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Ant-colony Algorithm Based Routing Using Swastika Clustering in WSNs

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ABSTRACT

Sensor nodes are the structural and functional unit of a Wireless Sensor Network (WSN), group of nodes form a cluster and all cluster collectively constituent the WSN. The prime concern of all researcher is to choose proper topology of the sensor nodes and the design of cluster in a network, along with that the intra-cluster routing between nodes and the inter-cluster routing techniques between cluster head have also been an another prime concern of researchers. In this paper, we are using SWASTIKA model as a cluster which has selected only the orthogonal path to send the traffic to the cluster head using Dijkstra algorithm and the Ant-colony Algorithm (AA) is used to send the collected traffic by Cluster Head (CH) to the destination. Here we have focused on the impact of implying AA to CH for sending traffics in a WSN in context to Total Power Consumption (TPC) and Average Power Consumption (APC). We have simulated the result in MATLAB and able to minimize the TPC and APC which ensure to have a network with a longer lifetime.

Keywords: AA, SWASTIKA, CH, TPC, APC.

1. INTRODUCTION

Now a days, data transmission is becoming a very import factor in communication. In a network like WSN which is very small in size and have abilities to compute and sensing various environment condition like temperature, pressure, and humidity etc. The WSN is applicable in different field like air pollution monitoring, quality of water checking, forest fire detection, military application, health etc. In WSN the resource area is energy consumption because it is a very important factor when the sensor node is deployed in the sensor field area, it is very difficult to replace the battery which having fixed value of Electro Motive Force (EMF).

Therefore, it has been a challenging task to optimize power consumption in a WSN. During the data transmission in WSN, network consumes most of its power from the battery [14], [15], [16].

In WSN, it has one sink node which will communicate with all other nodes in the same network. Generally, in a large network, each sensor does not send a message directly to the sink node because it has not having enough battery power. Therefore, they are forming a number of clusters connected with some number of nodes. Each cluster having a coordinator CH, which will be responsibility for gathering data from the nodes and sending it to the sink or through the other cluster of cluster head [11].

The wireless sensor nodes are deployed randomly and uniformly in the sensor field, which has embedded with power unit, sensor, a microcontroller with a small memory, Analog to Digital Converter (ADC), Digital to Analog Converter (DAC) and transceiver. Each sensor node is responsible for self-organizing of a particular infrastructure. In this sensor architecture, the sensor scenes the environment condition of sensing data and transmitted to the ADC (Analog to Digital Converter), which converts the analog signal to digital

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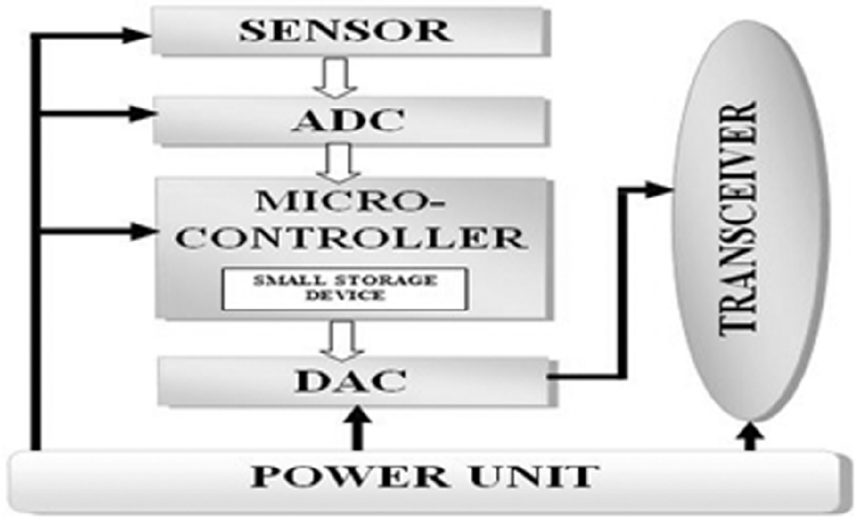

Figure 1: The architecture of wireless node[16].

signal. Then the microcontroller processes this digital data and which will store in the memory and then the signal transmits by transceiver as an analog signal, passing through the DAC, which can convert digital signal to analog signal on the same network and the Power unit is supplying power to whole system which generally backed by a dry cell [14], [15], [16].

