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AN ENERGY EFFICIENT FITNESS BASED ROUTING PROTOCOL IN WIRELESS SENSOR NETWORKS

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Abstract
A wireless sensor network is a self-organized multi hop network that consists of a large number of sensor nodes. The efficiency of the sensor networks depends upon the routing protocol used. There are different routing protocols exists to extend the network lifetime by efficiently consuming the energy of the nodes. The nodes have limited energy resources and are battery powered. Therefore, designing an effective routing protocol that conserve scarce energy resources is the major critical issue in WSN. In this paper, a Fitness based Routing Protocol (FRP) is proposed to optimize energy efficient data transmission. The energy consumption of nodes is reduced by selecting the nodes with minimum hop count and distance. Genetic algorithm is used as an optimization technique to find the fitted node based on its fitness value. The FRP could increase the network lifetime and throughput comparing to the other protocols. The protocol could also reduce the packet loss and end – end delay.

Keywords:
Fitness Value, Genetic Algorithm, Hop Count, Wireless Sensor Networks

1. INTRODUCTION

A wireless sensor network is a pool, consisting of larger number of smaller nodes called sensor nodes. Each sensor node has the sensing, computing and wireless communication capabilities that enable it to sense and gather information from the surrounding environment and send the data to other nodes in the network or to the base station. These sensor nodes generally use battery power which is the main source. The wireless sensor networks [1] find their application in battlefield surveillance in military, industrial process monitoring, environment monitoring, machine health monitoring etc.

In wireless sensor networks, the size and cost constraints on the sensor nodes led to constraints on energy, memory, computational speed and bandwidth. These limitations should be considered when designing protocols for WSNs. Minimization of energy consumption is considered as a major performance criterion to provide extended network lifetime in wireless sensor networks. Various routing protocols [2] were designed for wireless sensor networks to improve the network lifetime.

In [3], SPAN protocol that is proposed for multi hop ad hoc networks that reduces energy consumption without diminishing the connectivity of the network. SPAN helps sensors to join a forwarding backbone topology as coordinators that will forward packets on behalf of other sensors between any source and destination. SPAN does not extend network lifetime as much as the energy savings it offers, because energy consumption rate is not constant.

In [4], Geographic Random Forwarding (GeRaF) protocol. This paper focuses on the multi hop performance, in terms of average number of hops to reach a destination as a function of the distance and of the average number of available neighbors. All the sensor nodes are aware of their physical location and checks for the collision in the channel. It divides the forwarding area into different regions and forwards the packets based on different priorities. When practically implemented, the energy and latency performance is yet to be resolved.

In [5], energy efficient technique based on graph theory that can be used to find out minimum path based on some defined conditions from a source node to the destination node. The technique will always find the minimum path and an alternate path is also saved in case of node failure. The length of the alternative path will be extended due to the node failure which in turn minimizes the energy savings.

In [6], routing protocol that uses a forward address based shortest path routing in the network. Genetic algorithm with elitism concept is used to obtain energy efficient routing by minimizing the path length and thus maximizing the life of the network. The protocol fails to minimize the packet loss.

In [7], Particle Swarm Optimization Routing (PSOR) protocol is proposed. The PSOR does routing by taking energy as a fitness value. By calculating the fitness value of the nodes, the protocol finds a new path to route the packets. From the various paths found it selects the optimized one that consumes less energy to route the packets. In case of node failure, choosing an alternate path is difficult.

It can be seen from the above survey that the energy conservation is the major issue in wireless sensor networks. In order to increase the network lifetime through energy efficiency, a new energy efficient routing protocol should be developed. Hence energy efficient fitness based routing protocol is proposed that is categorized into four phases: Network Initialization, Data Congregation, Fitness Calculation and Packet Routing. The proposed routing protocol works by selecting the nodes based on the minimum hop count and the maximum residual energy. In addition, the protocol finds the fit node to route the packet so that the energy of other nodes in the network will be conserved.

