ARTIFICIAL INTELLIGENCE AND ANT COLONY OPTIMIZATION BASED WIRELESS SENSOR NETWORKS TO MINIMIZE ENERGY OF NETWORK

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Abstract - The network lifetime, energy and packet loss are the major concerns in wireless sensor network. So for minimizing the energy of network and increasing the network lifetime, the ant colony optimization algorithm is proposed. Firstly, the proposed algorithm focuses on two parameters i.e. energy consumption and network lifetime. In Ant swarm algorithm, EAAR (Energy-aware ant-based routing) and ANTHOCNET (Adaptive nature-inspired algorithm for routing in mobile ad-hoc networks) protocols are used to minimize the energy of overall network and to follow the shortest path to reach the destination. These protocols are also used to find the number of dead nodes due to which packet loss reduces and network lifetime improves. Lastly, APTEEN protocol with threshold energy finds the number of dead nodes by draining threshold energy to 50% and with maximum energy cluster head is selected. Results of EAAR, ANTHOCNET, MMBCR, AODV, APTEEN and proposed protocol (APTEEN with threshold energy) are analyzed in which proposed algorithm shows better results than APTEEN protocol where energy consumption is optimized.

***Keywords*: Artificial Intelligence; ant colony optimization; wireless sensor network; network lifetime.**

1. Introduction

A wireless sensor network is the network of sensor node without wired communication between the nodes. A wireless sensor network (WSN) typically consists of a sink node sometimes referred to as a base station and a leaf node verbally expresses diminutive sensor node. The base station is surmised to be secure with illimitable available energy while the leaf nodes are surmised to be unsecured with inhibited available energy. The sensor nodes including cluster node, leaf node monitor a geographical area and capture data say Sensory information. The same information is communicated to the sink node through secure wireless mesh networks. To conserve energy this information is aggregated at intermediate sensor nodes say cluster head by applying a suitable aggregation function collected data across from the whole network. The intention behind aggregation is to reduce the amount of network traffic which avails to decrease energy consumption on sensor nodes. Providing data security to aggregate data in wireless sensor networks is also called as secure data aggregation in WSN. The wireless sensor networks stages such as node placement, network coverage, clustering, data aggregation and routing by using a genetic algorithm can be optimized. And by using ant colony optimization these stages gives optimized results with efficiency, accuracy, and speed. In Ant colony optimization, this ant swarm algorithm used for optimization of wireless sensor networks. And EAAR protocol is used to maximize the network lifetime and for data routing in WSN. Also, modified APTEEN gives the number of dead nodes by threshold energy drained to 50%.

Wireless sensor networks (WSN), sometimes called wireless sensor and actuator networks (WSAN), are spatially distributed autonomous sensors to visually examine physical or environmental conditions, like temperature, sound, pressure, etc. and to hand and glove pass their information through the network to the main location. The lot of trendy networks square measure bi-directional, conjointly facultative management of sensing element activity. The event of wireless sensing element networks was actuated by military applications like a parcel of land surveillance; these days such networks square measure utilized in several industrial and shopper applications, like process observance and management, machine health observance, and so on.

Wireless sensors are of low cost, so in many applications, they are not tampering resistant. It is composed of small, low cost, low power nodes. It is used for transferring data to the destination sink node without tampering. It is used to increase Packet Delivery Ratio (PDR) for real-time applications. It also decreases extra computation overhead for efficiency. In the wired network that- it has high costs for the communication between networks. The motivation from above concern is that the Wireless Sensor networks- kill the high cost of the wired network. Optimization of various stages of WSN can be easily optimized from artificial intelligence techniques.

2. Review of Literature

A literature survey or a literature review in a project is that section which shows the sundry analyses and research made in the field of your interest and the results already published, taking into account the various parameters of the project and the extent of the project.

A.H. Mohamed, K.H. Marzouk in 2015 focuses on energy consumption in WSN. The author explains about the genetic algorithm (GA), where it is used for optimizing the node deployment, node locations and dividing the sensor nodes into two form of operation that can minimize the energy consumption of the WSN. Recommended system has been applied for a simulated WSN used in the radiation discovering sites as proof of concept in industry standard [1]. The energy consumption is the major concern in WSN so to minimize the energy of network [6-7] explains about optimizing the energy consumption and the energy-efficient coverage in WSN by using the Genetic algorithm. All the issues of coverage, connectivity, and energy consumption are solved in [6-7]. But at the lower bound the performance is not optimal. Authors Mohammed Abo-Zahhad et al. [8] explains about network lifetime and stable period of WSN. GAEEP protocol is utilized to increment the reliability of clustering process. It is difficult to recharge the batteries due to network lifetime cannot be achieved.

