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ANT COLONY OPTIMIZATION BASED GEOGRAPHIC ROUTING IN WSN

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***Abstract*--Wireless Sensor Networks consisting of nodes with limited power are deployed to gather useful information from the field. In WSNs it is critical to collect the information in an efficient manner. It is applied in routing and difficult power supply area or area that cannot be reached and some temporary situations, which do not need fixed network supporting and it can fast deploy with strong anti-damage. In order to avoid the problem In this paper, we first propose a Ant Colony Optimization Boolean Expression Evolver Sign Generation based Geographic Routing in WSN, that periodically selects the cluster heads according to the ant colony optimization. ACO is a dynamic and reliable protocol. It provides energy-aware, data gathering routing structure in wireless sensor network. It can avoid network congestion and fast consumption of energy of individual node. Then it can prolong the life cycle of the whole network. ACO algorithm reduces the energy consumption. It optimizes the routing paths, providing an effective multi-path data transmission to obtain reliable communications in the case of node faults. This paper defines implementation of WSN and comparison of its performance with Efficient Homogenous Cluster (EHC) geographical routing protocol based on ant algorithm is done in terms of packet delivery ratio, throughput and energy level. Performance of our algorithm in comparison of EHC is much better.**

Index Terms*- *Ant Colony Optimization Boolean Expression Evolver Sign Generation, Energy efficiency and Wireless sensor networks.

I. INTRODUCTION

Wireless Sensor Networks comprises of small sensor nodes communicating with each other in an ever changing network topology, i.e., which keeps on varying. These wireless nodes or Berkeley motes (or simply motes) [2] have embedded electronic sensors along with battery's and RF devices. These sensors sense and detect various environmental parameters such as temperature, pressure, air pollution etc. They are also deployed in monitoring of agriculture, smart homes, structures, passive localization, tracking [5] etc. The motes in WSN transmit data depending on local information and parameters such as signal strength, power consumption, location of data collection and accretion. Only reachable nodes are able to communicate with each other directly to collect and transmit data. The motes have limited energy resources along with constraints on its computational and storage capabilities [1]. Because of these limitations the communication between any two devices in the network requires cooperation between intermediate forwarding network nodes, i.e. the node devices act as routers and end systems at the same time. Communication between any two nodes may be trivially based on simply flooding the entire network [3].

Routing in WSNs is very challenging due to the inherent characteristics that distinguish these networks from other wireless networks like mobile ad hoc networks or cellular networks. Presence of large number of sensor nodes and constraints in terms of energy, processing, and storage capacities requires careful management of resources. Due to such differences, many algorithms have been proposed for the routing in WSNs.
These routing mechanisms have taken into consideration the inherent features of WSNs along with the application
and architecture requirements. The task of finding and maintaining routes in WSNs is nontrivial since energy restrictions and sudden changes in node status (e.g., failure) cause frequent and unpredictable topological changes [4].

Minimizing the energy consumed while ensuring the connectivity of a network is an important issue to be addressed in WSNs because the batteries powering the sensors may not be accessible for recharging often. Cluster-based routing in WSNs has been investigated by researchers to achieve the network scalability and management, which maximizes the lifetime of the network by using local collaboration among sensors [2]–[5], [6]–[7]. In a clustered WSN, every cluster has a cluster head (CH). CHs periodically collect, aggregate, and forward data to the sink.

In any application of WSNs, connectivity is considered to be an important metric to measure the quality of service of WSNs. A network is said to be connected if all sensors in the FoI can reach to the sink. Geographic routing [5]–[7] has been considered as an attractive approach in large scale WSNs because it does not require the global topology of a WSN. A sensor can make routing decisions based on the geographic position of itself and its neighbors. The sensor forwards the sensory data to a neighbor, which is closest to the sink. This reduces the average hop count. However, geographic routing cannot optimize the number of hops when a sensor has no neighbor closer to the sink. This problem is known as local minimum problem in the literature [5]. The occurrence of the problem can be caused by many factors, such as sparse deployment of sensors, physical obstacles, and sensor failures.

Swarm intelligence based techniques can be used in a number of applications such as controlling unmanned vehicles, controlling nano robots within the body for the purpose of killing cancer tumors [7],telecommunication networks, mobile media [6], and intrusion detection. This paper focuses the application of swarm intelligence algorithm (Ant Colony Optimization) to detect sinkhole attacks in a wireless sensor networks.