1.1. Energy Consumption Issues in WSN

In the network lifetime, energy consumption is an important factor because sensor node in WSNs backed by a battery which is fixed and is not possible to replace after deployment. The energy optimization can be done by using an energy awareness routing and an optimal network design. A sensor node consists of four sub-systems.

1.1.1. Computation Subsystem

A computing subsystem is consisting microprocessor or micro-controller unit (MCU). It is responsible for the control the sensor and implementation of communication protocols. MCU propose is operating power management. This operating mode is engaged for the consumption of power of each sensor.

1.1.2. Communication Subsystem

A communication sub-system is consisting short range radio which is communicated to the other neighboring sensor node in the same network. It is the important factor for saving power that radio is putting in the idle mode when it is not transmitting or receiving.

1.1.3. Power Supply Subsystem

A power supply subsystem is consisting a battery which is supply power to the sensor node. It is not possible to replace the battery can be increased by using low power components and power management operation mode.

1.1.4. Sensing Subsystem

A sensing subsystem is nothing but it consists of a large number of a group of the sensor, which is communicated with all node of the same network. Energy consumption can be reducing by using the low-power component.

1.2. Ant-colony Algorithm (AA)

AA is the best approach to solving computational problems and the problems that need to identify or required to choose the probable shortest path among the thousands of available paths. It has been an important optimization technique in computer science and operational research which use Swarm Intelligence (SI) which is initially proposed by Marco Dorigo in 1990. This algorithm is based on the behavior of ants for seeking between their host location to the food location. Later on, the study on the algorithm extended and now it has become one of the best optimization tool available to find out the shortest path between two points in a system that needs to passing through many sub-point [1], [11].

1.3. Our Contribution

We have used AA to optimize the routing distance between the cluster head to the destination. Here we have taken the cluster in the form of SWASTIKA which follows its own rule to send traffic to the cluster head inside the cluster. We have implemented the whole network model in MATLAB and realized the optimized path deduced from the AA, we have implemented both swastika routing and Ant-colony to reduce the power consumption of the whole network so that we could able to increase the lifetime of the network.

2. LITERATURE SURVEY

Many researchers have been working on the routing techniques in WSN and have been designed different topology of cluster where their prime aim is to minimize the TPC and APC of the network and cluster respectively, so as to minimize the power consumption of the system by retaining fixed battery power of the node, which in total enhance the network lifetime. Here we have cited some surveyed paper which is related to our work.

Marco Dorigo and Christian Blum [1], both have surveyed about the Ant colony optimization where they have told the history and evolution of AA and how it has been a novel technique for the difficult combinatorial task which needs to be optimized. And they have also found the relationship between AA and other methods available for optimizing. In the paper of Jiajia He and Zaien Hou [2], both have given a better explanation regarding AA where they have implemented the said algorithm for traffic signal time optimization. They have done the both analysis part of AA i.e. one uncertainty and another convergence analysis. They have compared it with the existing algorithm present, webstar algorithm, genetic algorithm where they have found AA is simple and is the best method to optimize the traffic timing problems. In advance to that Chen ling et al. [3], explained how AA can be used for the big parallel processor and how the well-known traveling salesman problem can be applied convergence analysis. Adding to that, AA has been using for continuous optimization and have done by Tianjun Liao and his research team[4]. We then found the AA application in network field, the paper by Gurpreet Singh and his team[5] have done a review on application of AA in mobile ad-hoc networks. In this paper, they have said that in a network like MANETs which can be established at any time without any prior centralized administration, AA will give a better result as they are following Swarm intelligence, which is best for this type of temporary huge network. To maximize network lifetime different research has been done, optimization in routing is one of them. Francesco Carrabs et al. [12], they have able to maximize network lifetime by developed an approach which is based on column generation algorithm which can be solved by genetic and ILP algorithm. In this paper, they have found that by using genetic algorithm they could able to speed up the process with minimal time. The research done by Shu Li and Jeong Geun Kim [13] is another paper addition to maximizing network lifetime where they have done it with constructing a Markov chain model and get a closed form expression for RF and DF respectively. Where they have analyzed the different random forwarding scheme and which is outperforming over which scheme.Manas R. Mallick and Jagamohan Padhi [14], both succeeded to form a network model and have developed routing techniques by which they could able to maximize network lifetime. They have developed CGNT model which is basically based or collective form of CCGNT and

