimization, Association rule mining, Classification purposed and particularly in Wireless Sensor Network (given in the section IV).

3.2. Ant Colony Optimization

Ant Colony Optimization is paradigm of Swarm Intelligence that is inspired by the collective behaviour of ants. The Ant Colony Optimization algorithmic approach models the concept of food foraging, net building, and division of labour, cooperative support, self assembly and cemetery organization of real ants for the meta-heuristic approaches, for the optimization problems. ACO meta-heuristic computational approach was proposed by Marco Dorigo in 1996. The basic principle of ACO is simulation of ability of ants to find the shortest path between their nest and a food source. Ants are capable to find the shortest path between their nest and food source, without any visible, central and active coordination mechanism. The real ants drop a pheromone, chemical from their bodies naturally, on the path which leads them for the various decisions. The path optimization between nest and food is achieved by ant colonies by exploiting the pheromone quantity dropped by the ants. The path selection of the ants is done on the bases of the pheromone concentration deposited on the set of paths. With high concentration of pheromone value path's selection probability is greater than others. The indirect pheromone based communication is known as stigmergy. There is a natural evaporation of the pheromone, which favours the shorter path than the larger one.

An artificial ant can be considered as a simple

computational agent. In the implementation of artificial ant, probabilistically path selection mechanism is introduced. In basic ACO algorithm pheromone value update and pheromone value evaporation is done by using the mathematical formulae. Generally the pheromone evaporation rate is directly proportional to the length of path. The ACO based meta-heuristic approaches are very suitable for the problem scenarios where optimized multi-path section is desired. Similarly, to the PSO, ACO works in iterative manor and various termination criteria are proposed. The stopping criteria for ACO algorithm suggested in literature are, a) fixed number of iterations, b) acceptable solution and c) the number of ants that following the same path repetitively.

Here some important features of ad hoc networks which flavours the designing of swarm intelligence based protocols, particularly ACO inspired algorithm routing protocols. Some of them are given as following.

Dynamic Topology: The dynamically change topology, causes bad performance of mostly routing algorithm in mobile multi-hop ad hoc networks. The working principle of ACO is based on agent systems and works individually and flavours high adaptation to the current topology of the network.

Local Work: The ACO based algorithms are based only on local information, so it no needs the transmission of routing tables or other information to neighbour nodes in networks.

Support for Multi-path: The selection decision is based on the pheromone value on the current node. It provides the multi-path selection choices.

The representative application areas of Swarm Intelligence based meta-heuristic algorithmic approaches **[**12], are stochastic optimization problems, NP-hard, industrial problems, dynamic optimization problems, telecommunication networks, multi-objective optimization and continuous optimization.

3.3. Honeybees

The bees algorithm is population based, bio inspired approach for optimization problems that mimics the food foraging behaviour of swarms of honey bees. The bee's algorithmic approaches exploit the concept of honey bees for food searching, defence and locatable behaviour of real honey bees. The artificial bees mostly are divided into three groups namely as employed bees, onlooker bees and scout bees performing their corresponding duties. The literature survey shows that the Honey Bee Algorithm (HBA) was proposed by Craig A Tovey in 2004, Vertia Bee Algorithm (VBA) formulated by Xing-She Yang in 2005 and same time Artificial Bee Colony (ABC) by D Karabogo for numerical function optimization. The working of the bee's algorithm starts with the placement of scout bees in the search space and fitness of the scout bees is evaluated. The bees having higher fitness then a threshold is chosen as selected bees and corresponding visited sites by then are selected for neighbourhood search. As SI based approaches are iterative and termination criteria are proposed for the termination of the algorithm. Like other SI approaches, Honeybee algorithms have vase domain of application, training neural networks, scheduling jobs, data clustering, tuning a fuzzy logic controller, computer vision and multi-objective optimization. The prominent application of Honeybees based algorithms are in the field of ad hoc and wireless sensor networks.

4. Swarm Intelligence Based Routing Algorithms

Route optimization is one of the most important parameters of Mobile Ad hoc Network and Wireless Sensor Networks routing protocols that influences the performance of whole protocol and is constraint to other various parameters. Swarm Intelligence which is bio inspired computational intelligence field that provides mainly three techniques Ant Colony Optimization, Particle Swarm Optimization and Honeybees. We will focus here routing algorithms based on SI in MANETs and WSNs. These approaches are meta-heuristic and provide approximately optimized routing. The advantages and limitations of algorithms are given in the table 1. The design and working of the algorithms is illustrated in the corresponding sub sections.

