# ENERGY AWARE ROUTING ALGORITHM FOR WIRELESS SENSOR NETWORK

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**Abstract**

Technological advancements made major research challenges in the area of wireless sensor network. Power saving is the foremost criteria in this field. Consumption of energy is considerably reduced on properly designed protocol. This paper focuses on energy aware fuzzy based routing protocol. Protocol based on fuzzy logic computation reduces power consumption by the ratio of 10 when compared to classical routing protocol.

***Keywords:*** Fuzzification, wireless sensor network, power savings, energy aware

## 1. Introduction

Recent advances in wireless communication and micro-electro-mechanical Systems (MEMS) have lead to the development of implementation of low-cost, low Power, multifunctional sensor nodes.[ Akyildiz.I, W et al 2002] [Doumit S., Dharma and. Agrawal P, 2002] Sensor network have a large number of unattended, self-organized micro sensors, of size of the order of a cubic centimeter, scattered in an area for a specific application. Each micro sensor is capable of sensing data from the environment, performing simple computations and transmitting this data over wireless medium either directly to command centre or through some cluster head, commonly known as gateway. [Kemal Akkaya and Mohamed Younis 2005] Though it has some similarities with ad-hoc networks it differs due to their more severe energy constraints, much larger density of sensor nodes, lower cost and usually static nature of nodes. Sensor Networks are designed for information gathering, rather than distributed computing. An important challenge in the design of wireless and mobile systems is that two key resources communication bandwidth and energy are significantly more limited than in a wired network environment. These restrictions require innovative communication techniques to increase the amount of bandwidth per user and innovative design techniques and protocols to use available energy efficiently.

### *1.1 Architecture*

Figure 1 clearly shows sensors nodes are battery operated. Nodes collect information from environment process data according to requirement. Processed data is transmitted through a transceiver to the target and mobile station and finally to the internet or remote location for user. Major design goals of network are it should be of ease of deployment, latency and quality. Key challenges in meeting goals are protocol framed should reduce the energy dissipation of the network at least by half to increase the lifetime of the network, protocol should be robust to node failures in order to maximize system lifetime, designed protocol should be fault tolerant and scalable. Once deployed they are unattended and expected to operate for a long period of time, usually from a few months to years. Thus, energy is a scarce resource in a wireless sensor network. Hence its efficient usage is crucial for extending the life time of network. Energy is mainly consumed in the three main activities: sensing, computing and communicating. Current approaches for optimizing the energy usage in wireless sensor networks include physical-level design decisions such as modulation scaling, voltage scaling etc., to energy aware routing and energy-aware MAC protocols. Network layer plays vital role in routing protocols. Routing protocol should be framed to reduce the energy consumption of network and for guaranteed delivery of pa

