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Biologically Inspired Energy Efficient Routing Protocol in Disaster Situation

Shankar D. Chavan, Amruta S. Thorat, Monica S. Gunjal, Anup S. Vibhute, and Kamalakar R. Desai

***Abstract*—Wireless sensor network (WSN) plays a crucial role in many industrial, commercial, and social applications. However, increasing the number of nodes in a WSN increases network complexity, making it harder to acquire all relevant data in a timely way. By assuming the end node as a base station, we devised an Artificial Ant Routing (AAR) method that overcomes such network difficulties and finds an ideal routing that gives an easy way to reach the destination node in our situation. The goal of our research is to establish WSN parameters that are based on the biologically inspired Ant Colony Optimization (ACO) method. The proposed AAR provides the alternating path in case of congestion and high traffic requirement. In the event of node failures in a wireless network, the same algorithm enhances the efficiency of the routing path and acts as a multipath data transmission approach. We simulated network factors including Packet Delivery Ratio (PDR), Throughput, and Energy Consumption to achieve this. The major objective is to extend the network lifespan while data is being transferred by avoiding crowded areas and conserving energy by using a small number of nodes. The result shows that AAR is having improved performance parameters as compared to LEACH, LEACH-C, and FCM-DS-ACO.**

***Keywords*—WSN;ACO; AAR; path optimization; efficient routing**

I. INTRODUCTION

THE Wireless Sensor Network (WSN) is a network that is primarily used to gather data from the deployed network area, which is received in the form of data packets. The WSN is intended for monitoring an environment. WSN networks are meant to sense the analytical data and collect it based onevents such as attackslikea Blackhole, Wormhole, Malicious node, etc. In WSN queue mechanism is adopted which is used for the transmission of the data packets [1]. If a heavy traffic load condition occurs, then the queue handling capacityofthe sensor node is not efficient which may cause a data queue overflow in the sensor nodes. So that efficiency and reliability in the transmission of data cannot be obtained.

The sensor nodes create the energy hole in the routing path, this is then created by multiple hops operation which is based on relaying the data packets [2].

Because of these energy holes, the lifetime of the wireless sensor networks is greatly reduced. WSN network has some limitations as well such as less storage capacity (use of microprocessor and controllers limits some memory constraints), slow operational speed, battery constraints, etc. as it performs complex operations to deal with events that are not paradigm to the natural behavior of thesystem. Butthe behavior of WSN also made available some facilities for researchers, like low cost, doesn't require much power as sometimes they are battery-operated and able to do multiple functions at one time. As the use of the battery is not always able to provide an advantage because it is not easy to change the battery in the nodal network area, this is achallenging task for researchers to find out solutions over it but some research has been done like the use of lithium battery, use of the solar operated battery,etc [3][4].

A wireless network thatconsistsof several nodes can provide an idealized network when network is formed in a "Cluster Head (CH)" manner, in which distributed nodes are trying to find out which node is closer to the destination node(CH) and collects all necessary data from neighboring nodes and process it and makethesimple task for other nodes as they will not be longer part of the network and helps to saves network energy [5].

Military Applications at the battlefield sincerely and very carefully make use of the WSN network as regular time and precisely delivery of information contained packet data is needed within a small interval of time [6].

Different kinds of attacks on the nodes may cause disturbance in the packet transmission and data may be lost through the affected node. Therefore, for secure transmission, it is necessary to detect the attack on the WSN node and retransmit the lost data [7].

In this paper, for disaster management in WSN we have used the ACO algorithm to find the secure path through which data packets can be sent to the nearest base station efficiently. Also, we have simulated the black hole attack on the network. If black holeattacksaredetected then it retransmits the packets to the base station through another optimized path obtained from the ACO. The flowchart of the proposed system is shown in figure 1.

Dr. Shankar D. Chavan, Amruta S. Thorat, Monica S. Gunjal and Dr. Anup S. Vibhute are with Dr. D. Y. Patil Institute of Technology, Pimpri, Pune, (M.S.), India (e-mail: shankar.chavan@dypvp.edu.in, amruta.thorat@dypvp.edu.in, moinca.gunjal@dypvp.edu.in and anup.vibhute@dypvp.edu.in).