Sneha More, et al. [3] focuses on optimization of WSN stages and also the energy consumption parameter. The author explains about the artificial intelligence techniques which optimizes the stages of WSN and for more accuracy APTEEN protocol is used. Ajit A. Chavan, et al. [4] focuses on energy consumption and throughput of the network. COAPs and COAPs+RPK protocols are used to compare energy and throughput due to which energy consumption of nodes, memory requirement, network response and authentication interoperability is efficient. Mininath Nighot et al. [5] explain about the GDCP protocol in which energy efficient routing is achieved using local communication among sensor nodes. The simulated results show the overall energy of network that is improved. This technique cannot be worked in a mobile sensor network.

Sohail Jabbar, et al. [9] focuses on the energy consumption of WSN. EASARA (Energy-aware simple Ant routing algorithm) improves the route discovery procedure and mainly concentrate on energy efficient forwarding node and route selection so that the network lifetime can be increased. In M2M, IOT, Cyber-physical systems this technique is not used so encryption method can be used. Authors Gurjeet Singh, Er. Karandeep Singh [10] explains about the modified APTEEN routing protocol. A modified clustering technique is introduced with a variable value of threshold energy for nodes to aggregate and transmit data is utilized. The variable value withal modifies the cluster head selection, where energy utilization is improved. The improvement in energy efficiency and lifetime comes at the cost of an increase in complexity of the protocol. This protocol cannot use in mobility.

Arati Manjeshwar, et al. [11] gives a detailed explanation of the APTEEN protocol. In APTEEN (Adaptive Periodic Threshold-sensitive Energy Efficient Sensor Network Protocol), when best features of both proactive and reactive networks combine then it provides periodic data collection as well as near real-time warnings about critical events. This protocol is mainly used for energy consumption of network. Ahmed M. Abd Elmoniem, et al. [12] concentrates on Load balanced multi-route AODV Ant routing algorithm. In MRAA strategy, data packets are balanced over discovered paths and energy consumption is distributed across many nodes through the network [12]. A load balancing technique to use the routes found by the well-known ant colony optimization technique which finds various disjoint routes between source and destination node[12].

Charles E. Perkins, et al. [13] explicates about Ad-hoc On-Demand Distance Vector Routing (AODV), a novel algorithm for the operation of such ad-hoc networks. Each Mobile Host operates as a specialized router, and routes are obtained as needed (i.e., on-demand) with little or no reliance on periodic advertisements [13]. Our incipient routing algorithm is quite opportune for a dynamic self-starting network, as required by users wishing to utilize ad-hoc networks. AODV provides loop-free routes even while rehabilitating broken links. A route to a destination may be returned by any intermediate node [13]. Link breakages are reported immediately, and routes are expeditiously re-established. Dormant routes are expeditiously aged out of the system because they are more liable to go stale. This technique cannot work in various interconnection topologies with fixed networks.

3. Problem Definition

To optimize the stages of wireless sensor networks i.e. node placement, network coverage, clustering, data aggregation and routing using a genetic algorithm for grid architecture and to overcome its limits the ant colony optimization algorithm is proposed. ACO can be worked on grid architecture for the balancing energy consumption and the proposed protocol is used to maximize network lifetime.

4. System Architecture

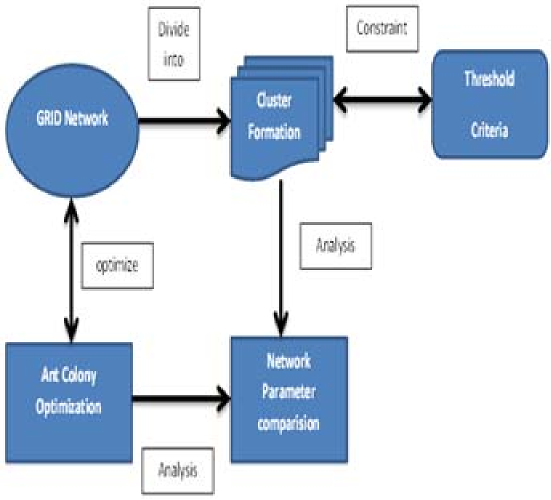

Fig. 1. Proposed System Architecture.