MCGNT. R. K. Guha et al. [15], the team has given an idea of fair coalition routing and for that routine he has used the Dijkstra algorithm to find the next node to send the traffic. K.Das et al.[16], proposed new techniques to route the traffic by selecting few nodes and by excluding the high loaded node, in which he could able to increase the network lifetime by reducing the variance of the power of the network.

3. MATHEMATICAL POWER MODEL

The ant-colony algorithm is inspired by the ants' behaviors of finding foods for them from nature. Pheromone is a kind of hormone present in every organism so as in ant, which they use to lay during the search of their food which can be sensed by the other ants of the colony, from which they could also able to identify the strength of the pheromones. Ants generally follow the path having a high density of pheromones, the stronger pheromones path has been chosen by the incomers. This algorithm uses a positive feedback that different individual information transmitting and receiving works in collaboration to get the outcome [1], [11].

In '*m*' ants in '*n*' cities, each ant will choose a city. In time *t*, the probability $p_{ij}^{k}(t)$ of the ant '*k*' from city '*i*' to choosing city '*j*' as the target city is

$$P_{ij}^{k} = \begin{cases} \dfrac{\tau_{ij}^{\alpha}(t)\eta_{ij}^{\beta}(t)}{\sum \tau_{ij}^{\alpha}(t)\eta_{ij}^{\beta}(t)}, & j \notin allowed_k \\ 0, & \text{otherwise} \end{cases} \tag{1}$$

In this formula, τ_{ij} is ant 'k' does not reach to chosen city with certain strategy, refreshing the pheromone strength. 'α' is the relative importance of the residual information. 'β' is the relative importance of the expectation. η_{ij} is the inspiration information from city 'i' to city 'j'. $allowed_k$ is the collection of cities which ant k allow to access [1], [6], [11].

$$\eta_{ij} = \frac{1}{d_{ij}} \tag{2}$$

Where d_{ij} is the distance between city 'i' and city 'j'.

The residual information is too much, that why to avoid this submerge the inspired information is essential to update as residual information. Updating the pheromone concentration is [8], [13].

$$\tau_{ij}(t+n) = \rho \times \tau_{ij}(t) + \Delta\tau_{ij} \tag{3}$$

In above formula, $\Delta\tau_{ij}$ is the strength of pheromone which information by ant 'k' is visits on the path city 'i' to city 'j' at time 't' to 't + n'. $\rho(\rho < 1)$ is the reservation of the residual information $1 - \rho$ is the reduction of the residual information.

$$\Delta\tau_{ij} = \sum_{k=1}^{m} \Delta\tau_{ij}^{k} \tag{4}$$

$$\Delta\tau_{ij}^{k} = \begin{cases} \dfrac{Q}{d_{ij}}, & \text{if ant } k \text{ goes through } ij \\ & \text{at time } t \text{ to } t+1 \\ 0, & \text{Otherwise} \end{cases} \tag{5}$$

The AA of the WSNs basically built with three stages; 1. Initialization, 2. Cluster Construction, 3. Inter-cluster routing and routing maintenance [11].

3.1. Initialization

To make aware of the hops between the cluster nodes and the sink, and to know about the topology of CH, we need to make inform to the sink node first. For the initially the sink send a query message to all nodes , in reply all nodes send back the energy and distance from sink information back to the sink. By which each node able to know the neighbored node's distance and power information [11].

3.2. Cluster Construction

After initialization, sink knows about the number of nodes of the network, a total number of the energy of the network and the average energy of the network [11].