4.1. NNNA

Mohammad Golshahi et al proposed routing algorithm in MANETs in[13] named as Node Neighbour Number Algorithm (NNNA) that is based on sub field of Swarm Intelligence, Ant Colony Optimization (ACO), particularly. The NNNA hybrid algorithm has reactive as well as proactive behaviour. This algorithm takes advantage of the neighbour nodes for the selection of next hop. The working process of NNNA algorithm consists of three stages i.e. reactive path installation, proactive path maintain, contrasting with Link failure. The next hop selection decision is done under the consideration of the node's neighbour intensity. The node having greater number of neighbours provides more information than the others. The simulation results (in NS2) of NNNA are more promising than AODV for packet delivery rate and end-to-end delay. The authors concluded that the performance of NNNA algorithm is better in situation with high speed moving, outspread and dense networks.

4.2. GPSAL

Danial Camra et al presented routing algorithm for mobile ad hoc net works known GPS/Ant-Line Routing Algorithm (GPSAL) in[14]. The routing in GPSAL protocol is based on the physical location stored in the routing table of destination host. On the presence of an entry in the routing table for the host, the best available route is selected by using a shortest path algorithm. For the collection and dissemination of

information among the nodes is by collected by the ants. Second characteristic of GPSAL is the usage of fixed hosts as well as possible to route packets. In GPSAL, by using the local information routing overhead is decreased as compared to other algorithms. The proposed approach assumes the presence of an on-board GPS device. The locally and globally routing information is exchanged sending forward ants to destination geographically. The simulation results are promising that GPSAL algorithm is better in performance with less routing overhead as compared to LAR that is also a location-based algorithm.

4.3. AAR

Hiroshi Matsuo,and Kouichi Mori have proposed swarm intelligence based routing protocol named as Accelerated Ants Routing (AAR) in[15]. As main features of MANETs are frequent and unpredictable changes in the network topologies. So the evaluation metric of routing algorithm is considered as converging speed of routing table. The design objective of the AAR algorithm is to accelerate convergence speed. The functionality of the proposed approach consists of two ideas, probabilistically table update and curtailed algorithms. The proposed algorithm, AAR is compared with Q-Routing and DRQ-Routing approaches by exploiting simulation results. The results of AAR are promising than other approaches.

4.4. Ant-AODV

Shivanajay Marwaha et al proposed a hybrid routing scheme for MANETs which combines the on-demand capacity of AODV with a distributed topology discovery method by using ant-like mobile agents. This approach is named as Ant-AODV[16]. This approach is promising to compensate the limitations of AODV and DSR routing protocols. The pure reactive routing protocol is not applicable for multimedia communications and real-time data. In Ant-AODV routing protocol, uniform ants are used to update the routing table. By using this technique a route from the source to destination is increased by using its neighbours. The simulation results (inNS-2) show that the Ant-AODV has better performance than the Ant based and the AODV algorithms by considering end-to-end delay and routing overhead.

4.5. PERA

John S. Baras and Harsh Mehta proposed a Probabilistic Emergent Routing Algorithm (PERA) for Mobile Ad Hoc Networks in[17]. The proposed technique SI inspired, ant-like agents are for the discovery and maintenance of paths in mobile ad hoc networks. The working of Probabilistic Emergent Routing Algorithm (PERA) is very similar to AntNet. The PERA algorithm decreased routing overhead and increased/improved the efficiency of the route discovery. This algorithm is purely reactive algorithm. In this algorithm, each forward ant packet possesses source node IP address, destination node IP address, net hop IP address, stack and hop count. The stack of the forward ant dynamically grows due to the IP addresses of the nodes. AAR has inherently broadcasting capability in wireless networks. The route discovery is achieved by using a flooding approach. The proposed approach is compared with AODV algorithm. The simulation results are promising for AAR.

4.6. ACO-AOMDV

Xun-bing Wang et al proposed ACO and AOMDV based routing protocol namely, ACO-AOMDV to improve multipath routing performance in ad-hoc networks in[18]. The strength of the proposed approach is the use of routing information already available in AOMDV protocol. Due to this feature, there is little overhead occurs for the computation of multiple paths pheromone. There are two main differences between ACO-AOMDV and AOMDV protocols. The first, ant packets are exploited for the route discovery and the route maintenance. The pheromone value of ant packets reflects the routing list information. The second one is, ACO-AOMDV extended two more fields, flag and route-list, than AOMDV protocol. Flag is used to distinguish different ant packets and Route-list is used for recording the information of mobile nodes that ant packets visited. In ACO-AOMDV, ant packets are divvied into four types:[18] a) forward ant (FA), b) backward ant, c) forward renewal ant(FRA), and backward renewal ant. The route discovery stage uses FA and BA while FAR and BRA are used in route maintenance stage. The ACO-AOMDV works in three phases namely, route discovery phase, route maintenance phase and route failure handling phase. Here routing parameters, average kink count of path, hops of path and average load of path are used.