In this paper an adaptation of Ant Colony Optimization (ACO) [6, 7] technique is demonstrated for network routing. This approach belongs to the class of routing algorithms inspired by nature's complex adaptive systems. Ant Colony Optimization (ACO) [3, 4], a combinatorial optimization framework that reverse-engineers and formalizes the basic mechanisms at work in a shortest path behavior observed in ant colonies. Ants in a colony are able to converge on the shortest among multiple paths connecting their nest and a food source. The driving force behind this behavior is the use of a volatile chemical substance called pheromone. While locating food, ants lay pheromone on the ground, and they also go in the direction where the concentration of pheromone is higher. This mechanism allows them to mark paths and subsequently guide other ants, and let good paths arise from the overall behaviour of the colony [8,11]. Wireless Sensor Network architecture, ACO algorithm for network routing and Simulation Results are presented in the following sections.

II. LITERATURE SURVEY

There is a wide range of routing algorithms that has been used to solve the problem of routing in WSN. Generally speaking, routing algorithms can be described in two broad classes, reactive (on demand) routing and proactive (table driven) routing. Reactive protocols establish a path between the source and destination only when there are packets to be transmitted. Two commonly found reactive protocols in WSNs are Ad-hoc On-demand Distance Vector (AODV) routing and Dynamic Source Routing (DSR).Proactive protocols always have a rout available, so they are more suited for dynamic networks, such as when the nodes are mobile. They are efficient if routes are used often. Reactive protocols create their routes just before data is about to be sent. This ensures the nodes have the most up to date routing information but there is a start up cost as the route is being acquired.

Reactive protocols have lower overhead than the proactive protocols and work better for intermittently links. [6] DSDV is a proactive routing protocol based on the Bellman-Ford algorithm. It expands on Bellman-Ford by having each entry in the routing table contain a sequence number. A route is considered more favorable, if it has a higher sequence number. If two routes have the same sequence number, the one with the lower cost metric is chosen. when a node decides a route is broken, it advertises that route with an infinite metric and a sequence number one greater than before. It can be shown that this routing algorithm is loop free.

DSR is a reactive protocol that is similar to AODV, the primary difference from AODV is DSR uses source routing instead of hop-by-hop routing. Each packet routed by DSR contains the complete ordered list of nodes that the packet travels through. The protocol consists of two phases, route discovery and route maintenance. Route discovery is used to obtain a path from a source to a destination. A route request packet is flooded through the network and is answered by a route reply packet. Route maintenance is used to detect if the network topology has changed. AODV is an reactive protocol that is a combination of DSR and DSDV. Route discovery and maintenance is similar to DSR, and uses the hop-by-hop routing of DSDV. It also uses sequence numbers for loop prevention, with the goals of quick adaptation under rapidly changing link conditions, lower transmission latency that the other protocols and less bandwidth consumption.

The Low Energy Adaptive Clustering Hierarchy algorithm (LEACH) [8] randomly selects a few sensor nodes as cluster head and rotates this role to distribute evenly the energy load among the sensors in the network. The algorithm named Power Efficient Gathering in Sensor Information Systems (PEGASIS) [9] proposes that, in order to extend network lifetime, sensor nodes need only communicate with their closest neighbors and take turns to communicate with the base station. When the round of all nodes communicating with the base station ends, a new round will start and so on. This reduces the power required to transmit data per round as the power draining is spread uniformly over all nodes [10] the Directed Diffusion algorithm is presented. It is a data centric (DC) and application aware paradigm in the sense that all data generated by sensor nodes are named by attribute value pairs. The main idea of the DC paradigm is to combine the data coming from different en route sources (in-network aggregation) by eliminating redundancy, minimizing the number of transmissions, thus saving network energy and prolonging its lifetime.

In [11] Rumor Routing is defined, and is a variation of Directed Diffusion and is mainly intended for applications where geographic routing is not feasible. The key idea is to route the queries to the nodes that have observed a particular event rather than flooding the entire network to retrieve information about occurring events.