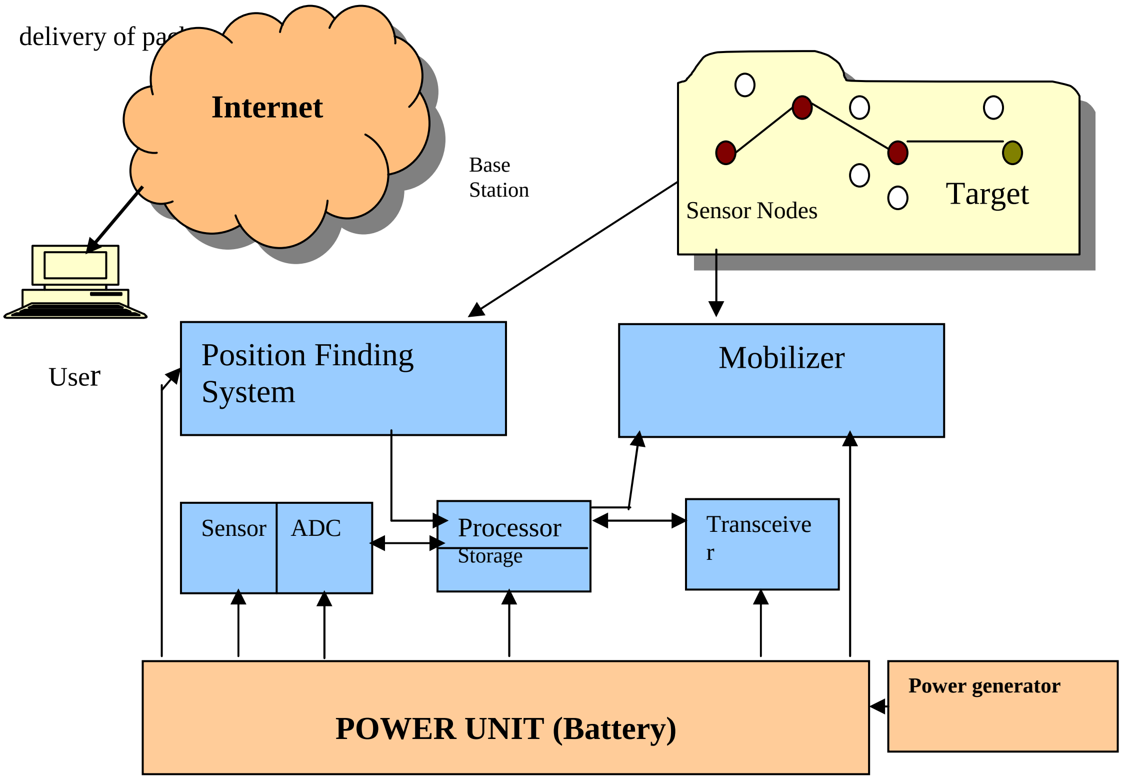


Fig 1 Architecture of wireless sensor network

In network layer, main aim is to find ways for energy efficient route setup and reliable relaying of data from the sensor nodes to the sink so that the lifetime of the network is maximized. Routing in sensor networks is very challenging due to several characteristics that distinguish them from contemporary communication and wireless ad-hoc networks. Key challenges in routing protocol of wireless sensor network are deployment of node, energy Vs quality of the network, Scalability, fault tolerance and network dynamics. This paper is focused towards energy aware routing to obtain a protocol that maintains better lifetime and quality. Routing is established in two phases with neighbor computation as first phase and link establishment as second phase.

## 2. Related Work

The routing protocols play a vital role in the life time of the sensor networks. Various routing protocol based on fuzzy logic system and the other techniques are discussed in this section. [Mohammad Zeynali et al 2009] proposes a novel tree based routing protocol (TBRB) based on clustering techniques. The author proposes a fuzzy based technique for cluster head selection. Based on the distance between two nodes and residual energy of each node at the end of each transmission a fuzzy election number FEN is allotted and based on the priority of the FEN cluster head is selected. [Zohre. Arabi et al 2010] proposes a Hybrid Energy Efficient Routing using a Fuzzy Method in Wireless Sensor Networks (HERF), in which the protocol switches between two algorithms EF-Tree (Earliest-First Tree) and SID (Source-Initiated Dissemination) based on fuzzy logic systems and selects a cluster head. This protocol makes use of node energy, node concentration and node centrality as the linguistic variables. Based on fuzzy “IF THEN rule” cluster heads are selected. [Mahmood R. Minhas et al 2008] his work claims that the routing path among the multi objective path is established based on fuzzy membership function residual energy. In this protocol when routing request is sent first it calculates the residual energy of the fuzzy membership function, secondly the residual energy using the fuzzy membership function around the edges and finally based on Dijkstra’s shortest path algorithm the transmission takes place.

[Shu-Yin Chiang et al 2008] proposed an algorithm called Routing Analysis Using Fuzzy Logic Systems in wireless sensor network for forwarding the packets to the destination. In this protocol residual energy, distance from node , Traffic Load and distance from shortest path are taken as linguistic variables. [ Qilian Liang et al 2005] proposed a protocol based on Energy and Mobility Aware Geographical Multipath Routing for Wireless Sensor Networks in which proper selection of neighbor based on fuzzy linguistic variables is done. The major linguistic variables taken in to account are energy, mobility and distance. [ Hee Wan Kim et al 2010] proposes a protocol in which using the fuzzy logic concepts, a fitness level is determined. On the basis of fitness level the protocol switches between various existing protocols for the selection of route. [ Tarique Haider et al 2009] also suggested a fuzzy model for the computation of neighbor node .

Apart from the fuzzy based protocol the other traditional protocols also work towards energy. Flooding and gossiping are the very traditional ways of transmitting data to the destination. LEACH [ Krishnamachari B and Orid F 2003 ] follows a hierarchical based cluster formation technique and also proposes a method for the selection of proper cluster heads. GEAR [Yan Yu et al 2001] protocol says that the entire network is divided in to partitions and within partitions, flooding technique is adopted. Geographic adaptive fidelity GAF [Y. Xu et al 2001] is an energy-aware location-based routing algorithm designed primarily for mobile ad hoc networks, but may be applicable to sensor networks as well. GAF conserves energy by turning off unnecessary nodes in the network without affecting the level of routing fidelity. It forms a virtual grid for the covered area.[ Sudir .G et all 2008] suggested The sensor data is classified using ART1 Neural Network Model. Wireless sensor network populates distributed nodes. The cooperative routing protocol is designed for communication in a distributed environment. The classified sensor data is communicated over the network using two different cases of routing: cooperative routing and diffusion routing. Ptolemy-II-Visual Sense is used for modeling and simulation of the sensor network. Lifetime improvement of the WSN is compared with and without classification using cooperative routing and diffusion routing. Sang Hoon Chi et al propose a new data propagation method in which the data transmission area is limited according to a threshold value for reducing the energy consumption in the network. The fuzzy rule based system is exploited to determine the threshold value by considering the energy and density of all the deployed nodes.