The system architecture of proposed work shown in Fig.1 is divided into 4 modules:-

1. Grid Network

In grid network, a number of a computer connected to each other with grid topology. Each node in the network is attached with a neighbor along with one or more measurements. Network frameworks, for example, FDDI utilize two counter-rotating token-passing rings will accomplish high reliability and performance. Done general, at an n-dimensional grid organize is joined circularly on more than you quit offering on that one dimension, those coming about network topology may be a torus, and the organize will be known as “toroidal”. At a number of nodes along every size of a toroidal network is 2, the coming about the system may be called a hypercube.

2. Cluster Formation

In this model, the grid network is divided into a number of clusters using the amount of energy of node as well as Queue size of the each node. Those nodes selected as Cluster Head node whose energy and queue size is greater than neighbor node. This is an existing system of the base paper which results in the amount of dead node, packet loss increases. That’s why; it defines a new constraint using threshold parameter.

3. Threshold Criteria

Here in this model, when cluster head energy is down to 50% so it will not reach zero energy value and number of the dead node with packet loss while cluster change will be minimized with our proposed system.

4. Ant Colony Optimization

The optimization techniques are performed and compared the proposed system with this mechanism which is as follows: An energy-aware routing protocol called as an Energy Aware Ant-based Routing protocol (EAAR) for wireless ad-hoc networks. This protocol includes the effect of power consumption in routing a packet and also gives the multi-path transmission properties of ant swarms so increases the battery life of a node. The algorithm used in this paper reduces energy consumption and discovers good path right from start. Here remaining power of the node is considered to help in reducing dead nodes. EAAR has parts like route discovery, route maintenance, and link failure. The AntHocNet algorithm is the inspiration for the basic structure of the path discovery mechanism but functionality is different. First, a source node s starts a communication with a destination node d, it broadcasts a reactive forward ant, says Fd. Initialize a “seen” set S of every node as NULL. To find a path between s and d, at each node, an ant is either unicast or broadcast; depending on whether or not the current node has to route information for d. journey information is stored in an array, J, which each packet maintains.

4.1. *APTEEN Protocol*

The APTEEN (Adaptive periodic threshold sensitive energy efficient sensor network) protocol is the most advantageous protocol to form the clustering with the help of cluster heads. A responsive network protocol called APTEEN is Adaptive periodic threshold sensitive energy efficient sensor network protocol. Hybrid Networks join the best components of proactive and reactive networks while minimizing their disadvantages. Nodes in such a network transmit information periodically at moderately longer intervals while in the meantime transmitting information when the detected esteem goes past its threshold. In this manner, the sensor energy is utilized effectively by decreasing the number of transmissions of noncritical information.

The client can change the periodicity, the threshold value(s) and the parameter to be detected in various regions. This network can copy either the proactive or the reactive network by reasonably changing the periodicity or threshold values. Along these lines, this network can be utilized as a part of an application by appropriately setting the different parameters. In any case, this adaptability and flexibility increase the complexity at the sensor. Here a new protocol APTEEN (Adaptive Periodic Threshold-sensitive Energy Efficient sensor Network Protocol) is presented for hybrid networks. There are applications in which the client needs time basic information furthermore needs to inquiry the system for examination of conditions other than gathering time basic information. As it were, the client may require a system that response quickly to time basic circumstances and gives a general picture of the network at periodic intervals, with the goal that it can answer examination inquiries.

APTEEN can consolidate the best components of proactive and reactive networks while minimizing their restrictions to make another type of network called a hybrid network. In this network, the nodes not just send data periodically; they additionally react to sudden changes in attribute values. Along these lines, it acts as a proactive protocol and additionally reactive protocol.

5. Proposed Work

The stages of wireless sensor networks such as node placement, network coverage, clustering, data aggregation and routing can be optimized by proposed work i.e. Ant colony optimization algorithm. Whereas balancing of energy consumption and increasing the network lifetime can be achieved by using ACO and EAAR protocol.

An ant colony optimization algorithm gives us objectives:-

- For data aggregation and routing of the network where EAAR protocol used for routing.
- To balance the energy consumption and to increase the network lifetime.

Ant colony optimization (ACO) is a population-predicated meta-heuristic that can be acclimated to find approximate solutions to arduous optimization problems.