The rest of this paper is organized as follows. The section 2 describes about the Genetic Algorithm. In section 3 the proposed protocol is explained. The section 4 deals with the simulation model and analysis of the comparative evaluation of the proposed protocol with the other protocols. Finally the last section deals with the conclusion part.

2. GENETIC ALGORITHM

Genetic Algorithm is an evolutionary algorithm based on the evolutionary ideas of natural selection and genetics. Optimization is the process in which GA selects the best, fit or optimal node for data transmission. The Genetic Algorithm is an optimization technique which includes the process like initial population creation, fitness evaluation, selection, crossover and mutation. The algorithm ends when it meets the termination criteria.

Every node in the network is referred as sequence of bits. The Genetic algorithm starts with the initial points called as Initial Population. The sensor nodes within the transmission radius are selected for the initial population. The Fitness function determines the quality of the node in extending the network lifetime. The fitness function is calculated for the nodes based on the distance and the residual energy. The node with higher fitness value has the better chance of survival in the network [1].

Then the Selection process starts which selects two nodes as parent nodes to produce the next generation. There are different types of selection methods exist. The Tournament Selection is used in this paper which selects two nodes randomly from the current population. For a predefined probability p, the more fit node is selected and with the probability (1-p) the node with less fitness is selected.

Crossover or recombination is the process in which the two nodes exchange the genetic information. The outcome of the crossover depends on the selection of nodes from the population. The Single point crossover is used in this paper in which the two parent nodes exchange information after the crossover point chosen at random. The Table.1 shows the example for single point crossover.

In Table.1, the bit sequences of the parent nodes are copied to new offspring until the crossover point and after that the first parent node bits are replicated in the second offspring node and vice versa. The next process is the Mutation in which a node is randomly selected from the best nodes obtained in the past generation and a randomly selected bit is changed to produce new offspring. An example for Mutation process is shown in Table.2.

Table.1. Single point crossover

	Parent 1	Parent 2
Node	10011 10011001101	11001 01100110101
Offspring	10011 01100110101	11001 10011001101

The Table.2 shows the nodes before and after mutation process in which the eighth bit of the offspring 1 is changed from 1 to 0. Thus the new offspring is produced after the mutation process.

Table.2. Mutation

	Offspring 1	Offspring 2
Before Mutation	1001101**1**00110101	1100110011001101
After Mutation	1001101**0**00110101	1100110011001101

Then the fitness value is calculated for the newly produced nodes. Then it is compared with the parent nodes and will be replaced if the new generated nodes have higher fitness value. Then the termination criteria should be checked. The algorithm terminates when the maximum number of generations has elapsed or the energy of the network has fallen below predefined level.

The GA process continues and finds the fit node when it meets the termination criteria. Genetic Algorithm is simple to implement. Genetic Algorithm finds its application in different fields like electronics, computer science including wireless sensor networks.