The total number of energy of the network is;

$$E_{total} = \sum_{i=1}^{n} E_i \tag{6}$$

Where 'E' is the energy consumption of each node of the network and 'n' is the number of node in the network.

The average energy consumption is;

$$E_{average} = \sum \frac{E_{total}}{n} \tag{7}$$

In each sensor, the energy consumption 'E' is calculated as the during of transmission in WSNs is directly proportional to d^α. Where d is the distance between two nodes in the wireless network and α is depend on the environment condition which value is $2 \leq \alpha \leq 6$. A α value is 2 for the small distance of two nodes or free space model and α value is 6 for the long distance of two nodes or shadowing model. Here α value is 4, has been taken as constant. Each sensor node has a finite range of transmission and obeys flow of balance condition to transmit data [14], [15], [16].

$$E \,\alpha\, d^\alpha$$
$$\Rightarrow E = K \times r \times d^\alpha \tag{8}$$

Where k is constant which value is 1 and r is the rate of outgoing traffics of each sensor node. The rate of Incoming Traffics + Rate of Origination Traffics = Rate of Outgoing Traffics. Let K = 1, $\alpha = 4$, $E = K \times r \times d^\alpha$.

Unit of Energy consumption is

$$E = (\mu W/M\ bit \times m^4) \times (Mbps) \times (m^4) = \mu W/sec$$

Yulong Shen et al. [11] have been proposed a model in Clusters Construction of network nodes are uniformly and heterogeneously distributed of 25 numbers of nodes in a square from. In this network of nodes, 'A' is the Cluster Head. All nodes have limited power source and limited range of transmission data using ant colony algorithm routing from source node to neighbor node until the data packet transmits to Cluster Head at the same distance.

Each node generated 1*Mbps* of data traffic. The distance is calculated by two processes, one is orthogonal path and another one is diagonal path. For example, in fig. 2 the orthogonal path is node-3 to node-8, the calculation of energy consumption 'E' is $1m^4$ and the diagonal path is node-1 to node-7, the calculation of energy consumption 'E' is $\sqrt{2}m^4$.