In ACO, a set from claiming programming operators called artificial ants quest for great answers for provided optimization issue. To apply ACO, the optimization issue will be changed under those quandaries for discovering the best way once a weighted chart. Those artificial ants (hereafter ants) incrementally fabricate results toward moving on the chart. The result development methodology will be stochastic, furthermore will be fractional Toward a pheromone model, that is, a set from claiming parameters connected with chart parts (either node alternately edges) whose qualities would change at run period Eventually Tom's perusing the ants.

This algorithm will be a part of the ant colony optimization algorithms family, to swarm intelligence methods; furthermore, it constitutes a few meta-heuristic optimizations. That pristine origination needs since differentiated to tackle a wider class of numerical quandaries; also as a result, a few quandaries need to emerge, drawing around different parts of the conducting technique for ants. Starting with a more extensive perspective, ACO performs a model-based scan and distribute portion homogeneous qualities with estimation for dissemination algorithms.

5.1. *Ant Colony Optimization Algorithm:-*

Step 1: Initialize

    Pheromone trail

Step 2: Iteration

    Repeat for each ant

        Solution construction using pheromone trail

        Update the pheromone trail

    Until stopping criteria

5.2. *Algorithm EAAR [2]*

Input:

The following blank tables of all nodes are input:

(1) The neighbor table: A table containing all nodes in the neighborhood of a node.

(2) Seen table: A table containing all packets received by a node and their paths.

(3) Routing table: A table containing next hop to transfer packets.

Initial pheromone for all nodes = 0.

Output:

Updated tables with all the values required to transmit data.

Pheromone value for the selected nodes.

Steps:

(1) Broadcast all the request packets and initialize a "seen" set S of every node as NULL.

(2) On receiving any route request:

  for all routes Ri in S of node check:

    if the route traveled by the request is not a super set of the Ri

    if the route is a subset of Ri OR the hop count is less than 1.5 times the highest in the set S:

      add a route in set S and rebroadcast it.

    else

      discard it

(3) On reaching the destination, the route request is converted to the route reply, the path traveled is returned to, and the pheromone PH in the routing table of each node of the path is added.

  PH= MBR/HOPS

(4) When the source receives the first reply, the delay of the first packet is made 5 times in order to receive more packets and the routing table is updated.

(5) Data transmission is initiated with each packet, selecting next hop with probability Pnd from all available, by taking the pheromone values from routing table in equation 3.

(6) On each transmission, the pheromone is reinforced and others are evaporated.

(7) On link failure, Step 1 is repeated from the node that has data to send, but no neighbors available.

6. Own Contribution

In APTEEN, find the number of dead nodes when one node's energy becomes zero. And this would be compared with own work is contributed in:

- Set the threshold energy to 50% that will check the dead nodes when one node's energy becomes zero. This method would be compared with the simple APTEEN protocol with various parameters that can be shown by the graph.

6.1. *Proposed Algorithm*

(1) Initialize all the variables and threshold energy=50.00 Joules

(2) Calculate the energy of all the nodes which is in the range and also its neighbor nodes.

(3) Compare one node's energy (val) with neighbor node's energy (nb_val)

  a. if val is greater than nb_val then select val.

(4) Now compare this val and threshold energy, if that val is less than threshold energy then select val as a

(5) cluster head.

(6) Now check cluster head is present in neighboring hops, if not then exit

(7) Else send cluster head to announce message.

In APTEEN protocol, node's energy is not setting to zero due to which the dead nodes cannot be obtained by which packet loss was more. So to overcome this problem, this proposed protocol is obtained. In this proposed protocol, dynamic cluster head selection becomes easy by setting threshold energy to 50 Joules. And to calculate a number of dead nodes also becomes easy by which the packet loss and network lifetime are improved. This proposed protocol is 90% better than APTEEN protocol.

7. Mathematical Model

Set Theory: A set is defined as a collection of distinct objects of the same type on the class of objects. The object of a set is called elements or members of the set. The object can be a number, alphabet, names etc.

S = Our System

System "S" contains the whole system with its combination of various network components including Base Station and other nodes.

Sa = System Architecture

The system architecture is the architecture of the proposed system with various components.

Sn = Source Node

The Source node whose responsibility is to send the data to the destination node.

Dn = Destination Node

This is the last node to which source node wants to send the actual data.