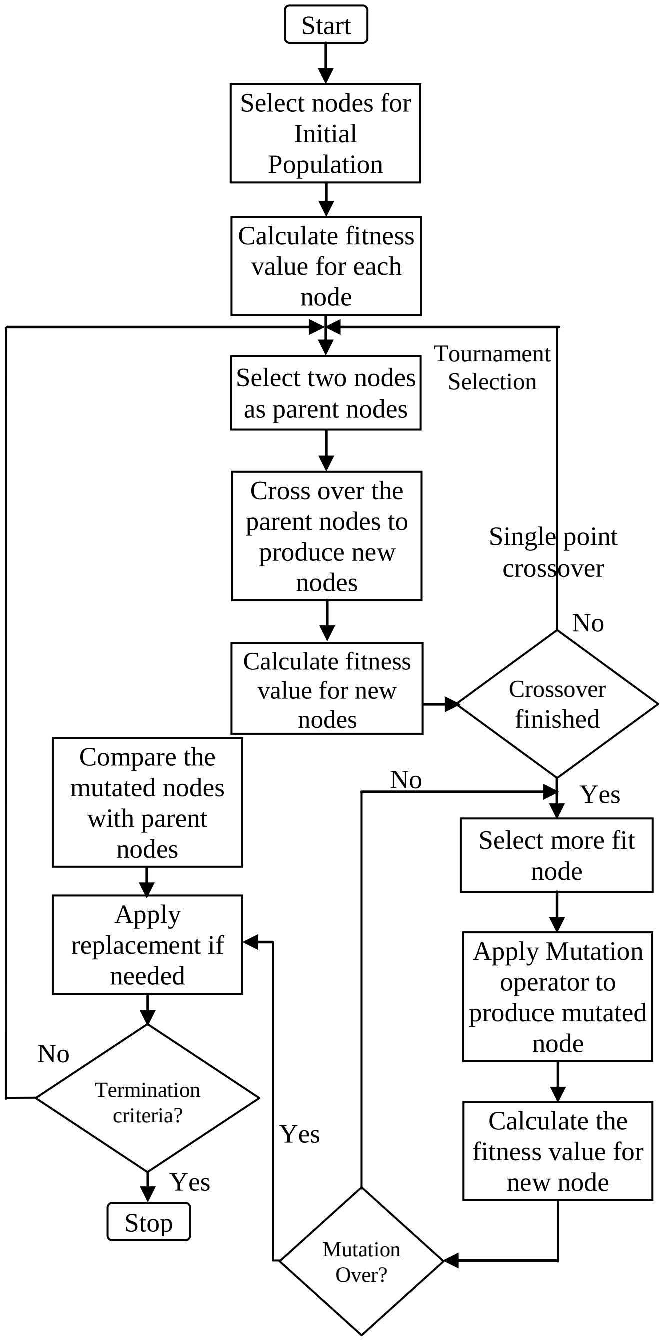

Fig.1. Flow chart for Genetic Algorithm

The proposed Fitness based Routing protocol also uses Genetic algorithm as an optimization technique for finding the fit node to route the packet. The fitness function based on the distance of the nodes from the base station is used to calculate the fitness value. Based on the fitness value, Genetic algorithm proceeds to find the fit node among the node population. Thus the data packet is routed in an optimized route to the base station by minimizing the usage of energy of other nodes and the lifetime of the network is also increased. The overall concept of Genetic Algorithm is shown in Fig.1.

3. FITNESS BASED ROUTING PROTOCOL

A new energy efficient Fitness based routing protocol is designed to extend the network lifetime through the conservation of energy of the sensor nodes. The routing of packet is based on the fitness value of the node which is calculated using the genetic algorithm. The fitness function uses the distance of the node to calculate fitness value. The new protocol consists of four phases: Network Initialization phase, Data Congregation phase, Fitness Calculation phase and Packet routing phase.

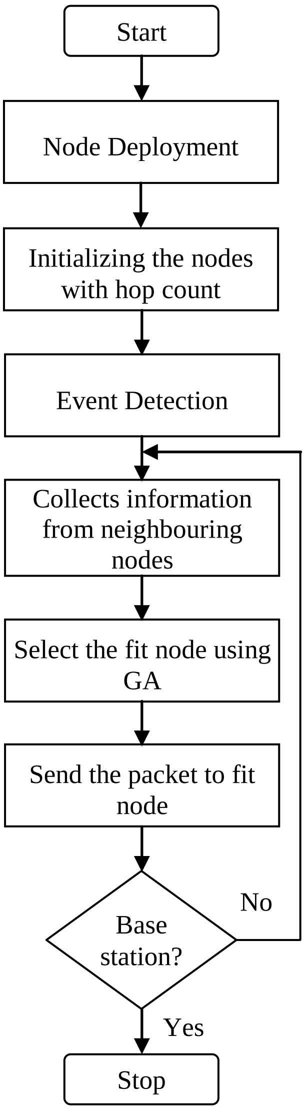

Fig.2. Flow chart for Fitness based Routing Protocol

The Fig.2 shows the flow chart for the Fitness based routing protocol. The protocol starts with the node deployment and after that hop count is initialized to all the nodes in the network. After detecting the event the node gathers information from the neighbouring nodes within the transmission radius. Using Genetic Algorithm the fit node is selected among those nodes based on the distance and packet is routed to it. The process continues until the data packet reaches the base station.