Dr. Kamalakar R. Desai is with Bharati Vidyapeeth College of Engineering, Kolhapur (M.S.), India (e-mail: kamalakar.desai@bharatividyapeeth.edu).

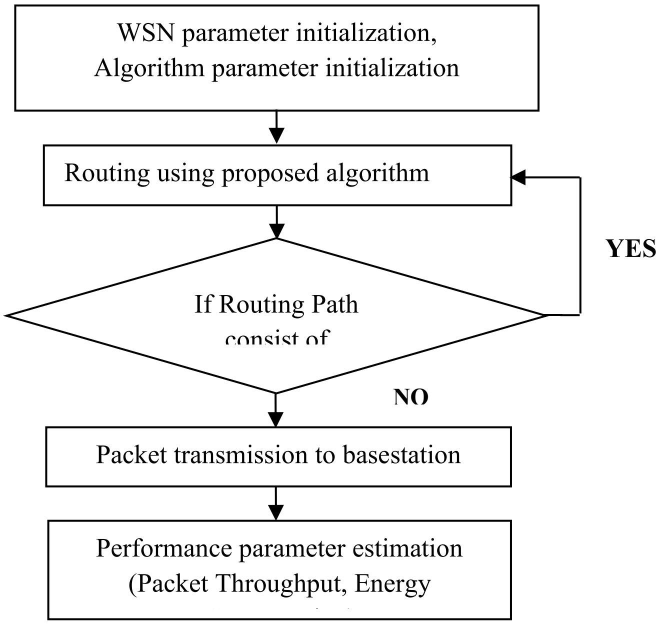

Fig. 1. Flowchart of WSN

The major contributions of the proposed research article are-

- Implementation of the energy-efficient bio-inspired algorithm for the WSN routing in disaster conditions.
- Implementation of black-hole attack detection and rerouting in WSN.
- To investigate the performance of the proposed network based on different network parameters which strengthen the network lifetime, energy efficiency.

This paper begins with a brief introduction of the wireless sensor network and attacks on the wireless sensor network. The rest of the paper is organized as follows. Section II gives an extensive literature survey on WSN routing and ACO. Section III describes the ant colony optimization algorithm. Section IV presents the experimental results carried out using different network and ACO parameters. Section V concludes the paper and gives the future scope of the work.

II. LITERATURE SURVEY

In the year 2020,Valanto Alappatt [8] works on increasing network lifetime by a hybrid protocol named Ant Colony Optimization and Binary Particle Swarm Optimization (ACO: BPSO). The proposed protocol is energy efficient protocol to route in MANET(Multi-Path network).They tested all network parameters such as throughput, residual energy, PDR on the NS-2 simulator and compared results with others to show proposed protocols enhancement and efficiency. The proposed algorithm shows tested results outperformingsimilar to AVDO and ACOALEEP.

In the year 2020, K. Shailesh [9] proposed an article to select a minimum hop routing path from the complex network.The proposed research has further works in the future enhancement of energy consumption. Also proposed article has been tested and shows it requires more time to find the minimum hop path. In a year, 2019, S. Roni [10] perform work on the data clustering method, which usually helps to gather information through books or news. As newspapers and books haveatag for each information, hence it is easy to categorize all information with the proposed algorithm.The proposed article works on grouping news based on their similarity.