It = Initialization Task

In initialization, the parameters such as

m = number of ants,

α = the relative importance of the pheromone trail

β = relative importance of the visibility,

γ = amplifying or decaying factor for updating of pheromone.

ρ = evaporation factor,

q0= the exploitation probability.

Q = scaling factor for the modification of the trail are randomly generated as binary strings to be subjected to GA search and are converted into the values within the limits, pheromone trail 0 is initialized heuristically to a small value.

T = Transition State

When a source node, s, starts a communication session with a destination node, d, and it does not have routing information for d available, it broadcasts a reactive forward ant, say F_s^d. Due to the initial broadcasting, each neighbor of s receives a replica, F_s^d, which is F_s^d.k (the notation ".k" refers to indexing – the k^{th} message of a single broadcast is represented as F_s^d.k). [2]

After the next hop, the next neighboring node will receive F_s^d .k.l and so on where (k, l, . . . are integers). The task of each F_s^d.k.l.m.n . . . is to find a path connecting s and d. At each node, an ant is either unicast or broadcast, depending on whether or not the current node has routing information for d. Since there will be no information initially, all are broadcast at that point. Also, each packet maintains an array, J, in which its journey information is stored. [2]

When a node receives several ants of the same generation, it will compare the path traversed by each ant to that of the previously received ants of the current generation.

Ff = Fitness Function ranges

1 < m< 2n

< α < 5.0

< β < 10.0

0.1 < γ < 3.0

0.0 < ρ < 1.0

0.0 < q0 < 1.0

0.0 < Q < 100.0

Pu= Pheromone update Rule

Once the data session starts, the data packets are sent through the host. The host will either distribute the packet or the packet will choose the next node from the set of neighbors, N_d^i , which have pheromone information in the table with probabilistic condition, P_{nd}, as in AntHocNet [2]:

$$P_{nd} = \frac{(T_{nd}^i)^\beta}{\Sigma(T_{jd}^i)^\beta}. \quad (1)$$

In above "Eq. (1)", β is a factor which can take in a set of integer values. The traversal of each data packet increases the pheromone values of each link by a factor π:

$$T_{n,d}^{i} = T_{n,d}^{i} \times (1 + \pi) \qquad (2)$$

In the results reported in this paper, took π = 1/10. The other nodes evaporate the pheromone deposits, resulting in a more frequent selection of better paths. Evaporation occurs periodically. For every τ time period, node will evaporate the pheromone value, $T_{n,d}^{i}$, automatically [2].

$$T_{n,d}^{i} = T_{n,d}^{i} \times (1 - \rho) \qquad (3)$$

In above "Eq. (3)" lies between 0 and 0.5. As soon as the first proactive backward ant is received by the host, it again sends another forward proactive ant analogous to the first one. This eventually leads one to a better path.

S = {Sn, Dn}

In above case, the system is a combination of Sn (System architecture), Sn (Source node), Dn (Destination Node).

Sn = {It, T, Pu, Ff}

Source node, as well as an intermediate node, perform the tasks of initialization, transition, an update of pheromone and fitness function which will result in the source to destination node path creation perform.

Ts = {S U Sa}

Finally, proposed system in mathematics called it as the Total system is the union of System and Generated proposed System architecture.

8. Results Analysis

Comparison of APTEEN, proposed protocol, EAAR, ANTHOCET, MMBCR and AODV protocols has been shown by the graph in NS2. The graphs are of the number of dead nodes, energy consumed per delivery packets, the number of packets dropped, dead nodes received packets, the number of packets delivered. The comparison shows that EAAR protocol is the most appropriate technique used for optimization as well as the enhancement of network lifetime.

8.1. *Number of dead nodes*

The main aim of the system is an analysis of all the systems that implements, the below image shows comparison output of the better system. X-axis has interval values and y-axis with a number of dead nodes as shown in Fig.2. To find the dead node who need to check in trace file when energy is zero and check that time and give correct output to the user.

Number of dead nodes=one node's energy is zero

This task has been done by creating the dead node awk script file which will give accurate results. The proposed system Apteen_threshold has results better than old APTEEN; EAAR has less number of dead nodes at each interval.

The graph shows the comparison of another existing system with the main proposed system. The graph contains x and y-axis values which show a number of nodes and number of dead nodes count respectively as shown in labels of graphs. EAAR system shows a slow increase in the graph which means a number of dead nodes at energy value zero will be very negligible as compare to MMBCR techniques which display in a blue color line graph.