4.7. Termite

Martin Roth and Stephen Wicker, first biologically inspired algorithm for mobile ad hoc networks named Termite, in[19]. It is inspired by the self organization of social insects, specifically that of termites. In the proposed approach routing decisions are probabilistic and preference is given to the regions of high throughput. The Termite algorithm, maintained the routing robustness and scalability. This approach aims to minimize routing traffic and computational load of the node. The working methodology of Termite is comparable to Ant Colony Optimization, meta- heuristic such as pheromone tables, probabilistic decisions, pheromone evaporation, etc. In the Termite algorithm, forward ants act as uni-cast while backward ant are routed stochastically. The performance of Termite was analysed by using formal analysis and by simulation. The experimentally performance of Termite was shown better than AODV.

4.8. ARA

Mesut Gunes et al proposed new swarm intelligence based, on-demand routing algorithm for mobile, and multi-hop ad-hoc networks known as Ant-Colony-Based

Routing Algorithm (ARA)[20]. The ARA routing protocol is promising in highly adaptive, efficient and scalable. The main objective in design of ARA is reduction of routing overhead. The routing protocol, ARA possesses properties like distributed operation; loop free, locality, sleep mode and multi-path. The overhead of the ARA algorithm is very small as there is routing table for interchanging between the nodes. ARA protocol only needs the information in the IP header of the data packets. There are three phases of Ant-Colony-Based Routing Algorithm. ARA exploits some basic features of AntNet into AODV. The ARA routing protocol is purely reactive algorithm. The performance of ARA is slightly better compared to AODV while it is worse than DSR in highly dynamic environments. Following is the three phases of Ant-Colony-Based Routing Algorithm for MANETs.

4.8.1. Route Discovery Phase

The following directed graphs; "Figure 3" shows the path discovery phase in the ARA by forward ant.

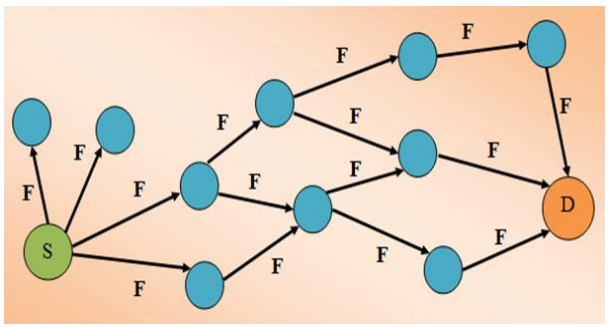

Figure 3. Route discovery phase; A forward ant (F) is sent from the sender(S) towards the destination (D)

The forward ant is relayed by other nodes, which initialize their routing table and the pheromone values.

The "Figure 4" shows the path establishment by the backward ant traveling in the stated algorithm. The moves back by same route.

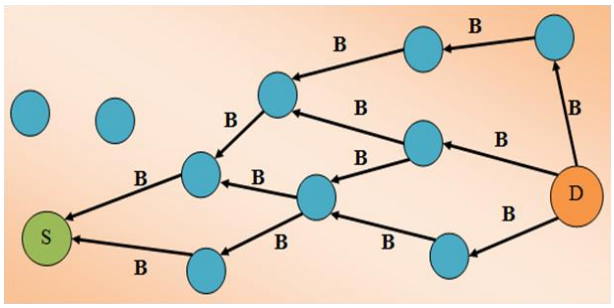

Figure 4. Route discovery phase

The backward ant (B) has the same task as the forward ant. It is sent by the destination node toward the source node.

4.8.2. Route Maintenance Phase

The second phase of ARA is "Route Maintenance Phase" that is used for the improvement of the routes during the communication. There is not required any special packets for route maintenance in Ant-Colony-Based Routing Algorithm. Once the pheromone tracks for the source and destination nodes are established by using the FANT and BANT, than subsequent data packets are used to maintain the path.

4.8.3. Route Failure Handling

The last phase of ARA protocol is route failure handling, in mobile ad-hoc networks, route failure occurs due to mobility. In f the packet is unsuccessful in finding the destination then the source initiates the new route discovery phase. In ARA recognizes a route failure through a missing acknowledgement. The properties of ARA are shown in the TABLE-1.

4.9. AntHocNet

Frederick et al proposed a routing algorithm for mobile ad hoc networks, inspired by bio ant colonies behavior, named as AntHocNet[21]. Ant Agents for Hybrid Multipath Routing in Mobile Ad hoc networks (AntHocNet) technique is used for the typical path sampling. The proposed algorithm works reactive an well as proactive components. Multiple paths are built up between the source and destination in reactive behavior. In AntHocNet data is stochastically spread over the paths depending on the estimated quality. Proactively all the paths are monitored during the course of session. The simulation of this algorithm is done in the Qualnet. The simulation results are better than the AODV algorithm. The ACO behavior is incorporated in the pheromone bootstrapping mechanism is exploited for the efficient learning of pheromone table.

The "Figure 5" shows the reactive path setup process which depicts the Kite-shaped scenario.