3.1 NETWORK INITIALIZATION

In the Network Initialization phase, the base station broadcasts a “HELLO” message to its neighboring nodes. The HELLO message holds the Base Station Address and Hop Count. The hop count is a parameter showing the distance of the node to the base station. After a node receives the HELLO message, it saves the hop count in its memory and then increments the hop count by 1.

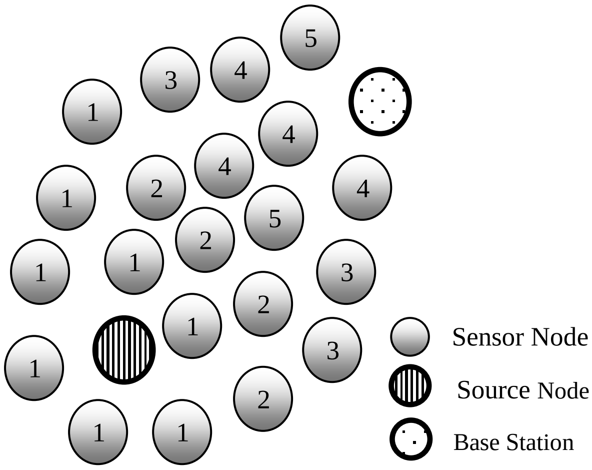

Fig.3. Network Initialization Phase

The above Fig.3 denotes the network initialization phase. After receiving the HELLO message, the node will check if a gradient is already present. If so, it checks if the hop count of the received message is smaller than its own message and replaces the message’s hop count with its hop count. But if the hop count of the received message is larger or equal to its own message, the message will be discarded. Likewise, every node in the network is assigned with the hop count.

3.2 DATA CONGREGATION

On detecting an event, the source node draws a transmission radius of 50m to connect with the neighbouring nodes. The source node then generates the request message that gathers information from its neighbouring nodes in the transmission radius. The information like the hop count, the distance to the base station and the residual energy are to be collected from the neighbouring nodes by the source node. The nodes that received the request message send the requested information to the sender node.

3.3 FITNESS CALCULATION

After receiving the requested message, the source node should select the next node to transmit the packet. Selection of the node is based on the fitness value which extends the network lifetime. Genetic Algorithm is used in this paper to calculate the fitness of the nodes and select the fit node. The fitness value of a node is calculated based on the distance of the node to the base station.

$$\text{Fitness} = dist(i, j) + dist(j, bs) \tag{1}$$

The distance between two nodes or node to the base station is calculated using the formula

$$dist(i, j) = \sqrt{(x1 - x)^2 + (y1 - y)^2} \tag{2}$$

where, i, j are parent nodes, bs is the base station.

3.4 PACKET ROUTING

The packet routing phase is done after the information is collected by the source node. Initially, the source node sends the message to the selected fit node. Then the process repeats from the data congregation phase until the packet reaches the destination node. During transmission, if any network failure occurs, the network chooses an alternate path. This is done by selecting the other node among the two nodes that were selected in the previous phase. Hence, transmission errors are minimized.