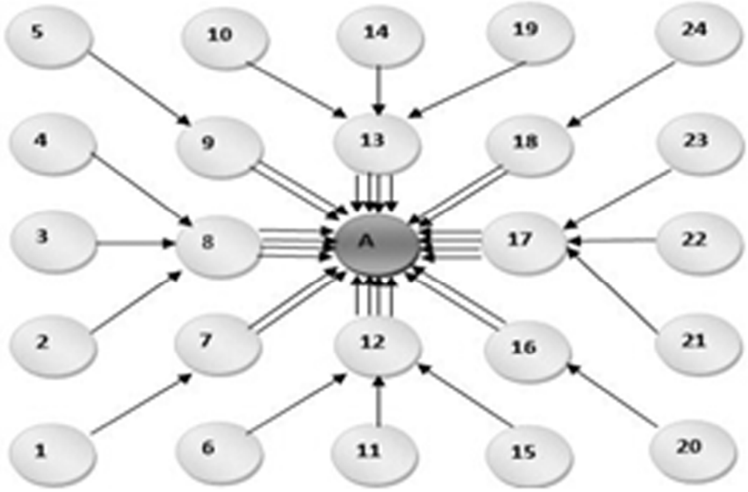

Figure 2: Clusters Construction of ACR model

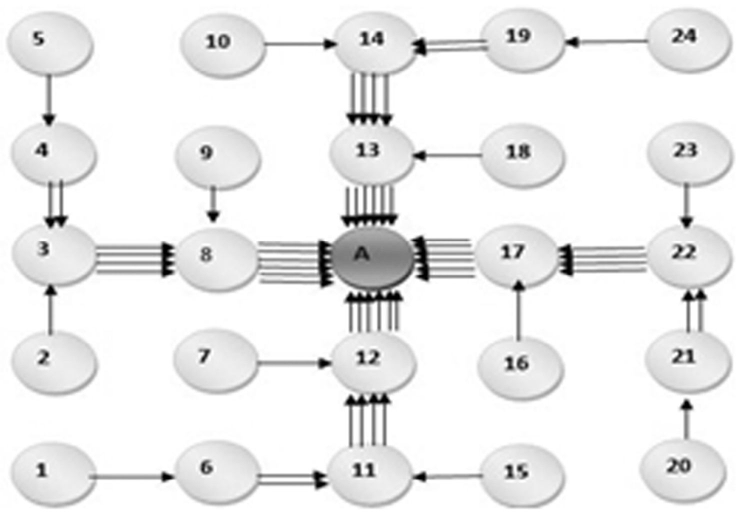

Figure 3: Cluster construction using swastika of SACR model

For example, in the orthogonal path between two nodes calculated as $K = 1$, $\alpha = 4$, $d = 1m^4$, $E = K \times R \times d^{\alpha}$ the energy consumption 'E' is 1 μW/Sec. In the diagonal path between two nodes calculated as $K = 1$, $\alpha = 4$, $d = \sqrt{2}m^4$ $E = K \times R \times d^{\alpha}$ the energy consumption 'E' is 4 μW/Sec.

In our apposed model using SWASTIKA, the network of cluster construction taking same numbers of 25 nodes distributed uniformly and heterogeneously in a square form in fig. 3.

3.3. Inter-Cluster Routing

In a network, each node has a routing table. This table records information about the link between it and its neighbors' nodes. In the network of the node as selected as a cluster head, it's declared about competency and other candidate of nodes will check the routing table of record about this competency. If the table does not maintain a new record then it will be created. This new record will have maintained as the residual energy of the neighbor competitive node, its location, and the pheromone concentration on the link. Otherwise, this record is updated about the neighbor node [11].

Inter-cluster routing depends upon the pheromone concentration on the link. When the link translates data and decreases over time, the pheromone concentration on the link is increased. ACR update periodically the pheromone concentration on the link between cluster heads. The method updates or creates the pheromone concentration between cluster head ch_i and cluster head ch_j.

$$\tau_{ij} \leftarrow (1-\rho)\tau_{ij} + a \times energy^{\alpha} + l^{\beta} \tag{9}$$

Where ρ is the amount of pheromone concentration volatile. 'a', 'α' and 'β' are system parameters. '*l*' is the distance between the cluster headers [11].

The pheromone concentration holds the pheromone during data translating and takes the energy of the neighbor cluster heads. Using the TDMA mechanism, cluster head from the inner cluster node are data transmitted. The cluster head is responsible for fusing data to reduce redundant data and communication traffic. When each cluster head transmits data, it computes the probability of routing table of each nearest cluster head to select according to the pheromone concentration. The probability of cluster head to cluster head is [11];

$$\rho_{ij} = \frac{(\tau_{ij})^{\beta 1}}{\sum_{j\varepsilon N} (\tau_{ij})^{\beta 1}} \tag{10}$$

Where N is set of cluster heads, 'β1' is explore action, a small 'β1' is the probability of neighbor nodes is closed and higher explore capability, a bigger 'β1' is the probability of neighbor nodes is greater different and poorer explore capability.

In fig. 4 the WSNs construct number of clusters, in that cluster of the nodes with more energy to be selected as a cluster head and cluster heads are distributed uniformly. Each cluster has the same number of nodes.

4. IMPLEMENTATION

We have implemented our proposed network model SACR in MATLAB and part of its also simulated in C programming language, to implement whole network model we have sectioned the whole simulation into two parts, first, one is to implement for intra- cluster of SACR and another with AA for inter-cluster SACR.

In table 1, we have calculated the energy consumption of each node of the ACR network model as shown in fig. 2 which is an example of one of the clusters of the total network. The total number of energy consumption is equal to100 μW/sec, which we can treat as the conventional routing model.

In our proposed SACR model as shown in fig. 3, we have calculated the each node power consumption as well as the TPC and APC for the said network which has been tabulated in table no. 2.