[Younis et al. 2002] have proposed a different hierarchical routing algorithm based on three tier architecture. Sensors are grouped into clusters prior to network operation. The algorithm employs cluster heads, namely gateways, which are less energy constrained than sensors and assumed to know the location of sensor nodes. In this paper, we propose a model which computes the selection of neighbors and route establishment using updated neighbors.

## 3. ENT Protocol

ENT protocol is implemented in two phases, first phase being computation of neighbor node and updating of routing table and route establishment is done in second phase.

### *3.1 Update of neighbor table*

Classical routing protocol implements different methodologies and estimates various metrics to update neighbor table. Though much efficient work has been implemented consumption of energy is high. Power consumption is reduced on computation of neighbors based on fuzzy logic concepts. This paper focuses on computation of neighbors based on fuzzy logic conditions.

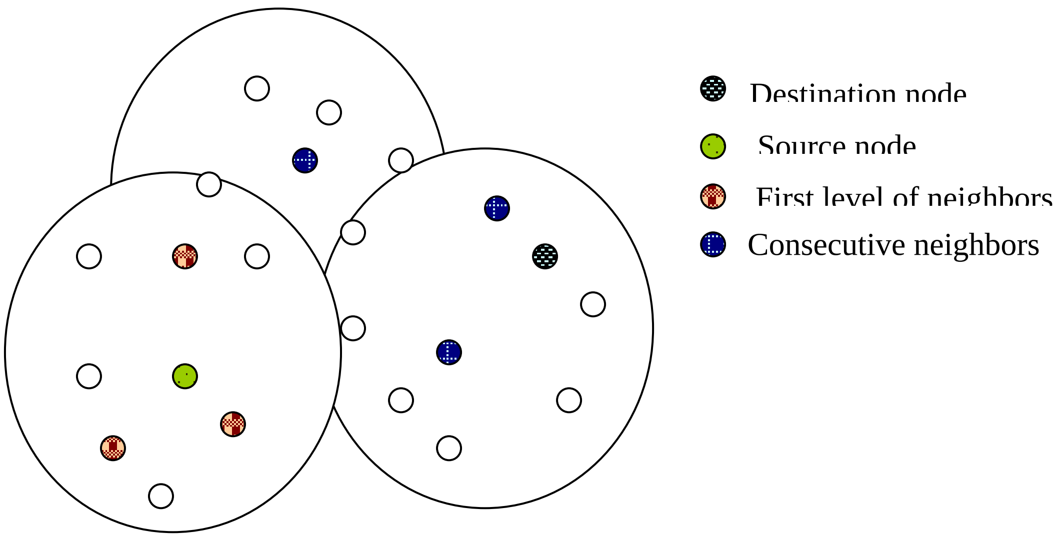


Fig 2 Neighbor node computation

Figure 2 shows the computation of neighbors. Source node is assigned a transmission range of 50 meter radius. It selects neighbors within this transmission range. Neighbors selected by source are first level neighbors. Consecutive neighbors for first level neighbors are selected and so on. Selection of neighbors is done till destination node is reached. Once all possible neighbors are computed neighbor table is updated. The parameters considered for computation of neighbors are distance between two consecutive nodes, queue size between each link and residual energy of each node. On Fuzzification and defuzzification process neighbors are selected. Table 1 and 2 provides membership functions, their values and some sample fuzzification rules.

Table 1 Membership Function For Neighbor Node Computation

| **Membership Function** / **Inputs** | **Very Small** | **Small** | **Medium** | **High** | **Very High** |
|---|---|---|---|---|---|
| **Energy (J)** | 0.0 - 1 | 0.5-2.0 | 1.5-3 | 2.5-4 | 3.5 -5 |
| **Queue Length(Packets)** | 00 -15 | 10-25 | 20-35 | 30-45 | 40-55 |
| **Distance(m)** | 0 -10 | 5 -20 | 15-30 | 25-40 | 35– 50 |