In the year 2019, HE Fa-mei [11] works on the renewal strategy of residual pheromones and the route selection strategy. They proposed an improved ACO algorithm to solve the time-dependent road networks' (TDRN) intelligence problem. They compared their result with other intelligence techniques and showed how their research works efficiently. Research also states that the optimal path has lower travel time consumption, In the year 2018, Mojgan Rayenizadeh [12] perform work on selecting Cluster Head (CH) using hesitant Fuzzy logic in (WSN). In this paper,theclustering technique is provided and analyzed to solve the energy consumption problem in WSN. In this study, a hesitant fuzzy method with three input parameters namely, remaining energy, distance to the BS, distance to the center of the cluster is proposed for efficient cluster head selection in WSNs. We define different scenarios and simulate them, then investigate the results of simulation. In the year 2018, Jusik Yun [13] perform work on secure routing in a centralized-based wireless network. Wireless sensor network-facing some challenges due to the presence of various attacks in the wireless network because of this data packets get dropped. To get prevent such network attacks, this letter provides a centralized trust-based routing scheme (CSR) for the WSN network.

In the year 2018, Raghunandan G. H., Dr. A. Shobha Rani [14] proposed their research on Routing algorithms to increase the overall efficiency of the wireless network. In which work is carried out by using centrality-based approach Wireless sensor network communicate with each other by transmitting data between them and elect the head of the cluster group, this technique that helps in energy conservation. In 2016, Pradeebaa and Lavanis [15] said that using their technique while a WSN is in sleep mode might extend network lifespan. They use a one-dimensional (1-D) network to do this and seek ways to save energy while routing data. To extend the lifetime of a WSN's network, routing protocols should not employ all of the network's nodes; instead, they should use the bare minimum. As a result, relay node selection is critical for energy savings. They employ two primary techniques to reduce energy consumption in this paper: energy saving via opportunistic routing algorithm (ENS-OR) and geographic random forwarding algorithm (GeRaF), as well as sleep mode. They demonstrate that using sleep mode enhances network performance.

III. ANTCOLONYOPTIMIZATION

Nature can react against the events they probably accept or makes changes in itself, this ability to livethings from nature such as Insects, Swarms, Ants, Bees,etc. inspired us to adapt to changes according to the requirements of specific conditions. The natural behavior of ants can search for food in the best banner so that they collect their food and remember that best path which is best efficient to reach towards destination. With this, they updated their path with a special kind of liquid in them called "Pheromone" and periodically updated the path with such path by Ants other Ants get to know which path is easy to reach food and other Ants also follows the same path, example of such path is shown in figure 2. More the density of path by following the same path by other Ants, the same path will be treated as optimal path to reach the destination. The algorithm which is developed by observing the basic behavior of Ants Colony firstly proposed by M. Dorigo in 1992 and such an algorithm is named as "Ant Colony Optimization" algorithm. With the help of some probabilistic and linear equations, based on the position (localization information) of each node we can find the minimal distance between the two nodes in the environment/network.

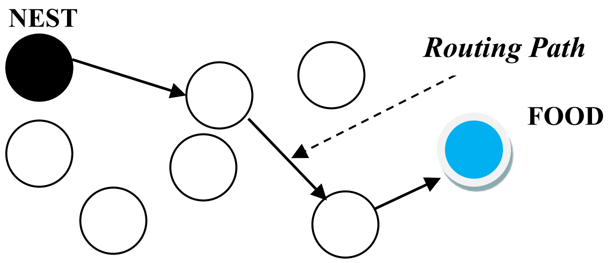

Fig. 2. Ants Finding an Optimal Path towards end Node

Described algorithm-generated some artificial ants which are idealized and initialized with Real Ant parameter such as Ant Colony(number of ants), initializing pheromone, evaporation rate and another parameter that are useful to make advancement in the proposed algorithm. From figure 1. Ants are supposed to find the optimal path which is directed towards the destination we consider it as *food* and source node as a *Nest.*

IV. ARTIFICIAL ANT ROUTING (AAR) ALGORITHM

A. Forward and Backward Ants for Creating Solution

While implementing the ACO algorithm,the working behavior of ants is described in two modes, Forward (*FAnt*) and Backward (*BAnt*) Ants. Severalants are distributed in different paths and travel from *Nest* to *food*, accounttheir role intocollecting necessary information such as distance between two nodes, number of hops during the whole path they required to reach the *food* and same Ants travels back with all information works in Backward mode *(BAnt*) providing optimal solution based on collected data. *FAnt* can determine and remember the different paths they travel while searching for food, this is called a *deterministic nature* of real Ants.