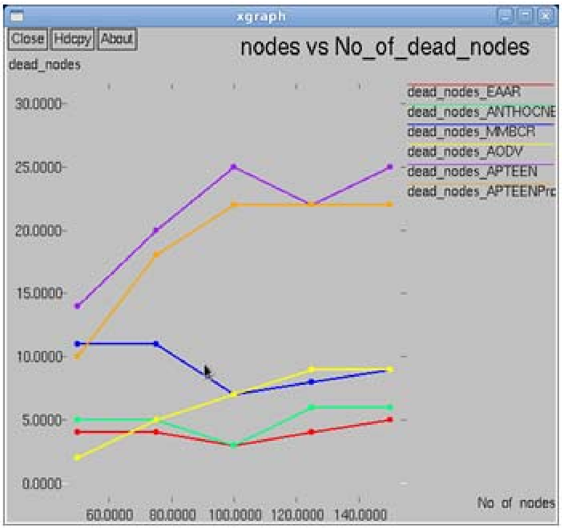

Fig. 2. Number of dead nodes.

To calculate the number of dead nodes, apply a condition on generated trace file.

```
if($7 ==0)
{
  DN[$5]=1;
  dead_nodes++;
}
```

This gives a number of dead nodes count. DN array stores the number of dead node values, which will satisfy only when energy is down to 0. This condition is applied and check the number of scenarios for different to analysis the trace file and get the accurate results.

8.2. *Energy consumed per delivered packets*

The amount of energy consumed by all the protocol is shown below in Fig.3. As discussed every time that ad-hoc network is more power consumed so main aim of achieving at this point that EAAR has less power consumption which will affect on every network parameter and prove the betterment of the system.

Energy consumed=Total energy/nodes

Energy consumed per delivered packets=Energy consumed/received packets.

Where number of delivered packets (recv) is calculated if-

recv==0 then 1 else recv

Fig. 3. Energy consumed per delivered packets.

The above graph show the amount of energy consumed for all the system. ANTHOCNET require more energy as compare to EAAR and other systems. The energy consumption is obtained using following condition check system in awk:

```
total_energy = 0;
residual=0;
for (i=0;i<nodes;i++) {
        residual_energy[i] = initial_energy[i] - energy[i];
        total_energy+=residual_energy[i];
        residual+=energy[i];
}
```

This will initialize variable to zero and record initial energy at the time of first packet transfer into an array. Residual energy will be the difference between initial energy and total energy of the node.

Total energy is the addition of residual energy with the total energy.

8.3. ***Number of packets dropped***

In given existing system, packet loss rate is very high, which will overcome in threshold criteria as shown in the Fig.4. EAAR has less pack loss rate than other 5 protocols which is ANTHOCNET, MMBCR, AODV, APTEEN and APTEEN with a threshold.

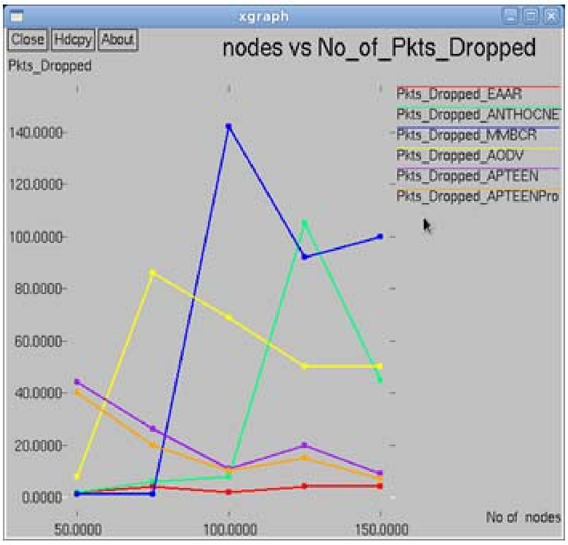

Fig. 4. Number of packets dropped.

The above graph shows the number of packets dropped by four systems respectively. It has been seen that EAAR has very less number of packets drop compared to the others. Red line which shows EAAR system graph, when the mobility is zero and the packet size is small; the network acts as an ideal one. As a result, every protocol behaves similarly. But in practical terms, this is not possible all the time.

The ANTHOCNET system is little bit difference with the minute. As increase, the network size MMBCR drop ratio will get increased due to mobility scenario as well. So this system shows the proposed system is stable than other systems.