Table 2 Fuzzy rule matrix for selection of neighbors

| **Rule No** | **Energy** | **Queue Size** | **Distance** | **Selection** |
|---|---|---|---|---|
| R1 | VS | VS | VS | REJECT |
| R2 | H | VS | M | SELECT |
| R3 | M | M | VH | REJECT |
| R | H | VS | VS | SELECT |
| R4 | H | M | M | SELECT |
| R5 | S | VS | VS | REJECT |
| R6 | VH | VH | VH | SELECT |
| R7 | VS | M | VS | REJECT |
| R8 | VS | VS | VS | REJECT |
| R9 | M | VS | VS | SELECT |
| R10 | M | S | VS | SELECT |
| R11 | H | M | M | SELECT |
| R12 | S | M | VS | REJECT |
| R13 | S | S | S | REJECT |
| R14 | H | VS | VS | SELECT |
| R15 | H | M | VS | SELECT |
| R16 | VS | VH | VS | REJECT |
| R17 | VS | VH | VH | REJECT |
| R18 | VH | VS | VS | SELECT |

VS -Very small, S- Small, M- Medium, H-High, VH-Very high

### *3.2 Establishment of link*

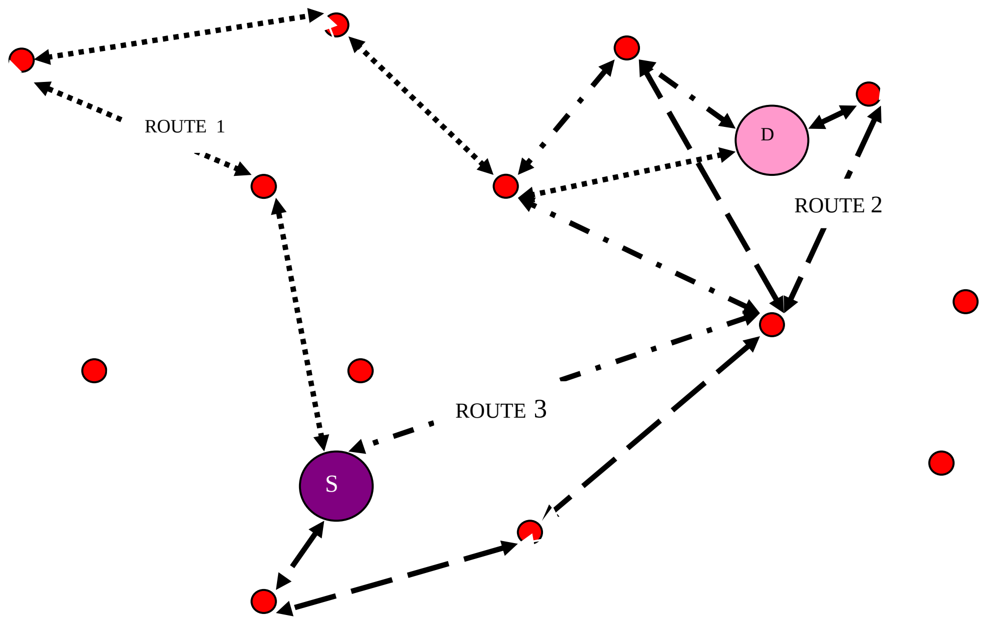


Fig 3 Schematic of Route Establishment S Source D Destination node

Figure 3 clearly shows link establishment. Of possible routes one best route is selected based on linguistic variable. Table 3 and 4 gives the details of membership functions and sample rules.

Table 3 Membership Function – route selection

| **Membership Function** / **Inputs** | **Very Small** | **Small** | **Medium** | **High** | **Very High** |
|---|---|---|---|---|---|
| **Energy (J)** | 0.0 - 1 | 0.5-2.0 | 1.5-3 | 2.5-4 | 3.5 -5 |
| **Hop count** | 0-2 | 1-3 | 2-4 | 3-5 | 4-6 |
| **Distance(m)** | 0 -10 | 5 -20 | 15-30 | 25-40 | 35 – 50 |

Table 4 Fuzzy rule matrix for route selection

| Rule No | Energy | Queue Size | Distance | Selection |
|---|---|---|---|---|
| R1 | VS | VS | VS | REJECT |
| R2 | H | VS | M | SELECT |
| R3 | M | M | VH | REJECT |
| R | H | VS | VS | SELECT |
| R4 | H | M | M | REJECT |
| R5 | S | VS | VS | REJECT |
| R6 | VH | VH | VH | REJECT |
| R7 | VS | M | VS | REJECT |
| R8 | VS | VS | VS | REJECT |
| R9 | M | VS | VS | SELECT |
| R10 | M | S | VS | REJECT |
| R11 | H | M | M | SELECT |
| R12 | S | M | VS | SELECT |
| R13 | S | S | S | SELECT |
| R14 | H | VS | VS | REJECT |
| R15 | H | M | VS | SELECT |
| R16 | VS | VH | VS | REJECT |
| R17 | VS | VH | VH | REJECT |
| R18 | VH | VS | VS | REJECT |