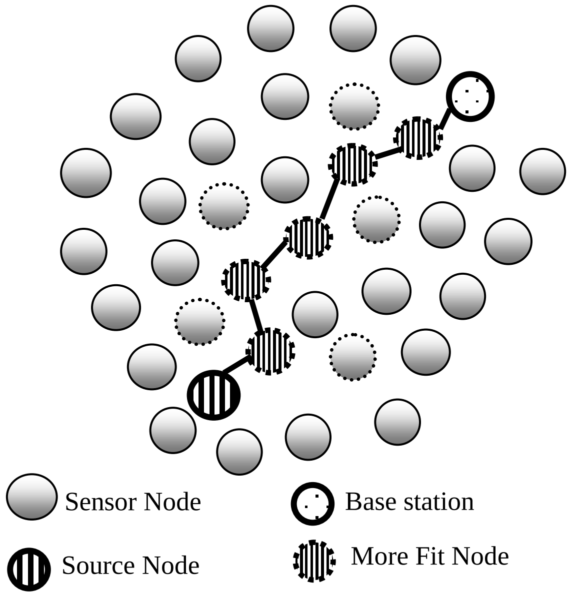

Fig.4. Packet Routing Phase

The packet being transmitted holds the message and the packet header. The packet header consists of fields like Source, Destination, Address of the current node, Address of the next node, TTL, Hop count, distance. When the message finally reaches the base station, the base station broadcasts a successful reception message to its neighbouring nodes. This helps in preventing other nodes to stop sending the same message again.

The packet routing phase is shown in the Fig.4. The packet is transmitted from the source node to the base station through the intermediate nodes. The intermediate nodes are selected based on its fitness and it routes the data packet to the other nodes until it reaches the base station.

4. SIMULATION AND EVALUATION

The proposed Fitness based Routing Protocol is implemented in the event based network simulator, Qualnet. Simulation results are generated using a Graphical animator. The performance can be analyzed and compared by using statistical graphical analysis tool.

The Fig.5 shows the graphical user interface of Qualnet in which the nodes are deployed in the sensing region. The FRP scenario consisting of 50 nodes is created in the network area 100 × 100 m^2. The scenario properties should be changed as shown in the Table.3.

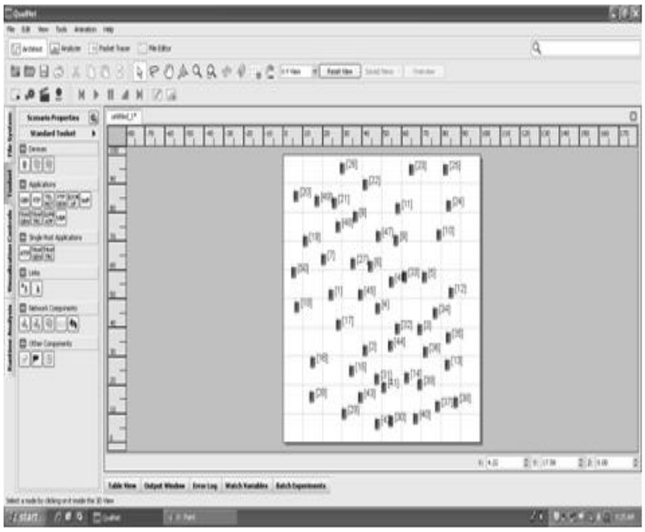

Fig.5. Graphical User interface of Qualnet

Table.3. Scenario properties

Simulation Time	300 seconds
Dimensions	100 × 100
Number of Nodes	50
Routing Protocol	FRP
Energy Model	Mica Motes
Item size(bytes)	50
Items to send	200
Source node	5
Destination Node	40
CBR Link	Enabled
Mobility	Random Waypoint

The sensor networks scenarios are created for employing various node counts. Each scenario is executed and records the transmission to show the quantitative results such as Total bytes sent, total bytes received, first packet received time, last packet received, throughput. The result of FRP protocol is compared with the AODV (Ad-hoc On Demand Vector) protocol for comparative analysis. The analysis is carried out based on the QoS parameters like Packet loss, Throughput, End to end delay, Energy consumption.

4.1 PACKET LOSS

Generally, when a sensor node detects the events, it requires time for sensing the information. This sensing cycle increases the data traffic of the sensor nodes in a routing path. So overflow occurs in the data queue and urgent important events could be lost. Packet Loss also occurs when one or more packets travelling across a network fail to reach their destination. The source will send the packet to the destination node. The number of packets to be sent is set to 200, each packet is of 50 bytes and hence a total of 10000 bytes is sent. The created scenarios are allowed to run for FRP protocol and the packet loss is determined using the formula, Packet Loss = No. of packets Sent – No. of packets Received