In [12] the Geographic Adaptive Fidelity algorithm (GAF) is defined. It is an energy aware location based routing algorithm designed primarily for mobile ad hoc networks, but may be applicable to WSN as well. The network area forms a virtual grid. Inside each zone, nodes collaborate with each other to play different roles. In [13] the Geographic and Energy Aware Routing algorithm (GEAR) is presented. It uses energy aware and geographically informed neighbor selection heuristics to route a packet towards the destination region. The key idea is to restrict the number of interests in Directed Diffusion by only considering a certain region rather than sending the interests to the whole network. By doing this, GEAR can conserve more energy than Directed Diffusion. There exist other kinds of routing algorithms, which are based on ACO (they also could be classified into flat, hierarchical or location based algorithms).

In [14] FL-LEACH protocol that employs fuzzy logic in order to determine the number of CHs that should be used in the WSN. FL-LEACH is a fuzzy inference system that depends on two variables: number of nodes in the network and nodes density. Assuming uniform distribution of the nodes over the sensor field, the novelty of the proposed approach is in its ability to determine the number of CHs without getting other information about the network. Matlab simulation is used to show the effectiveness of the FL-LEACH protocol compared with other protocols, such as the pure LEACH and the genetic-based protocol, LEACH-GA. Simulation results have shown that FL-LEACH outperforms LEACH and LEACH-GA in terms of network lifetime.

In [15] General Self-Organized Tree-Based Energy-Balance routing protocol (GSTEB) which builds a routing tree using a process where, for each round, BS assigns a root node and broadcasts this selection to all sensor nodes. Subsequently, each node selects its parent by considering only itself and its neighbors' information, thus making GSTEB a dynamic protocol. Simulation results show that GSTEB has a better performance than other protocols in balancing energy consumption, thus prolonging the lifetime of WSN.

In [16] an enhanced ant colony inspired self-optimized routing algorithm for WSN was presented. This mechanism was based on link quality, energy and velocity parameters. The adopted cross layer architecture helped WSN to improve the overall data throughput, especially in the case of real time traffic. In [17] a multipath routing algorithm (MRP) based on dynamic clustering and ACO was proposed. Such an approach can maximize the network lifetime and reduce energy consumption. In [18] a routing approach using an ACO algorithm was proposed for WSN consisting of stable or limited mobile nodes. This approach was also implemented into a small sized hardware component as a router chip. In [19] the authors proposed the algorithm Ant Colony Optimization Based Location Aware Routing (ACLR), a flat and location aware algorithm. It fuses the amount of residual energy with the global and local location information of nodes, to define the probability to select the next sensor node to jump to. An Energy Delay Based on ACO algorithm (E&D) was proposed. Its main goal was to find the optimal routing not only to maximize the lifetime of the network, but also to provide real time data transmission services.

A routing algorithm for data aggregation based on ACO (ACAR) was presented in [20]. The main idea of this algorithm was the optimization of data aggregation route by some cooperative agents called ants, using the factors: Energy, distance, and aggregation gain. In [21] the authors proposed a Pheromone based Energy Aware Directed Diffusion algorithm (PEADD) for WSN that extends the network lifetime by using pheromone values, and enhances the network reliability by maintaining the energy distribution relatively uniform among the network sensor nodes. It can be seen in [18] that the authors proposed an algorithm based on ACO for flat architectures and localization awareness. This proposal tries to maximize the network lifetime, as well as, to deal, react, and adapt itself to changes in the network.

III. EXISTING SYSTEM

Most of the existing solutions for the local minimum problem use perimeter routing technique (PRT). By the PRT, when greedy forwarding fails at a local minimum, *i.e.*, no neighbors closer to the sink, packets tend to be routed along the whole boundaries. In SPAN, a sensor associates with a CH in a step. A cluster with a higher CH degree may become highly loaded. Another drawback of existing clustering techniques is that they require more than one transmission power levels for routing the data. Such techniques are not suitable for low-cost sensors which have usually single power level. GPSR does not achieve shorter routing paths [14]. Similarly, GFVD does not construct a shorter routing path and may burden the energy consumption of sensors. In existing system, they have used an EHC technique in WSNs that periodically selects CHs according to their residual energy and the utility of the sensor to its neighbors. The main difference between existing clustering techniques and EHC technique is the utility of the CHs in WSNs. In the EHC technique, a sensor becomes a CH if the utility of the sensor is higher than its neighbors. Different from the existing work, a CH in EHC technique has maximum eleven neighboring CHs and does not make any assumptions about the density of sensors. The worst case processing time and space complexities of EHC technique is $O(1)$ per sensor [18].