VS -Very small, S- Small, M- Medium, H-High, VH-Very high

## 4. Fuzzification and Defuzzfication Techniques

### *4.1 Overview of fuzzy logic*

Fuzzy Logic is used in this work as main implementation of perceptive reasoning. Fuzzy Logic provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, or missing input information. It imitates the logic of human thought, which is much less rigid than the calculations computers generally perform. Fuzzy Logic offers several unique features that make it a particularly good alternative for many control problems. It is inherently robust since it does not require precise, noise-free inputs and can be programmed to fail safely. The output control is a smooth control function despite a wide range of input variations. Since the Fuzzy Logic processing is done using user defined rules governing the target control system, it can be modified and tweaked easily to improve or drastically alter system performance. Fuzzy Logic deals with the analysis of information by using fuzzy sets, each of which may represent a linguistic term like “Warm”, “High” etc. Fuzzy sets are described by the range of real values over which the set is mapped, called domain, and the membership function. A membership function assigns a truth value between 0 and 1 to each point in the fuzzy set’s domain. Depending upon the shape of the membership function, various types of fuzzy sets can be used such as triangular, beta, PI, Gaussian; sigmoid etc.Fuzzy Logic incorporates a simple, rule-based IF X AND Y THEN Z approach to solving a control problem rather than attempting to model a system mathematically. The FL model is empirically-based, relying on an operator's experience rather than their technical understanding of the system.

### *4.2 Terms used in Fuzzy Logic*

#### *4.2.1 Rule Matrix*

Linguistic variables are used to represent a Fuzzy Logic system operating parameters. . The rule matrix is a simple graphical tool for mapping the Fuzzy Logic control system rules. It accommodates two input variables and expresses their logical product (AND) as one output response variable. The system is defined using rules based upon the inputs, are decided appropriate output response conclusions, and these are loaded into the rule matrix. [Timothy .J.Ross, et al 2004 ][ S. Rajasekaran at al 2006][ Yaochu Jin,Physicia et al]

#### *4.2.2 Membership Function*

A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The input space is sometimes referred to as the universe of discourse. The membership function is a representation of the magnitude of participation of each input. It associates a weighting with each of the inputs that are processed, define functional overlap between inputs, and ultimately determines an output response. The rules use the input membership values as weighting factors to determine their influence on the fuzzy output sets of the final output conclusion. Once the functions are inferred, scaled, and combined, they are defuzzified into a crisp output which drives the system. There are different memberships functions associated with each input and output response. [Timothy .J.Ross, et al 2004 ][ S. Rajasekaran at al 2006][ Yaochu Jin,Physicia et al]

The degree of membership (DOM) is determined by plugging the selected input parameter into the horizontal axis and projecting vertically to the upper boundary of the membership function(s). [Timothy .J.Ross, et al 2004 ][ S. Rajasekaran at al 2006][ Yaochu Jin,Physicia et al] There is a unique membership function associated with each input parameter. The membership functions associate a weighting factor with values of each input and the effective rules. These weighting factors determine the degree of influence or degree of membership (DOM) each active rule has. By computing the logical product of the membership weights for each active rule, a set of fuzzy output response magnitudes are produced. These are output responses one combined and defuzzified.

### *4.3 Defuzzfication*

The process of transforming a fuzzy output of a fuzzy inference system into a crisp output is called defuzzification. The input for the defuzzification process is a fuzzy set (the aggregate output fuzzy set) and the output is a single number. As much as fuzziness helps the rule evaluation during the intermediate steps, the final desired output for each variable is generally a single number. However, the aggregate of a fuzzy set encompasses a range of output values, and so must be defuzzified in order to resolve a single output value from the set. Perhaps the most popular defuzzification method is the centroid calculation, which returns the center of area under the curve. The Defuzzification process involved in this protocol is Mean of maxima method [Timothy .J.Ross, et al 2004 ][ S. Rajasekaran at al 2006][ Yaochu Jin,Physicia et al]