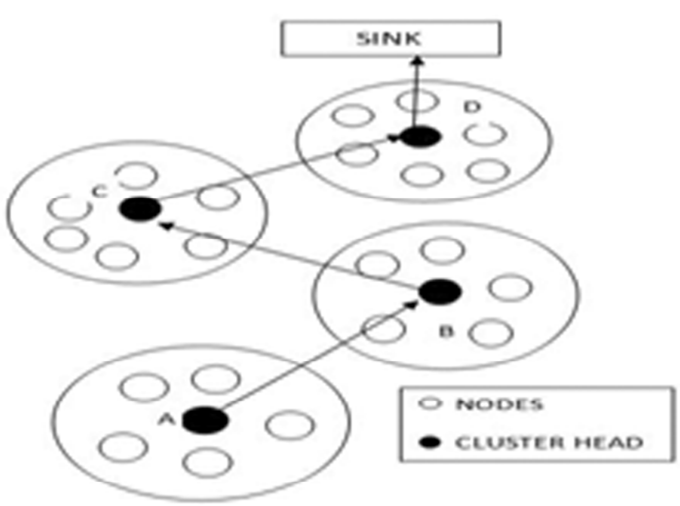

Figure 4: Inter-cluster routing model of WSNs.

Table 1
The power consumption of cluster ACR model

Nodes No	*Energy Consumption (E)*	*Node No*	*Energy Consumption (E)*
1	4	13	4
2	4	14	1
3	1	15	4
4	4	16	8
5	4	17	4
6	4	18	8
7	8	19	4
8	4	20	4
9	8	21	4
10	4	22	1
11	1	23	4
12	4	24	4
Total number of Energy Consumption is 100			

Table 2
Power Consumption of cluster SACR model

Nodes No	*Energy Consumption (E)*	*Node No*	*Energy Consumption (E)*
1	1	13	6
2	1	14	4
3	4	15	1
4	2	16	1
5	1	17	6
6	2	18	1
7	1	19	2
8	6	20	1
9	1	21	2
10	1	22	4
11	4	23	1
12	6	24	1
Total number of Energy Consumption is 60			

In table 3, We have tabulated the optimal distance after simulating AA between each CH to Destination, likewise, we have got 8 optimal distance for our proposed model, as it is holding 9 swastika cluster, where the centre of each swastika cluster after first round of sending traffic holding the maximum power, hence treated as the Cluster head (CH).

In Table 4, we have tabulated the hoping distance between the CH and the destination node by using Swastika routing (S-routing), where we have allowed sending traffic only in the orthogonal path to reduce power consumption and is been the best so far in context to total power consumption.

TPC and APC has been calculated by using the above said formula for both models, first column is TPC using Ant-colony Algorithm model and another one is for S-routing model and it has been tabulated in

Table 3
The shortest path finding between cluster heads and destination using AA in total network

Source to Destination	*Path*	*AA-Distance*
S1-D	S1-S5-S9-D 7.07+7.07+5	19.14
S2-D	S2-S5-S9-D 5+7.07+5	17.07
S3-D	S3-S6-S9-D 5+5+5	15
S4-D	S4-S8-S9-D 7.07+5+5	17.07
S5-D	S5-S9-D 7.07+5	12.07
S6-D	S6-S9-D 5+5	10
S7-D	S7-S8-S9-D 5+5+5	15
S8-D	S8-S9-D 5+5	10
S9-D	S9-D 5	5

Table 4
The shortest path finding between cluster head and destination using conventional S-routing

Source to Destination	*Path*	*S-Distance*
S1-D	S1-S2-S5-S8-S9-D 5+5+5+5+5	25
S2-D	S2-S5-S8-S9-D 5+5+5+5	20
S3-D	S3-S6-S9-D 5+5+5	15
S4-D	S4-S5-S8-S9-D 5+5+5+5	20
S5-D	S5-S8-S9-D 5+5+5	15
S6-D	S6-S9-D 5+5	10
S7-D	S7-S8-S9-D 5+5+5	15
S8-D	S8-S9-D 5+5	10
S9-D	S9-D 5	5

Table V. From the result it is very much clear that that the simulated results of APC and TPC for AA-routing to find the CH in sample WSN is very less than of all other models, here we have compared it with the so far best routing model i.e. Swastika model.