Issues in Existing System

- In existing, CHs to perform direct transmissions to the sink, thus it suffers from the cost of long-distance transmissions.
- More energy consumption
- They may not use efficient routing path
- Throughput is not much significant

IV. PROPOSED SYSTEM

4.1 ANT COLONY OPTIMIZATION (ACO)

Swarm Intelligence (SI) is the local interaction of many simple agents to achieve a global goal. SI is based on social insect metaphor for solving different types of problems. Insects like ants, bees and termites live in colonies. Every single insect in a social insect colony seems to have its own agenda. The integration of all individual activities does not have any supervisor. In a social insect colony, a worker usually does not perform all tasks, but rather specializes in a set of tasks. This division of labour based on specialization is believed to be more efficient than if tasks were performed sequentially by unspecialized individuals. SI is emerged with collective intelligence of groups of simple agents. This approach emphasizes on distributedness, flexibility, robustness and direct or indirect communication among relatively simple agents [2]. The agents are autonomous entities, both proactive and reactive and have capability to adapt, cooperate and move intelligently from one location to the other in the communication network. The basic idea of the ant colony optimization (ACO) meta-heuristic is taken from the food searching behaviour of real ants. Ant agents can be divided into two sections:

- FANT (Forward Ants)
- BANT (Backward Ants)

The main purpose of this subdivision of these agents is to allow the BANTs to utilize the useful information gathered by FANTs on their trip time from source to destination. Based on this principle, no node routing information updates are performed by FANT, whose only purpose in life is to report n/w delay conditions to BANT.

The various steps how these agents are passing routing information to each other are as follows:

1. Each network node launches FANT to all destinations at regular time intervals.
2. Ants find a path to destination randomly based on current routing tables.
3. The FANT creates a stack, pushing in trip times for every node as that node has reached.
4. When destination is reached, the BANT inherit the stack.
5. The BANT pop the stack entries and follows the path in reverse.
6. The routing table of each visited node are updated based on trip times.

4.2 VARIOUS FIELDS OF FANT

The FANT consist of six field as shown in the Fig. 1

Source address (4 bytes)	Sequence Number (2 bytes)	Destination Address (4 bytes)	Stack	Stack pointer (2 bytes)	Fwd (value =0 or 1)

Fig.1 Format of Forward Ant

These fields are defined as:
1. Source Address: The 4 bytes field, which contains address of source node discovered by route discovery phase.
2. Sequence Number: The 2 bytes field or local counter maintained by each node and incremented each time when FANT generated by source.
3. Destination Address: The 4 bytes field, which contains address of node where to send the information from source.
4. Stack: The memory area in which data gathered by FANTs is stored.
5. Stack Pointer: It is 2 bytes field, which keep track of number of visited nodes.
6. Fwd: The 1 bit field set to 1 when ant agent is FANT and set to 0 when ant agent is BANT.

When ants are on the way to search for food, they start from their nest and walk toward the food. When an ant reaches an intersection, it has to decide which branch to take next. While walking, ants deposit pheromone, which marks the route taken. The concentration of pheromone on a certain path is an indication of its usage. With time the concentration of pheromone decreases due to diffusion effects. This property is important because it is integrating dynamic into the path Searching process.

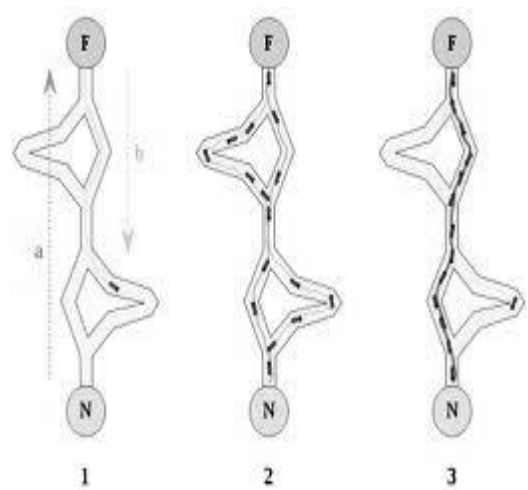

Fig. 2 : All ants take the shortest path after an initial searching time

4.3 ROUTING IN WSN USING ANT-LIKE AGENTS

4.3.1 ANTNET

AntNet[3] uses ant agents for routing in the network. Using AntNet , nodes in the network frequently send ant agents to randomly selected destinations in the network. After reaching the destination, the ant agent traverses the same path going back to the original source node. On the way back to the Source node, the ant agents update the routing table of the nodes. Launching ant-agents continuously increases the control overhead even more. In a dynamic network such as WSNs, by the time, the ant agent reaches the source node; the routing information may have changed.