### *4.4 Estimation of Degree of Membership*

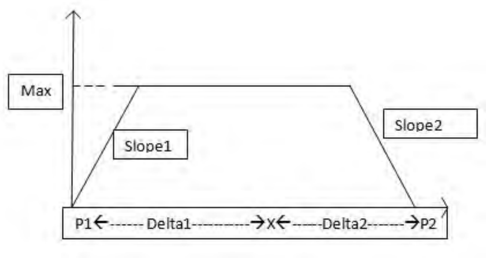


Fig 4 Fuzzification plot

Source Neural Networks, Fuzzy Logic, Genetic Algorithm Synthesis and Applications By S. Rajasekaran et al
From the figure 4

$$Delta\ 1 = X - P1 \text{ and } Delta\ 2 = P2 - X \quad (1)$$

If (Delta1 <= 0) or (Delta2 <=0), then Degree of Membership (DOM) = 0 Else

$$DOM = \min\{(Delta\ 1 * Slope\ 1), (Delta\ 2\ . Slope\ 2), 1\} \quad (2)$$

### *4.5 Estimation of Defuzzified Output*

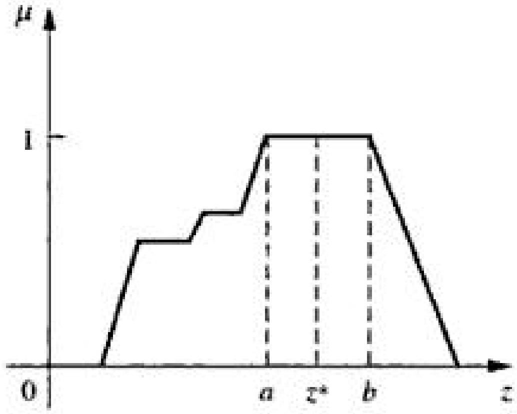


Fig 5 illustration of MOM

The defuzzification method used for finding out the crisp values is the mean of maxima method..

$$\frac{a+b}{2} = z^* \quad (3)$$

Equation 3 determines the defuzzified output.

## 5. Simulation results and discussion

The simulations are performed using the network simulator ns2 .The system requirements are Pentium 4 with a version of LINUX (Red Hat / Fedora) as the operating system. The version of ns2-29 [www.isi.edu ] [sennet 2007 ] is taken as simulator. The patch files for implementing the LEACH protocol is attached with the network simulator. The network is simulated with the initial parameters given in the table 5.

TABLE 5
Simulation Parameters

| **Simulation Parameters** | |
|---|---|
| Nodes | 100 – 200 |
| Mobility | All nodes are mobile nodes with 10 m/s speed |
| Initial Energy | 2800 J |
| Transmission Power | 97.2 mw |
| Receiving Power | 97.2 mw |
| Propagation Model | Two Ray Ground |
| Topology | Grid |

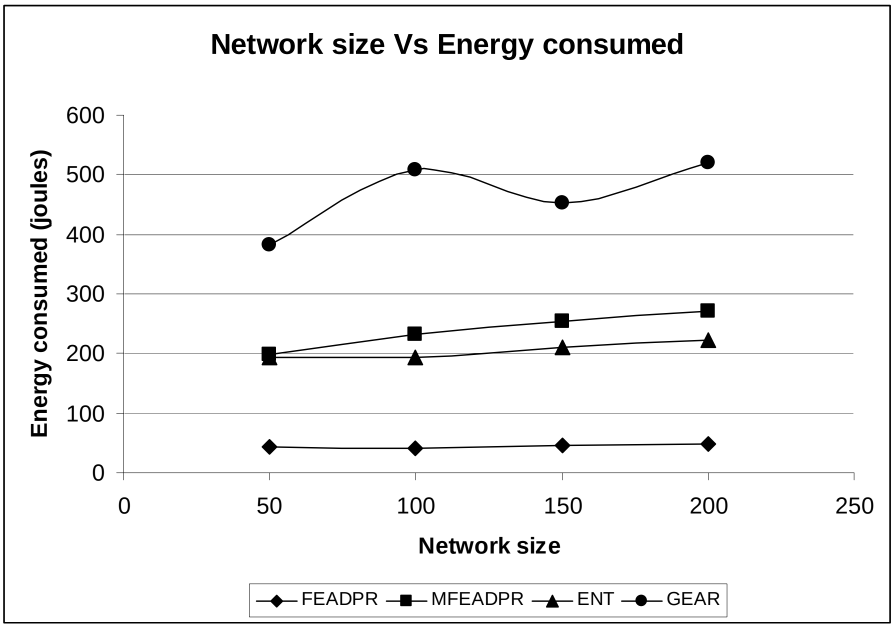


Fig 6 Network size vs. energy consumed (static nodes)