B. Evaporation of Pheromone

The ideal scenario happens while building an algorithm, we observed that for every trial of experiments there is a noticeable reduction in pheromone value and it is a certain thing that Ants uses this value to update the path (Increasing density of path) like Ants loses their Pheromone amount while updating the path. The evaporation rate is stimulated by the use of an already defined rule for Evaporation. [16]. The flowchart of the proposed AAR algorithm is shown in figure 3.

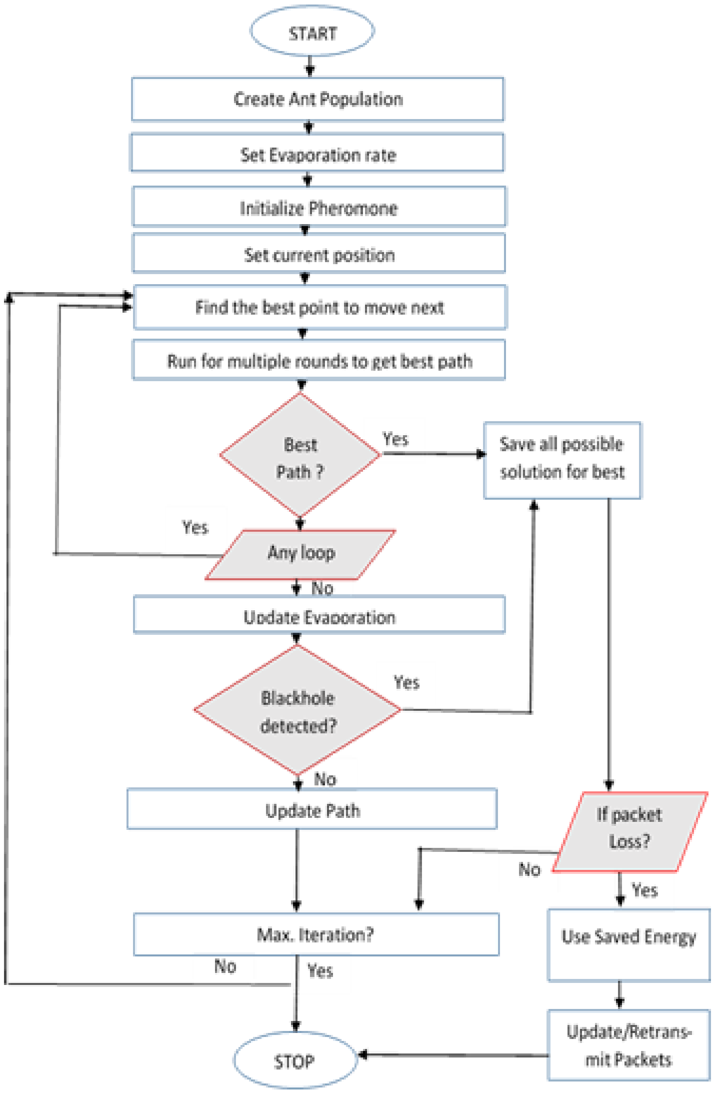

Fig. 3. Proposed AAR Flowchart

The initial pheromone is generated using equation 1,

$$tauo = \frac{10*Q}{nVar * Dmean} \tag{1}$$

where tauo is the initial pheromone, Q is taken as 1, nVar is several ants, Dmean is the mean distance of all the nodes.