The total network has been divided into 9 section, where each section is a cluster with cluster head defined as the highest power resource which is the center of the swastika model, which are as; S1, S2, S3, S4, S5, S6, S7, S8, S9. The traffic we need to transfer to the sink, so each node will send traffic to the CH and each CH send the traffic to the sink node and the path is decided by an ant-colony algorithm.

In fig. 7, we have drawn the result of the simulation, where it is clearly visible that with using AA routing to find the shortest distance between the CH and destination, resulting with a lower TCP and ACP as compared to the competent Swastika routing. The figure is drawn from the tabulated value of power consumption of two models in Table 5.

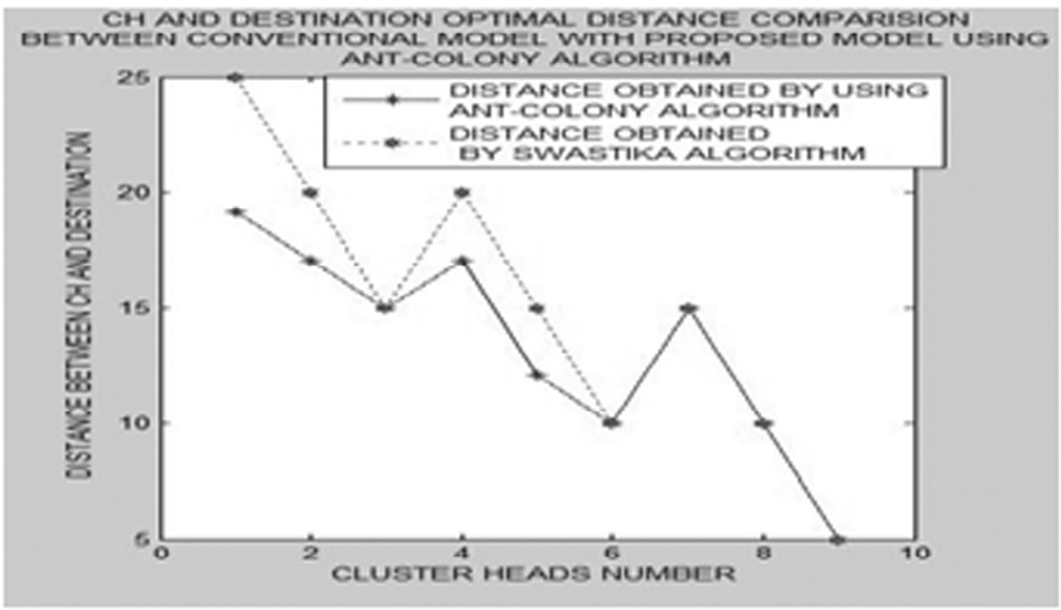

Figure 5: Comparison graph between the shortest path found by S-routing and using AA- routing