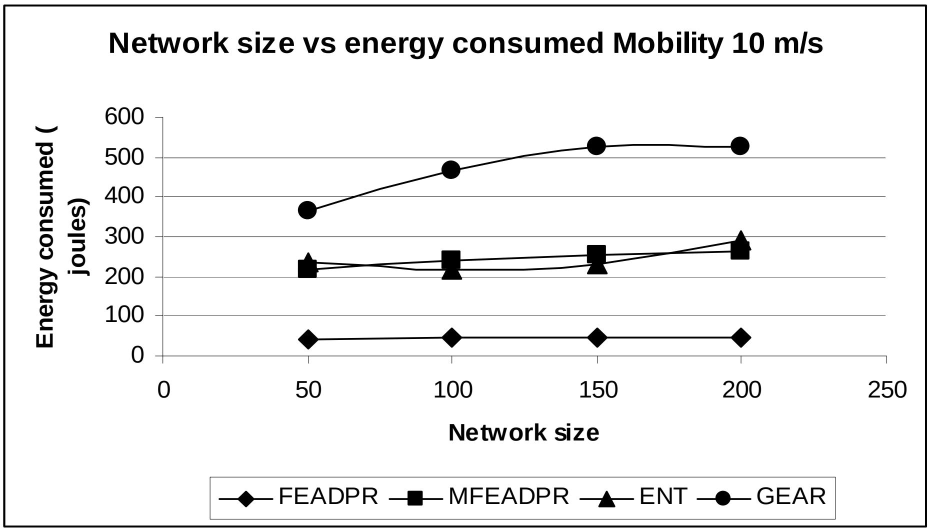


Fig 7 Network size vs. energy consumed (mobile nodes)

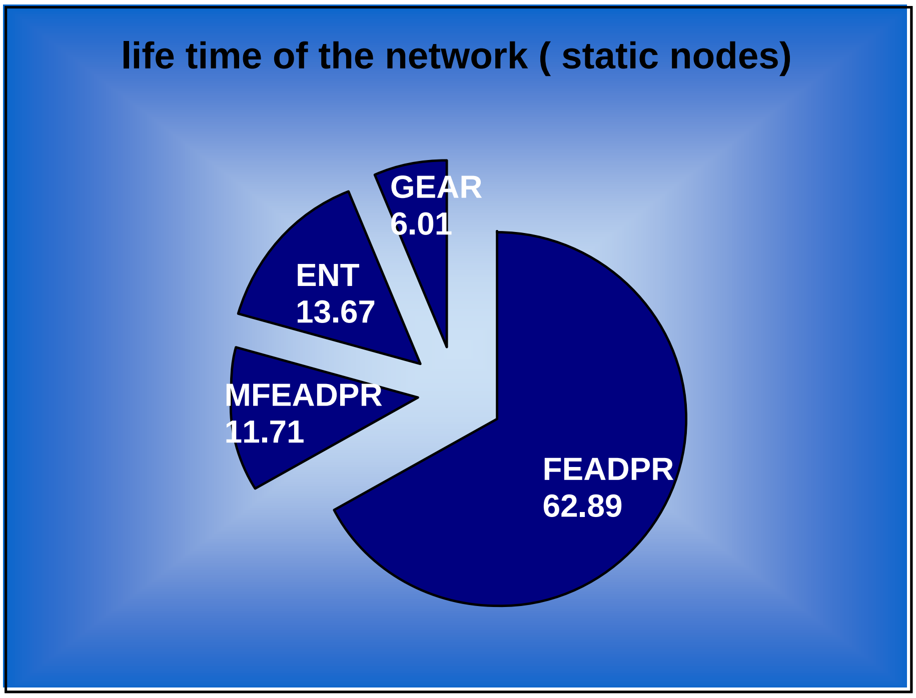


Fig 8 Life time of the network (Static nodes)