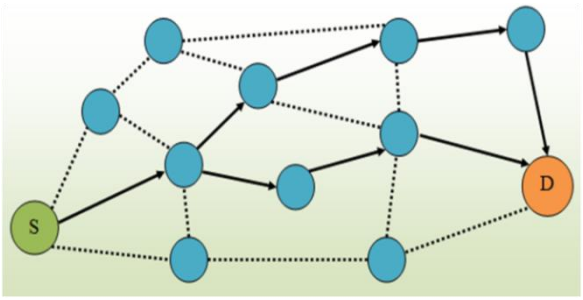

Figure 5. Kite-shaped, multiple paths

In the "Figure 6" shows the multiple path setup process in the AntHocNet algorithm which mesh of multiple paths.

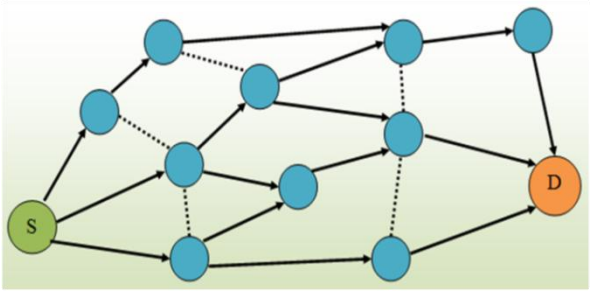

Figure 6. A mesh of multiple paths

AntHocNet algorithm is better in performance for larger, sparse and mobile networks scenarios than AODV protocol.

4.10. PSO-ODMRP

E.Baburaj and V.Vasudevan proposed a new, bio-inspired, PSO based On Demand Multicast Routing Protocol (PSO-ODMRP) to reduce the vulnerability in multicast routing protocols, due to component failure in ad-hoc networks[22]. The working procedure of On Demand Multicast Routing Protocol is a mesh-based. The ODMRP is a demand driven multicast protocol, forming a mesh of nodes used for forwarding data packets between source and receiver. A multicast tree is built by the source periodically for groups by flooding a control packet throughout the network and group members (nodes) responding to the flood joins the tree. Particle Swarm Optimization based class of algorithms is designed on the natural principle of a fitness function. Due to the influence of physical and social behavior such as movement of hosts, interference, terrain, battery power or weather, links can go up and down in a MANET. The simulation results are generated in NS-2 for ODMRP and PSO-ODMRP protocols for the performance evaluation. The performance metric for this comparison was consists on "packet delivery ratio" and "control overhead". The simulation results are promising for PSO-ODMRP than ODMRP. The author observed that the performance of proposed protocols is good in low mobility while it decreases with the increase in mobility. The proposed protocol is more appropriate for the MANETs where topology changes are frequent and power constrained.

4.11. ARAMA

Ant Routing Algorithm for Mobile Ad-hoc networks (ARMA) algorithms was proposed by O. Hussein and T. Saadawi in 2003[23]. Every node in the network can function as a source node, destination node, and intermediate node. The functionality of source, intermediate and destination nodes is sending forward ants for path request, updating of the probability routing table and gradation of forward and backward ants respectively. The search or path maintenance to a destination is done by sending forward ants. ARAMA is implemented and an OPNET simulation model for MANET node is used it to study the performance of ARAMA. In addition, ARAMA is self-built and self configured routing protocol for MANETs that combines both on-demand and table based routing features. The fair distribution of energy promises for the extension in node lifetime.

4.12. M-DiPSO

Ping Yuan et al proposed optimal multicast routing protocol in Wireless Ad hoc Sensor Networks named as Multiphase Discrete Particle Swarm Optimization (M-DiPSO)[24]. M-DiPSO algorithm, is an flavor of discrete version of particle swarm optimization algorithms. This approach incorporates hill climbing using random-sized steps in the search space. So the hill climbing speed up the convergence. The particles in the swarm deployed in M-DiPSO, are separated into groups that follow different search strategies. The proposed approach focused on connectivity and broadcast constraints as well as energy-aware multicast routing. This approach is suitable for static and low speed wireless ad hoc networks.

4.13. TPSO

Shahin Gheitanchi et al proposed a model for communication networks based on Swarm Intelligence approach, particle swarm optimization, named trained PSO (TPSO) in[25]. The proposed approach is promising to reduce traffic and computational overhead of the optimization process. The TPSO approach is employed for the finding of node, possessing highest processing load, in an ad-hoc network. The working of the TPSO is similar that of basic PSO with some modifications. Here each particle exploits fitness function specific for the measure of solution quality. The local best (LB) and global best (GB) solutions are saved simultaneously and comparison is done between LB and GB to choose direction. Due to the distributed nature of particles, the proposed model for ad hoc networks is promising for efficient distributed processing with multi-objectives. The authors simulated the TPSO against PSO, in ad-hoc collaborative computing network with 50 nodes and 30 particles. The simulations results show the very low traffic overhead for the TPSO against PSO. The particles convergence is near constant in comparison to PSO.