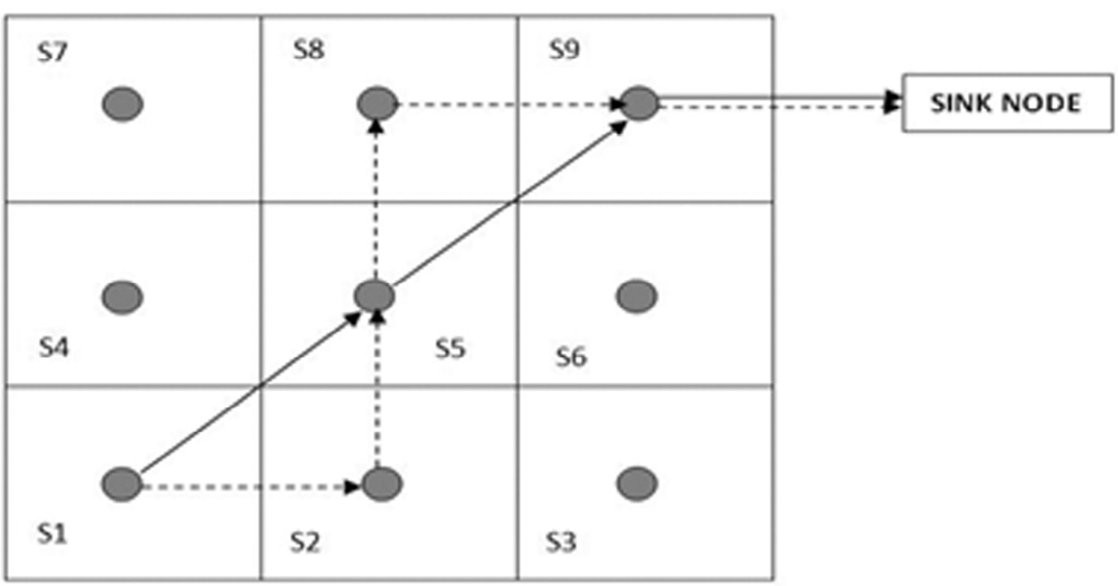

Figure 6: The whole network implementation where The dense-line is the AA routing and the dash-line is for S-routing

Table 5
TPC and APC for both AA_routing model and S- routing model

Nodes No	*Energy Consumption(AA) (E)*	*Energy Consumption(S) (E)*
S1-D	172506.5	250000
S2-D	187424.5	156250
S3-D	93750	93750
S4-D	140587.3	156250
S5-D	93712.26	93750
S6-D	46875	46875
S7-D	93750	93750
S8-D	46875	46857
S9-D	15625	15625
TOTAL ENERGY	891105.5	953125
AVERAGE ENERGY	99011.73	105902.8

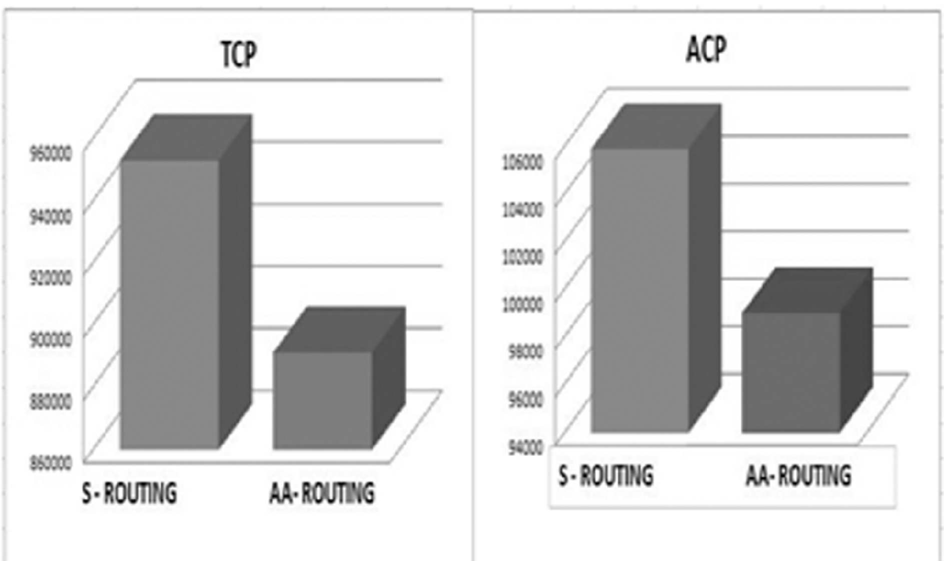

Figure 4: ANT COLONY algorithm based TCP and ACP comparing to conventional routing model (Swastika routing)

5. CONCLUSION

We have simulated a whole network and have used Ant-colony algorithm to find the optimal distance between each cluster head to the destination node which we found from the simulated results are minimum as compared to other shortest path forecasting methods. As a result of which the total power consumption of the network and the average power consumption per cluster head we have found is coming less compared to other models which ensure that our proposed model with AA routing will last for longer, in other word the network lifetime can be maximized using AA algorithm.

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