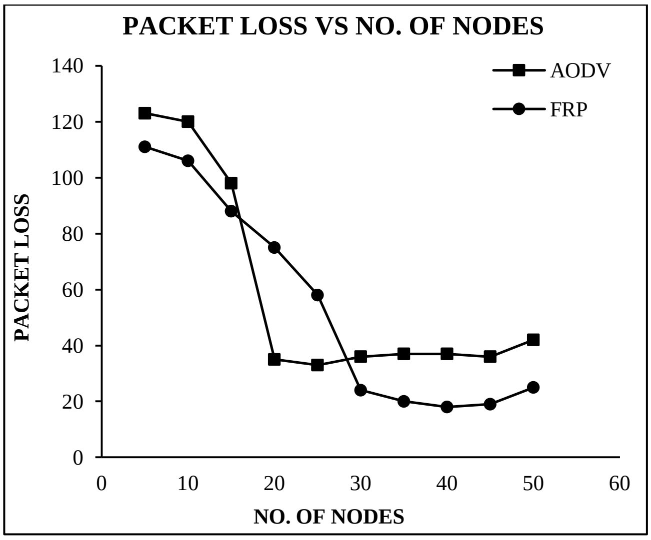

Fig.6. Packet Loss

The Fig.6 shows the comparison of packet loss of FRP and AODV protocols. The graph describes the decrease in the loss of packets as the no. of nodes increases for ADODV and FRP protocols. From the result, it is found that FRP provides a much lesser packet loss when compared to ADODV protocol. AODV protocol provides 3% packet loss while FRP protocol provides 2% packet loss, hence the FRP is efficient than the existing AODV protocol as it minimizes the packet loss.

4.2 THROUGHPUT

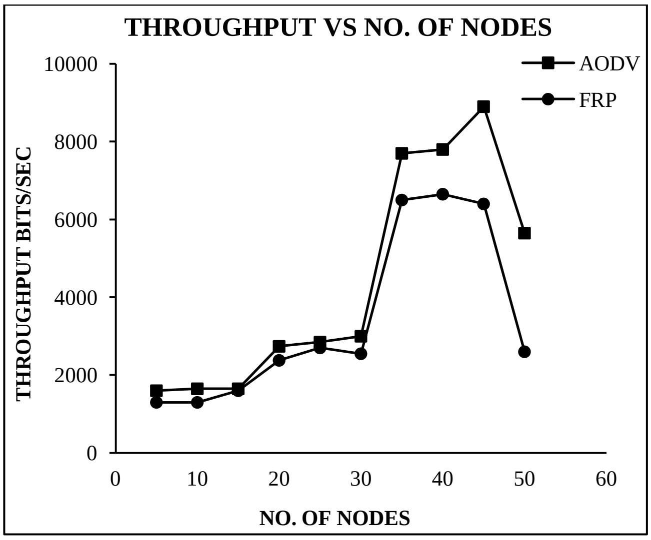

Fig.7. Throughput

Throughput is the amount of data transmitted in per unit time that is delivered from one node to another via a communication link. The throughput is measured in bits per second (bit/s or bps). The Fig.7 is the graph showing the comparison of throughput of FRP with that of AODV protocol. It is shown that the no. of nodes and the throughput are directly proportional to one another i.e. as the no. of nodes increases so does the throughput. In addition it is also clear that FRP shows greater throughput as compared to AODV. It is seen from the above results, the throughput of FRP is 31% higher than AODV protocol.

4.3 END-TO-END DELAY

End-to-End delay is an expression of how much time it takes for transmission of a data packet. The delay depends on the fitness value. It will vary depending on the distance between the source and destination nodes.