The Four Phases of Ant Based Algorithm

1. Route discovery phase
2. Route maintenance phase
3. Ant Colony Optimization Boolean Expression Evolver Sign Generation
4. Route failure handling

The detailed description of various phases of algorithm is as follows:[4]

4.3.1.1 ROUTE DISCOVERY PHASE

Route discovery phase uses control packet to discover route from source to destination. The control packets are mobile

agents which walk through the network to establish routes between nodes. Route discovery uses two ant agents called Forward Ant (FA) and Backward Ant (BA). These two ants are similar in structure but differ in the type of work they perform. A FA is an agent, which establishes the pheromone track to the source node, and BA establishes pheromone track to the destination. A forward ant is broadcast by the sender and relayed by the intermediate nodes till it reaches the destination. A node receiving a FA for the first time creates a record in its routing table. The record includes destination address, next hop and pheromone value. The node interprets the source address of the FA as the destination address, the address of the previous node as the next hop and computes the
pheromone value depending on the number of hops the FA needed to reach the node. Then the node forwards the FA to its neighbours.

FA packets have unique sequence number. Duplicate FA is detected through sequence number. Once the duplicate ants are detected, the nodes drop them. When the FA reaches the destination, its information is extracted and it is destroyed. BA is created with same sequence number and sent towards the source. BA reserves the resources at along the nodes towards source. BA establishes path to destination node.

4.3.1.2 ROUTE MAINTENANCE PHASE

Route Maintenance plays a very important role in WSN's as the network keeps dynamically changing and routes found good during discovery may turn to be bad due to congestion, signal strength, etc. Hence when a node starts sending packets to the destination using the Probabilistic Route Finding algorithm explained above, it is essential to find the goodness of a route regularly and update the pheromone counts for the different routes at the source nodes. To accomplish this, when a destination node receives a packet, it probabilistically sends a Congestion Update message to the source which informs the source of the REM value for that route. This Congestion Update message also serves an ACK to the source.

4.3.1.3 ANT COLONY OPTIMIZATION BOOLEAN EXPRESSION EVOLVER SIGN GENERATION

The ABXES algorithm [13] is employed to distribute keys to the alerted nodes in the group to sign the suspect list. Termed Ant Colony Optimization Boolean Expression Evolver Sign Generation (ABXES) algorithm, the novel technique serves to efficiently obtain a minimized Boolean expression, given the membership function of the alerted nodes in a group denoted by a truth table. According to this algorithm, a group of ant agents work together to obtain an optimal solution. Each ant agent moves to reach the solution by depositing pheromone. Each Boolean expression expressed as an ant agent consists of terms at respective position denoting the pheromone deposition combined using an OR operator.
It illustrates the ant agent representing the terms at each
position for a two variable case. For instance, in a two variable case, the ant agent with a pheromone deposition {1, 4} denotes the terms at positions 1 and 4. Thus the terms K1 and K2 at the corresponding positions for a two variable case is combined using an OR operator. Thus the pheromone deposition {1, 4} denotes the Boolean
expression K1 + K2.

4.3.1.4 ROUTE FAILURE HANDLING PHASE

This phase is responsible for generating alternative routes in case the existing route fails. Every packet is associated with acknowledgement; hence if a node does not receive an acknowledgement, it indicates that the link is failed. On detecting a link failure the node sends a route error message to the previous node and deactivates this path by setting the pheromone value to zero. The previous node then tries to find an alternate path to the destination. If the alternate path exists, the packet is forwarded on to that path else the node informs its neighbours to relay the packet towards source. This continues till the source is reached. On reaching the source, the source initiates a new route discovery phase. Hence ant algorithm does not break down on failure of optimal path. This helps in load balancing. That is, if the optimal path is heavily loaded, the data packets can follow the next best paths.