To obtain the dropped packet take the difference of a number of packets sends and delivers with d in the first event.

8.4. ***Dead node received packets***

EAAR has less dead node received packets as compared with other protocols i.e. ANTHOCNET, APTEEN, APTEEN with a threshold, AODV, and MMBCR. Here, maximum dead node packets are received in APTEEN as shown in Fig.5.

Dead nodes received packets is calculated from trace file of the network.

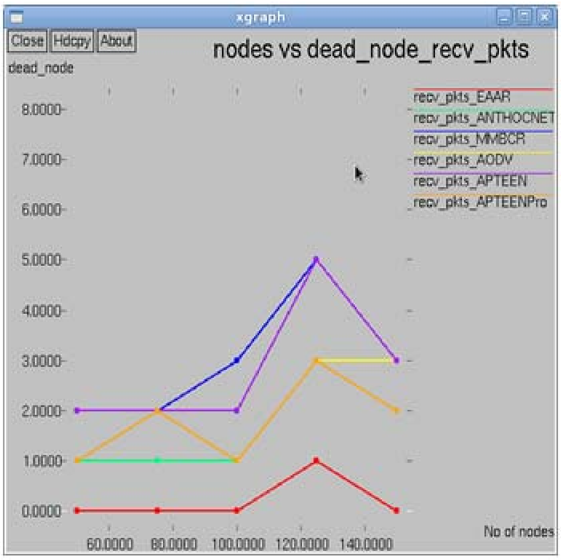

Fig. 5. Dead node received packets.

8.5. *Number of packets delivered*

EAAR has the highest Packet delivery ratio than another system. Existing system graph increases as interval increases which will show drawback of the existing system which improves it using threshold application, whose PDR is better than existing system.

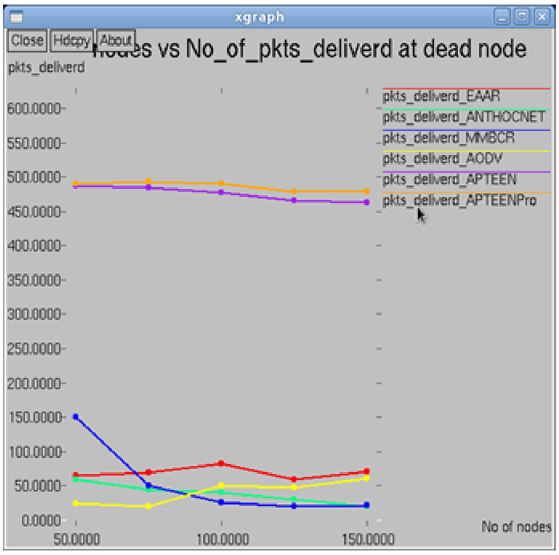

Fig. 6. Number of packets delivered.

The above graph shows the number of packets deliver at a dead node which will consider in loss of packets as well as shown in Fig.6. The AODV system gives the less number of packets deliver at a dead node because of its route request and route reply method of routing which will prevent the loss of packets at the dead node. The following condition is applied on trace generated file using awk and the results are obtained as shown in graph.

```
for (i=0;i<1000;i++)
{
  DN[i]=0;
}
dead_node_recv_pkts=0;
}
```

This will show for loop which will increase the value dead node packet received.

These above results are used to optimize the stages of Wireless sensor networks. It is used to balance the energy consumption. It is also used to increase the network lifetime. The EAAR protocol is used to select the cluster head and to send data to the base station in minimum time by following the routing mechanism. In less time, to aggregate the data and to reach the base station by following the shortest path through a routing protocol.

9. Conclusion

The proposed protocol (APTEEN with threshold energy) improves the packet loss and network lifetime which is compared with APTEEN protocol. To get more than 90% network lifetime, EAAR protocol is implemented and it shows better results than APTEEN protocol. The main concern of minimizing energy and network lifetime has been solved by using two protocols, for minimizing energy-EAAR protocol is proposed and for network lifetime- proposed protocol is obtained. These results give 80-90% accuracy as compared with the existing system.

Future Scope

The proposed system was tested on more than 150 nodes, for future work it can be tested for more than 500 or 1000 nodes and compares the results with this system. The simulator is used to analysis so instead of this on physical nodes it can be worked and check the results on physical nodes using other OMNET++ or say other tools.

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