The ants are selected randomly using the Roulette wheel algorithm. The pheromone is updated using equation 2.

$$tau = tau + Q/Cost_{new} \tag{2}$$

The natural phenomenon has evaporation of pheromone due to heat and environmental conditions. Here we are considering the evaporation rate of pheromone as given in equation 3,

$$tau=(1\text{-}rho)*tau \qquad (3)$$

where, rho is evaporation rate, and tau is updated pheromone. The cost of a path is selected as the number of hops traveled in the ant path. If the path cost is less than the previous path then the best solution is replaced by a new path cost as shown in equation 4.

$$Cost_{best} = \begin{cases} Cost_{new} \ , & if\ Cost_{new} < Cost_{old} \\ Cost_{old} \ , & otherwise \end{cases} \qquad (4)$$

V. EXPERIMENTAL RESULTS

For the simulation of system implementation, MATLAB software has been used. This tool is a higher-level technical and scientific programming language that is capable of visualization and faster computation. The software tool has strong software library package tools which perform higher numerical computational problems and visualize their results. It has several built-in numerical-functional solutions which help to analyze and implement the actual behavior of the system. These solutions can be used to provide an environment for network designerwho works for broad range communication, also for a linear system, matrix problems, differential equation, signal processing, nonlinear system, it has a solution over thousands of problems which makes system implantation easier. For the implementation, the WSN and ACO parameters are given in Table I.

TABLE I
IMPLEMENTATION DETAILS

WSN PARAMETERS	
Number of WSN Nodes	50, 100,200,300 etc.
Area of Simulation	1000 m x 1000 m
Initial Energy of Node	0.1 J
Range	200 m
Transmission power dissipation (ETX)	50 nJ
Receiver Power Dissipation (Eelec)	50 nJ
Amplification factor for free space(efs)	1.0×10^{-12}
Amplification Factor for multi path (amp)	1.3×10^{-12}
Number of bits per packet	500
ACO PARAMETER	
Number of ANTs	100
Number of iteration	100
Pheromone Exponential Weight (alpha)	1
Heuristic Exponential Weight (Beta)	1
Pheromone Evaporation rate (rho)	0.05

For the implementation, the position of the base station is kept at the center of the simulation area considered for the wireless sensor network as shown in figure 4. Normal WSN nodes are shown by empty circles and nodes which are affected byblack hole attacks are shown by black circles. The path obtained from the source node to the base station as a destination node is shown in figure 5. As in a disaster, it is necessary to send packets to the nearest base station, therefore the base station is taken as the destination node, and its position is kept at the center of the simulation area.

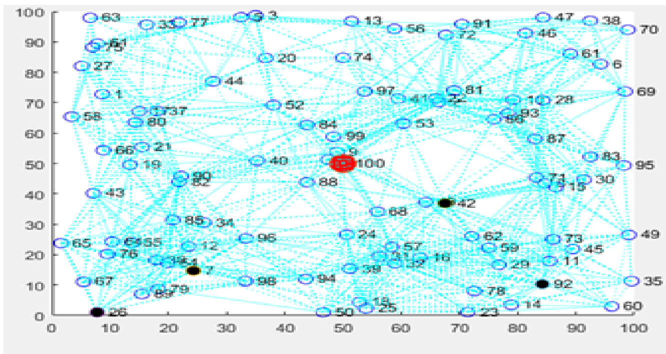

Fig. 4. Randomly Distribution of Nodes in WSN network

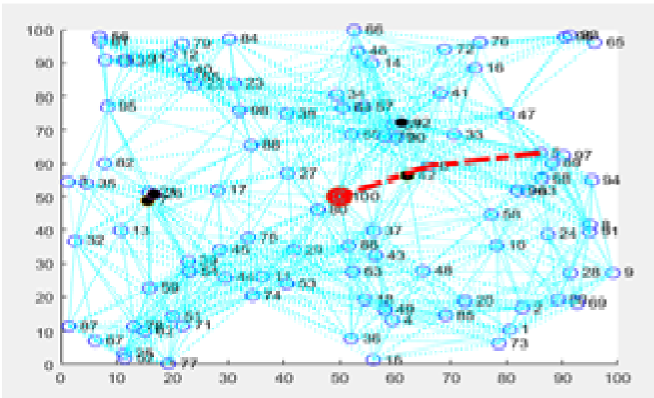

Fig. 5. The secure path from the source node to the base station

The total energy consumption for consumption of l bit data is given in equation 5.

$$E_{Tx} = \begin{cases} L * E_{elec} + L * E_{fs} * d^2, & if\ d < d_o \\ L * E_{elec} + L * E_{mp} * d^4, & if\ d \geq d_o \end{cases} \qquad (5)$$

Where L is the number of bits, ETx is the energy consumed for transmission of L bit, Efs is amplification factor for free space, Emp is amplification factor for the multipath channel, do is threshold distance, and Eelec is energy dissipated per bit. If the distance is less than the threshold distance, then less energy will be consumed than the distance which is greater than a threshold distance.