4.4 APPLICATIONS OF ACO ALGORITHMS

Since their introduction in the early 1990s, ACO algorithms have been applied to many optimization problems. First, classical problems such as assignment problems, scheduling problems, graph coloring, the maximum clique problem, or vehicle routing problems were tackled. More recent applications include, for example, cell placement problems arising in circuit design, the design of communication networks, bioinformatics problems, or problems arising in continuous optimization. In recent years some researchers have also focused on the application of ACO algorithms to multi-objective problems and to non static problems.

V. PERFORMANCE EVALUATION

A. Simulation Parameters

The proposed scheme has been implemented on the network simulator ns-2 [11] and the performance compared with some existing mechanisms. The 802.11 MAC layer implemented in ns-2 is used for simulation. There are 100 sensor nodes randomly deployed in the sensing area. In this section, we can evaluate the performance of simulation. We are using the xgraph for evaluate the performance. We use some evaluation metrics: Average Hop Count: The average hop count as the average number of hops travelled by any packet to reach the sink. The simulation for analysis of average hop count is conducted by varying the communication range of the sensors. Energy Consumption.

The energy consumption per round is the sum of energy consumed per round in Ant colony optimization and EHC. We therefore consider the energy consumption as the energy dissipated in transmitting and receiving packets., Packet delivery ratio: – it is the ratio of the number of packet received at destination and number of packet sent by the source, End-to-End delay: - the average time taken for a packet to be transmitted from source to destination, Energy level – number of energy consumed when the data should be transmitted.

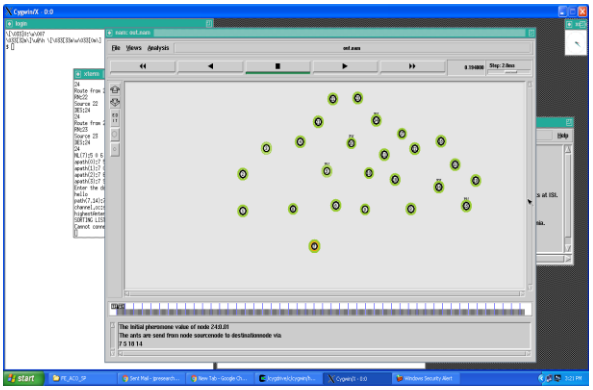

Fig.3 Network Topology

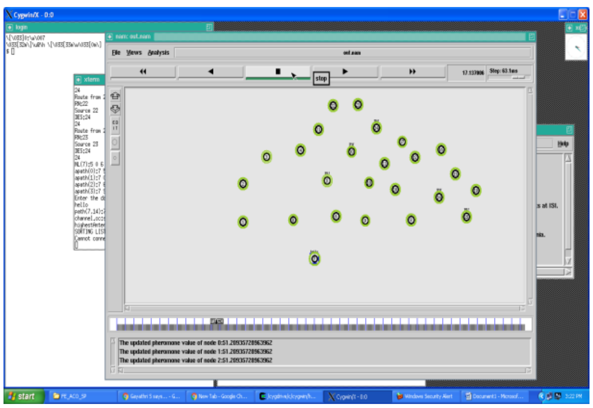

Fig.4 ABXES Algorithm

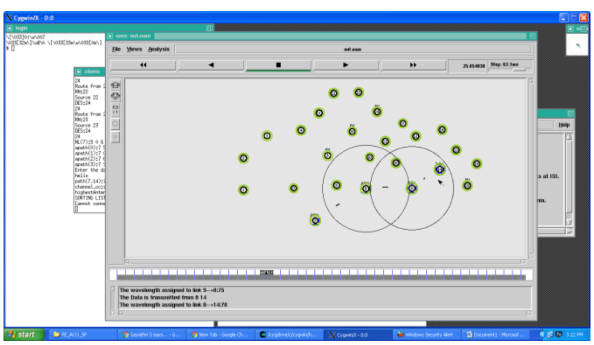

Fig.5 Pheromone updation

B. Performance Metrics

To increase the lifetime for wireless sensor networks, a ACO routing protocol is used. The data are selected and transferred from the source to the destination via the router. In this result we implemented the simulation of AODV protocol and calculated its performance such as throughput and energy

Table I. Stimulation parameters

Parameter	Value
Application Traffic	10 CBR
Transmission rate	4 packets/s
Packet Size	512 bytes
Channel data rate	11 Mbps
Area	100m*100m
Simulation time	800