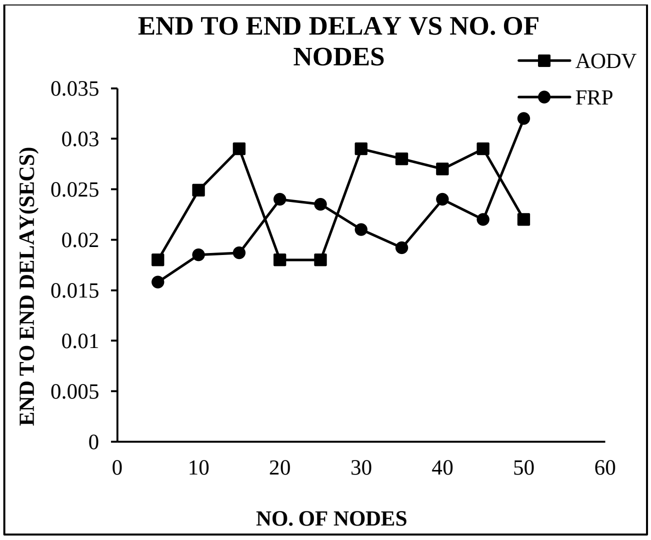

Fig.8. End to End Delay

The Fig.8 infers that the end to end delay is reduced in FRP protocol due to the efficient selection of fit node. However the end to end delay is increased in case of AODV, due to increase in overhead.

4.4 ENERGY CONSUMPTION

Every node in the network consumes some amount of energy. The nodes which are not involved in the routing path is said to be an idle node. Since the protocol finds the fit node to route the packet, the idle node saves its energy.

The energy consumption of the nodes has been reduced in FRP protocol when compared to AODV protocol which is shown in the Fig.9. Hence, FRP protocol efficiently conserved the energy of the nodes in the network.

It is seen from the above results, the throughput of FRP is 31% higher than AODV protocol. AODV protocol provides 3% packet loss while FRP protocol provides 2% packet loss hence the Fitness based Routing Protocol (FRP) is efficient than the existing AODV protocol as it minimizes the packet loss and considerably increases the throughput. The energy consumption of the nodes in the network is also minimized thereby increasing the network lifetime.

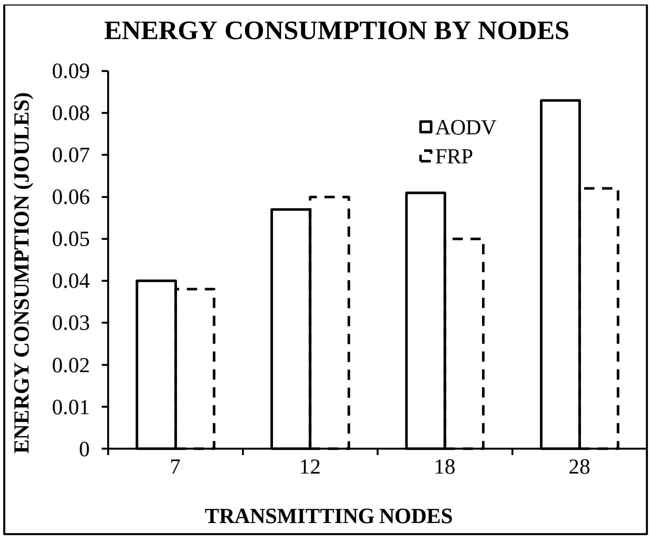

Fig.9. Energy Consumption

5. CONCLUSION

The communication between nodes along with design and deployment is a challenging task in wireless sensor networks. Many routing protocols have been designed for wireless sensor networks to enhance the QoS parameters. A new energy efficient routing protocol, Fitness based Routing Protocol was designed in this paper to reduce the energy consumption of the nodes. In the proposed work the energy consumed by the transmitting nodes was reduced when compared to that of the existing AODV protocol and packet loss was also to a minimum amount. In this paper, only two fit nodes were considered for routing, to avoid node failure, where the message is transmitted to the base station by finding an alternate path. This shows that the energy of the nodes is efficiently used to increase the network lifetime.

The future enhancements should be done by forming the clusters in the network. The fit node from each cluster is selected using Genetic algorithm and packet is routed. Security is also an important consideration since most of the applications aim at it; the transmitted message should reach the base station without any intervention. Implementing some cryptographic techniques in the project may enhance the security of system.

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