4.14. AD-ZRP

Alexandre Massayuki Okazaki and Antonio Augusto Frohlich proposed a bio inspired routing protocol for WSNs based on HOPNET named Ant-based Dynamic Zone Routing Protocol (AD-ZRP)[26]. The AD-ZRP is a multi-hop and self-configuring reactive routing approach for Wireless Senor Networks based on ACO and Zone Routing Protocol for MANETs. Bio inspired AD-ZRP algorithm uses pheromone metric for the routing decision proposes and exploits heuristic information for the pheromone deposit ratio. The focus of AD-ZRP protocol is on routing overhead to minimize the number of control packets from the network to require less effort in communication. AD-ZRP exploits dynamic zones keeping the best routes without significant losses in the data delivery ratio. The dynamic zones mechanism helps in improvement of routing and avoidance of complex structures and procedures resulting in enhancement of efficiency and reduction in routing complexity for the wireless sensor networks. Author compared proposed approach against HOPNET in a simulation environment in Global Mobile Information System Simulator (GloMoSim). The simulation results shows that AD-ZRP causes lower routing overhead against HOPNET due to the reduction of ants in the network. The performance of AD-ZRP is constant for large and dense

networks with respect to routing overhead. Data packet delivery ratio is higher and broken routes ratio is lower of proposed protocol than HOPNET.

4.15. EEABR

Tiago Camilo et al proposed a new energy constrained routing protocol based on subfield of Swarm Intelligence paradigm, Ant Colony Optimization for Wireless Sensor Networks, known as Energy-Efficient Ant-based Routing algorithm (EEABR) in[27]. The EEABR algorithm exploits bio inspired, ant behavior, meta-heuristic approach, Ant Colony Optimization (ACO) for optimization in selection of paths between the sensor nodes and destination node with under consideration of short in length, energy efficiency and lifetime maximization of the Wireless Sensor Network. In this algorithm, the selection of next network node probability is a function of the node energy and pheromone value deposited on the connections between the nodes. The proposed approach promises for the reduction of communication load related to the ants and the energy consumption during communications. The energy saving is directly proportional for the lifetime of the network. In EEABR algorithm, ant information is stored on every node while timeout value, previous and forward node information and the ant identification is stored in the routing table. On the arrival of forward ant, node searches the routing table for the corresponding ant identification, if found then ant is eliminated otherwise node saves necessary information relevant to the ant. On receiving of backward ant, node searches its routing table for the next node. Backward ant record is updated according to a defined time period. The authors have given simulation results in NS2, comparison of proposed approach (EEABR) against basic ant-based routing algorithm (BABR) and improved ant-based routing algorithm (IABR). For the performance comparison, four metrics were used, that are average energy, minimum energy, standard deviation and energy efficiency. With respect of performance metrics, the proposed approach is promising.

4.16. LEACH-P

Liao Ming-hua et al proposed a energy aware routing algorithm based on ant colony principle and Low Energy Adaptive Clustering Hierarchy (LEACH) protocol named LEACH-P, for wireless sensor networks in[28]. The proposed routing approach concentrates on the minimization of energy consumption during the data transmission to the sink by multiple hops. In the new protocol, the node energy consumption is predicted during the next-hop probability calculation. The proposed algorithm works in four steps. The cluster-head nodes are elected according to LEACH protocol and a cluster-head is selected from the cluster-head set. The LEACH-P algorithm is simulated in MATLAB 7.0. The proposed approach (LEACH-P) is compared with LEACH, with respect to the network lifetime and cluster-head energy consumption. The simulation results show the performance of LEACH-P algorithm is promising. As a future work, the relationship between the node hop and the optimal path can be researched.

4.17. ABDRA

Rajeshwar Singh et al proposed routing algorithm for MANETs based on Swarm Intelligence paradigm named as Ant Based on Demand Routing Algorithm (ABDRA) in[29]. The proposed algorithm is multi-path routing algorithm, resulted in improvement in packet delivery ratio. The ABDRA routing algorithm exploits various features of both AODV and DSR algorithms. This algorithm is capable of reducing the route discovery time that results in effectively network topology change management. In ABDRA, two ants FANT (forward ant) and BANT (backward ant) are used. FANT is created at source and moves to destination while BANT is created at destination and follows the part of FANT. The route discovery is done by searching the destination route from the routing table. On the non availability in the routing table, forward ant is created and broadcasted to all adjacent nodes. The congestion is controlled by the route maintenance phase by changing the pheromone value which results in not further loading of the corresponding path. The proposed algorithm is simulated in NS2.29 and compared with AODV protocol. The performance metrics was end to end delay and packet delivery fraction for evaluation of AODV and ABDRA. The simulation results show the performance of ABDRA is better than AODV with respect to the performance metrics.