The total energy consumed for receiving L bit is given by equation 6.

$$E_{Tx} = L * E_{elec} \tag{6}$$

The performance of the proposed AAR algorithm is compared with LEECH [17], LEECH-C [18], and FCM-DS-ACO [19] algorithms based onanumber of live nodes per round, a number of dead nodes per node, residual energy, a packet transmitted to BS and packet transmitted to CH. The proposed algorithm shows a better network lifetime as given in Fig. 6-8.

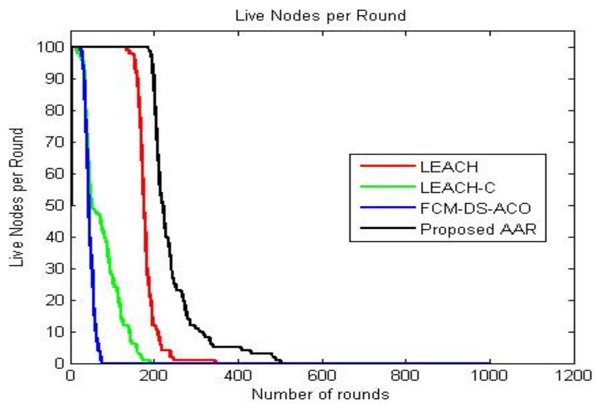

Fig. 6. Live Nodes per round

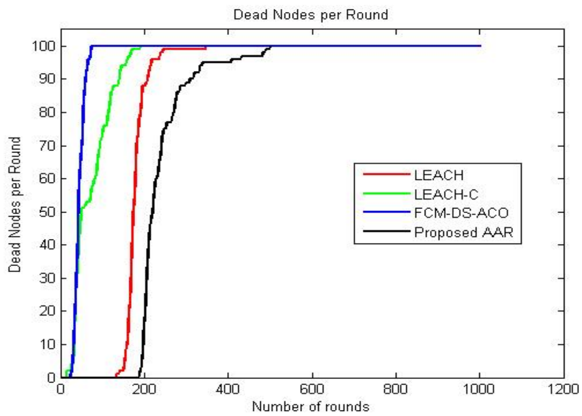

Fig. 7. Dead Nodes per round

The proposed algorithm shows longer network lifetime based on number of live nodes per round, number of dead nodes per round and residual energy per round. The self adaptability quality of AAR helps to save the energy and maintain the balance in the network. The residual energy dissipation in the WSN is given in figure 8, which shows that we can transmit the data till path node energy is greater than zero. In the transmission of the data packets, energy dissipates at the transmission and receiving the packets. The energy consumption depends on the distance between two nodes, amplification factor for free space and multipath, and on transmission and receiving energy factor. Respective algorithm utilizes these parameters and consumes some amount of energy.