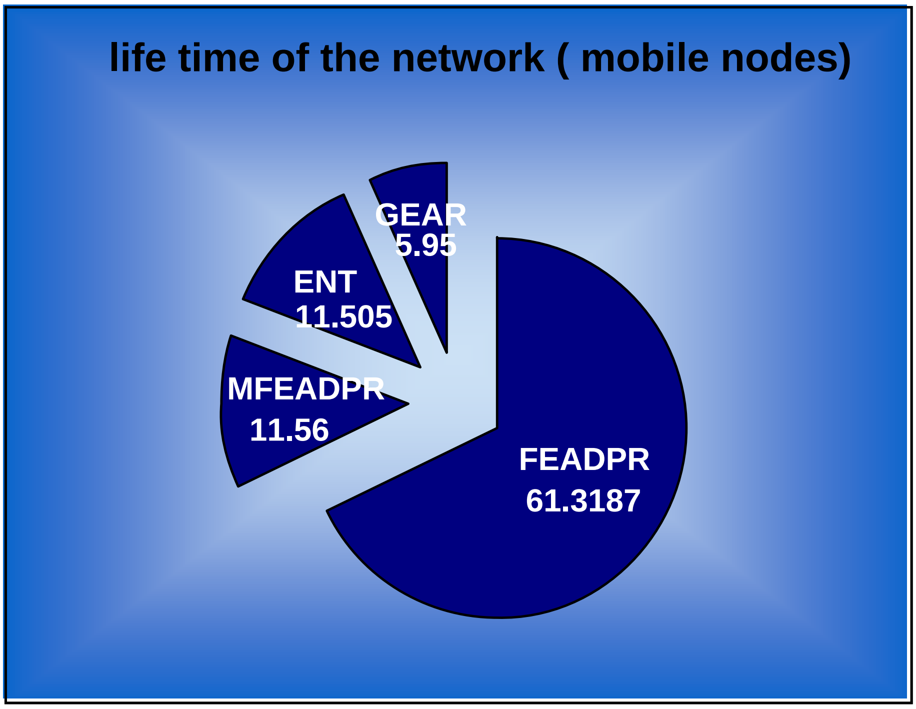


Fig 9 Life time of the network (mobile nodes)

From figure 6-9 shows the results of simulation. The protocol has been run in the simulation platform for 25 iterations. The parameters taken for analysis are energy consumed by the entire network to reach the destination from source. Average lifetime of the network. When two AA batteries are connected for single node each node will have an initial energy of 2800 joules henceforth initial energy of each node is taken as 2800 J. Simulation results are run for both static and mobile nodes with a mobility speed of 10 m/s.

In **F**uzzy based **E**nergy **A**ware **D**ynamic **P**ath **R**oute for wireless sensor network - **FEADPR** only neighbor table is updated with only two linguistic variables distance between two consecutive nodes and residual energy of nodes at the end of each transmission. **M**odified **F**uzzy based **E**nergy **A**ware **D**ynamic **P**ath **R**oute for wireless sensor network – **MFEADPR** one more linguistic variable queue length is added up as in FEADPR the PDR obtained is only an average value of 44.520 % which is not efficient. **E**nergy **A**ware dynamic path route with improved **T**hroughput – **ENT r**oute is also established based on fuzzification. Table 6 clearly shows the energy consumed and average life time of the entire network for different protocols. Results are also compared with existing protocol **GEAR.**

Table 6 Energy consumed by network for different protocol

| **Protocol** | **Energy Consumed (J)** | | **Life time (sec)** | |
|---|---|---|---|---|
| | Static | Mobile 10 m/s | Static | Mobile 10m/s |
| FEADPR | 44.5205 | 45.663 | 62.89 | 61.3187 |
| MFEADPR | 239.035 | 242.18075 | 11.71 | 11.56 |
| ENT | 204.80475 | 243.3625 | 13.67 | 11.505 |
| GEAR | 465.301125 | 470.4365 | 6.01 | 5.95 |

Table 7 and 8 clearly shows the variation in energy consumption with respect to different protocol for mobile nodes and static nodes respectively. Of the fuzzy based protocol FEADPR consumes very less energy when compared to other two fuzzy based routing protocols. MFEADPR and ENT consume more power due packet overhead. Though energy consumption increases in fuzzy based routing protocol, when compared with existing classical routing protocol GEAR power consumption is reduced to a minimum of 48.62 % and hence fuzzy based routing protocol is energy efficient. In FEADPR protocol the entire network exist for an average of 62 seconds. Whereas other two fuzzy based protocol the life time of the entire network is 11 seconds. Life time of the network is defined as the time at which the first node dies out of its energy in seconds.

Table 7 Variation of savings of energy in percentage

| **Mobile nodes** | **FEADPR** | **MFEADPR** | **ENT** | **GEAR** |
|---|---|---|---|---|
| **FEADPR** | -------- | Decreases by 81.14 | Decreases by 81.23 | Decreases by 90.29 |
| **MFEADPR** | Increases by 81.14 | ---------- | Increases by 0.48 | Decreases by 48.51 |
| **ENT** | Increases by 81.23 | Decreases by 0.48 | ________ | Decreases by 48.26 |

Table 8 Variation of savings of energy in percentage

| **Static nodes** | **FEADPR** | **MFEADPR** | **ENT** | **GEAR** |
|---|---|---|---|---|
| **FEADPR** | -------- | Decreases by 81.375 | Decreases by 78.26 | Decreases by 90.431 |
| **MFEADPR** | Increases by 81.374 | ---------- | Increases by 14.32 | Decreases by 48.62 |
| **ENT** | Increases by 78.26 | Decreases by 16.71 | ________ | Decreases by 55.9 |

Energy consumption of the MFEADPR and ENT algorithm could be further reduced if the packet information is modified. Efficient protocol can be achieved if the linguistic variable in ENT algorithm is taken as geographical distance between source to destination and residual energy of the link.

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