4.18. ADHOP

Alexandre Massayuki Okazaki and Antonio Augusto Frohlich introduced a self-configuring reactive routing protocol for dynamic WSNs approach inspired on HOPNET and an evolution from AD-ZRP, known as Ant-based Dynamic Hop Optimization Protocol (ADHOP) in[30]. The proposed approach, ADHOP focuses on the architectural design of the protocol by considering constraints such as memory, bandwidth, processing power and energy consumption, in order to achieve suitability for Wireless Sensor Networks. Based on dynamic hops, ADHOP algorithm is promising to deal with the traffic overhead, route discovery and unreliable links between nodes relevant issues. The designing of the ADHOP, is promising in improvement of the routing decisions due to a self-configured reactive routing protocol. The ant structure in ADHOP contains source node, previous node and destination node address information as well as heuristic information sequence no and hop count. The proposed approach is compared with HOPNET and AODV by using GloMoSim. The ADHOP algorithm is evaluated compared with HOPNET and ADOV in terms of data delivery ratio, routing overhead and congestion avoidance. The results of introduced protocol are promising as compared to other approaches.

4.19. ACS

Jian-Feng Yan et al introduced an ant colony optimization based heuristic to reduce energy consumption in Wireless

Sensor networks[31]. For the heuristic three algorithms ACO based (Ant System, Ant Colony System and improved AS), are introduced and applied in wireless sensor routing process. In ACS, local pheromone updating is introduced in the process of tour building. After each construction step, all ants used to update the local pheromone value. The next node choosing mechanism in AS and ASW is same while pheromone update mechanism is different. For evaluation of the protocol six scales of WSNs were designed. The total energy of ACS is less than AS and ASW and also energy consumption standard deviation of ACS is more stable and lower than the AS and ASW approaches. So the application of ACS to WSNs is promising for routing and prolongs the network life.

4.20. ACO

Xie Hui et al proposed a routing protocol for wireless sensor network based on Ant Colony Optimization (ACO), subfield of SI[32]. The proposed WSNs routing protocol exploits the ant behaviour for the globally balancing of the node power consumption that causes the lifetime of network as long as possible. For the dynamic and adaptive routing, ACO based approach considers path delay, node energy and the frequency. The proposed technique consists of three stages, neighbour discovery, routing and data transmission, and route maintenance. The neighbour discovery is launched on the destination node. During the neighbour discovery process broadcast packets, (consisting of send time, receive time and packet delay) are exchanged between the nodes. In the second phase, data is transmitted, by exploiting information of earlier phase, from source to destination. The selection is done probabilistically depending on the path delay, node energy and frequency of a node working as a router. The last phase is route maintenance, in which inquiries are flooded through the destination node to the source node. The route maintenance helps in maintaining the routes, validity of route and checking of alternate routes for the future usage. The proposed approach is simulated in GloMoSim2.0. Author compared ACO routing protocol with SPEED protocol and EAR protocol to show the enhancement in the lifetime of WSNs. The simulation results shows that energy consumption Vs node density is very low and node operational time is very high with respect to stated protocols (SPEED and EAR.

Table 1. Features Analysis of SI based Algorithms

Routing Protocols / Features of Protocols	AntHocNet	ARA	ACO-AOMDV	NNNA	ARAMA	Termiite	MABR	PERA	PSO-ODMP	CGSR	AAR	GPSAL	Ant-AODV	TPSO	AD-ZRP	EEABR	LEACH-P	ABDRA	ADHOP	ACS	ACO
Topology-adaptive	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Traffic-adaptive	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Multi-path	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Local representation	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N
Hierarchical	N	N	N	N	N	N	Y	Y	Y	Y	Y	P	N	N	N	N	N	N	Y	Y	Y
Constructive	Y	Y	Y	Y	Y	N	N	Y	N	N	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N
Loop-free	N	N	N	N	N	Y	P	P	N	P	P	Y	N	N	N	N	N	Y	P	P	N
Proactive behavior	Y	Y	Y	Y	Y	Y	P	Y	Y	Y	Y	P	Y	Y	Y	Y	Y	Y	P	Y	Y
Reactive behavior	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Stoch. exploration	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Stoch. data Routing	Y	Y	Y	Y	Y	P	N	N	N	N	N	N	Y	Y	Y	Y	Y	P	N	N	N
Formal properties	N	N	N	N	N	N	N	N	N	P	P	N	N	N	N	N	N	N	N	N	N
Phy. implementation	N	N	N	N	N	N	Y	Y	Y	P	P	Y	N	N	N	N	N	N	N	N	N
Energy-aware	N	N	Y	N	Y	P	Y	Y	P	P	Y	Y	N	Y	Y	P	Y	P	Y	Y	Y
Load balancing	Y	N	Y	Y	N	Y	Y	P	P	Y	Y	Y	Y	P	Y	Y	P	Y	Y	P	P
Self-Configuration	P	P	Y	Y	Y	P	Y	Y	Y	N	P	N	P	P	Y	Y	Y	Y	Y	P	Y

The general characteristics and features of routing protocols and algorithms for MANETs and WSNs that are studied in[5, 10] and extended set of SI based algorithmic approaches with their features, are shown in the following comparative feature analysis Table .1. The extracted features have been discussed in corresponding sections of algorithms. Swarm Intelligence based algorithms are analysed with the state of art routing protocols deployed for MANETS and WSN with considering various features that are depicted in the table 1.1. In the table Y" and "N" stand respectively for Yes" and "No" while "P" shows that the algorithm partially possesses that feature. The comparative study, shows that bio inspired algorithms are more promising than other conventional approaches.