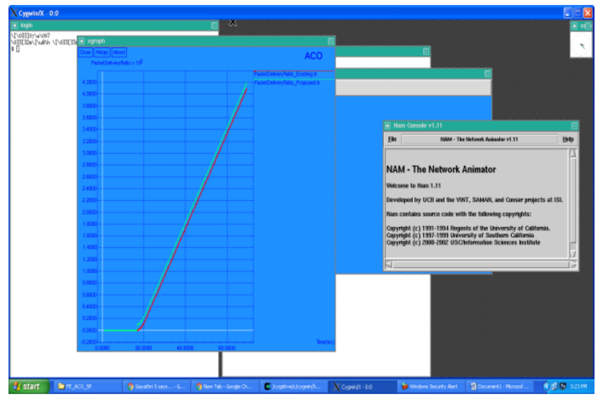

Fig.6 Packet Delivery Ratio

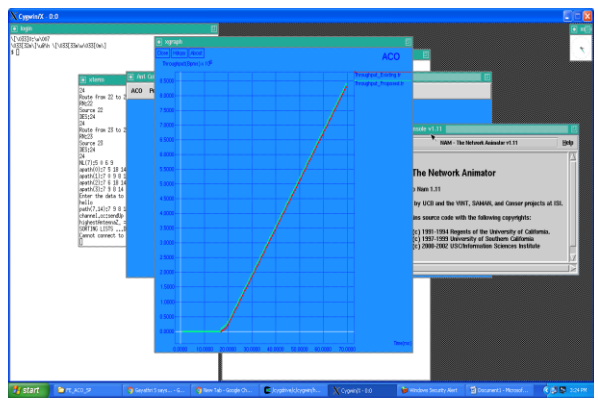

Fig.7 Throughput

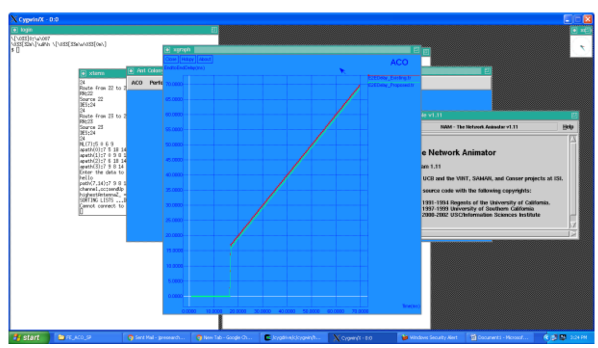

Fig.8 End to End delay

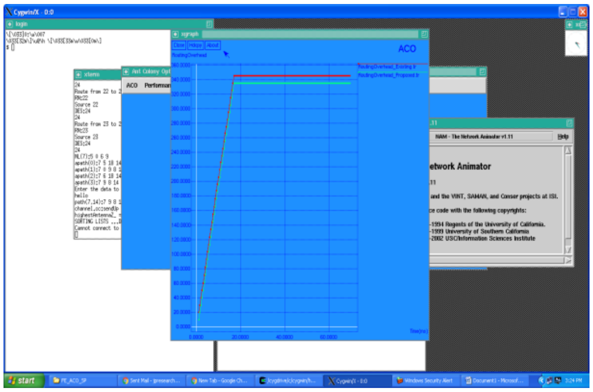

Fig.9 Routing Overhead

VI. CONCLUSION

In this paper, we presented a new protocol for WSN routing Operations. The protocol is achieved by using Ant Colony Optimization Boolean Expression Evolver Sign Generation (ABXES) algorithm to optimize routing paths, providing an effective multi-path data transmission to obtain reliable communications in the case of node faults. We aimed to maintain network life time in maximum, while data transmission is achieved efficiently. Our study was concluded to evaluate the performance of ant based algorithm and EHC routing protocol in terms of Packet Delivery Ratio, Average end-to end delay and Normalized Routing Load. From the comparison it is concluded that overall performance of ant based algorithm is better than EHC in terms of throughput. Our proposed algorithm can control the overhead generated by ants, while achieving faster end-to-end delay and improved packet delivery ratio. The future work could be to investigate different methods to further limit the traffic or load and compare the ant based algorithm for other proactive and reactive routing protocols.

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