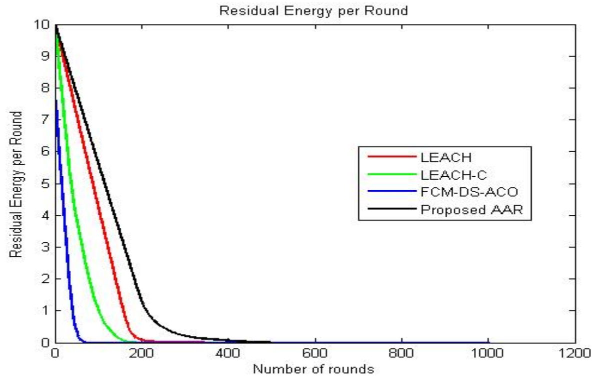

Fig. 8. Residual Energy per round

Packet transmission depends on the parameter such as number of node in the secure path, initial energy of the WSN nodes, number of bits in the packet etc. While transmission we have considered interference in the packet transmission, for that we have considered adaptive white Gaussian noise with 2 dB SNR. The packet transmitted to the BS and CH are represented in Fig. 9 and 10. In terms of delivering more numbers of packets more packets are gets affected by noise, but AAR performs much better in terms of noise as well.

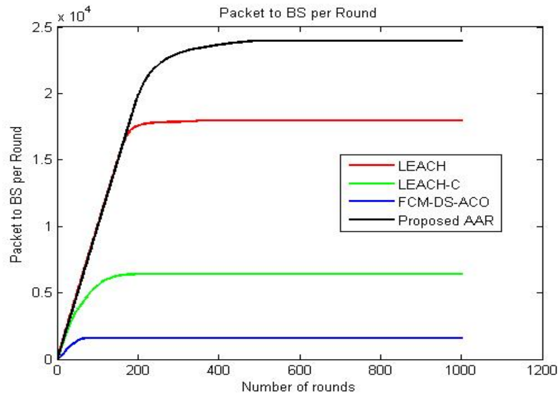

Fig. 9. Packet Transmitted to BS

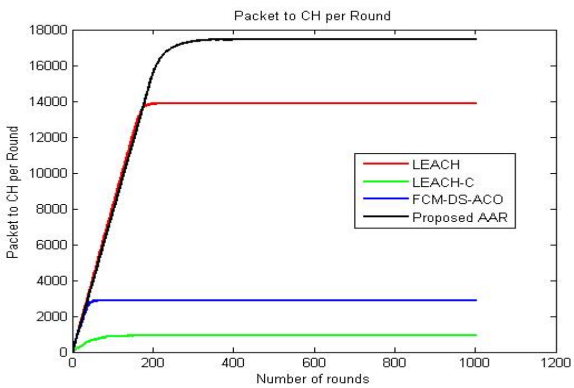

Fig. 10. Packet Transmitted to CH per round

While transmission we have considered interference in the packet transmission with respective of addition of Adaptive White Gaussian Noise with 2 dB SNR, hence there are some packets which get affected by AWGN noise and observed that 12.48% of noise parameter is affected on the transmission of packet delivery.

TABLE II
RESULT COMPARISON

Performance \Metrics	Energy (Joules / Round) Total Energy - Used Energy = Remaining Energy		Throughput $\frac{PacketsDilievere}{TotalPackets\ (2000 * 500Bits)}$	
LEACH	0.056		67.10	
LEACH-C	0.052		80.93	
PEGASIS	0.024		92.43	
FCM-DS-ACO (*referred*) [5]	0.0156		94.53	
Proposed Artificial Ant Routing (AAR)	**0.031**	**0.0231**	**92.71**	**98.41**

VI. CONCLUSION

In this work, we presented Artificial Ant Routing (AAR)Algorithmfor disaster management in WSN. This work analyses the problem in a complex network and builds solutions over them by use of the AAR algorithm. The suggested technique aids in the optimization of routing pathways, allowing for efficient multi-path data transfer and dependable communications in the event of node failures. We have simulated the routing in the presence of the black hole attack. If the black hole attack is found in WSN routing, then the data packets are retransmitted. From the experimental results, it is observed that AAR performs algorithm in case of disaster situation. In a comparative way network, parameter AAR Algorithm presents sustainable results in the case of energy consumption and packet throughput. As residual energy saved by AAR algorithm in presence of less number of packets (shown in table 2) i.e. up to 0.031Jand in highly generated packets residual energy saved is up to 0.0231J. When discussed packet transmission in presence of a less congested path and transmission between nearby nodes packet delivery is up to 98.41% and in heavily congested path packet transmission done is 92.71%.

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