5. Conclusions

In this survey paper, Swarm Intelligence based paradigms, PSO, ACO and Honeybees, nature inspired routing algorithms in MANETs and WSNs are critical analysed and their appropriateness is observed. SI based routing algorithms are more promising for specific nature of Ad hoc & Sensor Networks due to the freely mobility and frequent topology changes. The computational intelligence approaches are very effectively applied to NP-hard problems and results more promising. The similar multi-objective constraints based issues like mobility, path optimization, resource utilization and energy awareness, are effectively solved by exploiting SI based meta heuristics in MANETs and WSNs. This research concludes that ACO approaches are very promising for route optimization in MANETs while PSO is very effective for load balancing and energy optimization in WSNs. The author concluded in the view of algorithmic approaches under observation that bio inspired, Swarm Intelligence based routing protocols are more promising for Ad hoc & Sensor networks particularly and for wired networks generally.

REFERENCES

[1] Charles E. Perkins and Elizabeth M. Royer. "Ad hoc On-Demand Distance Vector Routing." Proceedings of the 2nd IEEE Workshop on Mobile Computing Systems and Applications, New Orleans, LA, pp. 90-100, February 1999.

[2] David B Johnson and David A Maltz, "DSR : The Dynamic Source Routing Protocol for Multi-Hop Wireless Ad Hoc Networks", in Computer and Information Science, Volume: 5, pp. 1-25, 2001.

[3] T. Clausen, P.Jacquet, A Laouiti, P.Muhlethaler, A. Qayyum, and L.Viennot, "Optimized link state routing protocol for ad hoc networks," in Proceedings of IEEE, INMIC, pp. 62 - 68, 2001.

[4] Zygmunt J. Haas and Marc R. Pearlman, " The performance of query control schemes for the zone routing protocol", In Proceedings of the ACM SIGCOMM '98 conference on Applications, technologies, architectures, and protocols for computer communication (SIGCOMM '98), pp.167-177, 1998.

[5] Muddassar Farooq, Gianni A and Di Caro: Routing Protocols for Next-Generation Networks Inspired by Collective Behaviors of Insect Societies: An Overview. Swarm Intelligence 2008: pp. 101-160, 2008.

[6] Fatih Çelik, Ahmet Zengin and Sinan Tuncel, "A survey on swarm intelligence based routing protocols in wireless sensor networks", International Journal of the Physical Sciences , Vol. 5, pp. 2118-2126, November, 2010.

[7] M. Anupama and Dr. Bachala Sathyanarayana, "Survey of Cluster Based Routing Protocols in Mobile Ad hoc Networks," International Journal of Computer Theory and Engineering vol. 3, no. 6, pp. 806-815, 2011.

[8] Arash Dana, Amir Mansour Yadegari, Marzieh Hajhosseini, and Tina Mirfakhraie, "A Robust Cross-Layer Design of Clustering-Based Routing Protocol for MANET," pp. 1055-1059.ICACT, 2008.

[9] Al-Karaki, J.N. Kamal, amd A.E., "Routing techniques in wireless sensor networks: a survey", IEEE, Wireless Communications, Volume 11, Issue 6, Page(s): 6 – 28, Dec. 2004.

[10] Zulfiqar Ali and Waseem Shahzad "Critical Analysis of Swarm Intelligence based Routing Protocols in Ad hoc and Sensor Wireless Networks," in IEEE International Conference on Computer Networks and Information Technology (ICCNIT), pp. 287-292, July 2011.

[11] E. Baburaj and V. Vasudevan "An Intelligent Mesh Based Multicast Routing Algorithm for MANETs using Particle Swarm Optimization," , IJCSNS International Journal of Computer Science and Network Security, vol. 8 No.5, May 2008.

[12] Marco Dorigo, Mauro Birattari, and Thomas Stutzle, "Ant Colony Optimization Artificial Ants as a Computational Intelligence Technique", IRIDIA – TECHNICAL REPORT SERIES: TR/IRIDIA/2006-023.

[13] M.Golshahi, M.Mosleh and M.Kheyrandish, "Implementing An ACO Routing Algorithm For AD-HOC Networks," IEEE, International Conference on Advanced Computer Theory and Engineering, 2008.

[14] Camara, D and Loureiro,A.A.F, "A novel routing algorithm for ad hoc networks", in International Conference on System Sciences, Jan 2000.

[15] Hiroshi Matsuo and Kouichi Mori, "Accelerated Ants Routing in Dynamic Networks" In Proceedings of the International Conference On Software Engineering, Artificial Intelligence, Networking and Parallel/Distributed Computing (2001).

[16] Marwaha, S, Chen Khong Tham and Srinivasan, D. "A NOVEL ROUTING PROTOCOL USING MOBILE AGENTS AND REACTIVE ROUTE DISCOVERY FOR AD HOC WIRELESS NETWORKS" in 10th IEEE International Conference on Networks, 2002, pp. 311 – 316, 2002.

[17] John S. Baras and Harsh Mehta "A Probabilistic Emergent Routing Algorithm for Mobile Ad Hoc Networks", in WiOpt03: Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks, 2003.

[18] Xun-bing Wang, Yong-zhao Zhan, Liang-min Wang and Li-ping Jiang, "Ant Colony Optimization and Ad-hoc On-demand Multipath Distance Vector Based Routing Protocol," IEEE Fourth International Conference on Natural Computation, pp. 589-593, 2008.

[19] Roth Martin and Wicker Stephen, "Termite: ad-hoc networking with stigmergy", in IEEE Conference, Global Telecommunications, vol.5, pp. 2937 – 2941, 2003.

[20] Mesut Gunes,, Udo Sorges and Imed Bouazizi, "ARA – The Ant-Colony Based Routing Algorithm for MANETs", International Workshop on Ad Hoc Networking (IWAHN 2002), Vancouver, British Columbia, Canada, August 18-21, 2002.

[21] Di Caro, G., Ducatelle, F. and Gambardella, L. M., "AntHocNet: An Adaptive Nature-Inspired Algorithm for Routing in Mobile Ad Hoc Networks", European Transactions on Telecommunications (ETT), Special Issue on Self Organization in Mobile Networking, Volume 16, Number 5, pp. 443-455, September-October 2005.

[22] E. Baburaj and V. Vasudevan "An Intelligent On Demand Multicast Routing Protocol for MANETs,", IEEE, First International Conference on Emerging Trends in Engineering and Technology, pp. 214-217, 2008.

[23] O. Hussein and T. Saadawi ,"Ant Routing Algorithm for Mobile Ad-hoc networks (AMMA)," , IEEE, Performance, Computing, and Communications Conference, pp.281 – 290, 2003.

[24] Ping Yuan, Chunlin Ji, Yangyang Zhang and Yue Wang, "Optimal Multicast Routing in Wireless Ad Hoc Sensor Networks" , International Conference on Networking, Sensing & Control, IEEE , 2004.

[25] S. Gheitanchi, F. H. Ali, and E. Stipidis, "Trained particle swarm optimization for collaborative computing networks," in Proceedings of the Convention Communication, Interaction and Social Intelligence (AISB '08), vol. 11, pp. 7-12, Aberdeen, Scotland, 2008.

[26] Okazaki, A.M and Frohlich, A.A., "Ant-based Dynamic Hop Optimization Protocol: A routing algorithm for Mobile Wireless Sensor Networks", in conference GLOBECOM Workshops (GC Wkshps), IEEE, 1139 – 1143, Dec. 2011.

[27] Tiago Camilo, Carlos Carreto, Jorge Sá Silva, and Fernando Boavida. "An energy-efficient ant-based routing algorithm for wireless sensor networks", In Proceedings of the 5th international conference on Ant Colony Optimization and Swarm Intelligence (ANTS'06), pp. 49-59, 2006.

[28] Liao Ming-hua, Zhang Hua, Sun Guang, "Energy Aware Routing Algorithm for Wireless Sensor Network Based on Ant Colony Principle", JCIT: Journal of Convergence Information Technology, Vol. 7, No. 4, pp. 215 – 221, 2012.

[29] Rajeshwar Singh, Dharmendra K Singh and Lalan Kumar, "Performance Evaluation of ACO Based on Demand Routing Algorithm for Mobile Ad Hoc Networks", in Internal Journal Engineering Science and Technology(IJEST), Vol.3, Issue 3, pp. 1809-1815, March 2011.

[30] Okazaki, A.M and Frohlich, A.A., "Ant-based Dynamic Hop Optimization Protocol: A routing algorithm for Mobile Wireless Sensor Networks", in GLOBECOM Workshops (GC Wkshps), IEEE, pp. 1139 – 1143, Dec. 2011.

[31] Jian-Feng Yan, Yang Gao and Lu Yang, "Ant colony optimization for wireless sensor networks routing", International Conference on Machine Learning and Cybernetics (ICMLC), pp. 400 - 403 , July 2011.

[32] Xie Hui, Zhang Zhigang and Zhou Xueguang, "A Novel Routing Protocol in Wireless Sensor Networks Based on Ant Colony Optimization", on International Conference, Environmental Science and Information Application Technology(ESIAT), pp. 646 – 649, July 2009.