Energy Aware Routing Scheme for Wireless Sensor Networks (WSN)

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Abstract

Intelligent and smart environments are the next step in evolution looking at the automation of various systems. Such areas as any other sensor organism should rely on sensor information. Wireless Sensors or WSN networks are responsible for providing intelligent locations with the required sensor information. Nodes have some special constraints/restrictions on their particular usage and the size. Similarly, they have limited computing power, memory and communication power without the most critical source of long term usage battery. This research project focuses on addressing WSN's energy barriers and constraints. In wireless sensor networks, low power consumption and bad power allocation affects network performance. Therefore, proper tracking algorithms are required to achieve the highest quality of service. Wireless Sensor Networks get a lot of attention from different domains because it's easy maintenance, self-configuration, and features. The sensor nodes are independent and are networked in ad-hoc networks topology. However, the main limitations of the sensor nodes are their own limited resources for power management, data storage, transfer and power processing. Researchers have come up with many theories that incorporate many aspects of sensible sensor areas but the research is still on to develop effective algorithms. The results of this research intervention shows promising results. In addition to energy efficiency, it has led to loss rate and improved data transfer reliability.

Keywords: WSNs (Wireless Sensor Networks), Energy Efficient Environment

Background

1.1. Introduction

WSN is a small collection of many nodes that performs certain activities and perform communications at different locations. Such locations or nodes are randomly assigned to a greater or lesser degree, and has become an important field of study because these networks are being used today by many consumers as well industrial applications, for example in health care, industry, transportation, government security and military, environmental and agricultural programs and underwater sensor systems. If the sensor value is high, this allows for greater vigilance with greater accuracy, but it may be too expensive or impossible to charge or replace the batteries due to the challenging environment. These scattered sensor nodes are able to collect transferred data back to internal data center or other sensors. The best way to improve the life of WSN is to choose data transfer methods and to reduce the load between places. Base station sensor can be a mobile or node that connects the sensor network with the current communication network or the Internet. As WSNs have become an integral part of modern communication infrastructure in the 21st century, hence the life of the network has become a critical factor. Dealing with energy-saving issues is done by choice of routes depending on the specification of systems and network construction. The basic generic structure of a wireless sensor network is shown below.

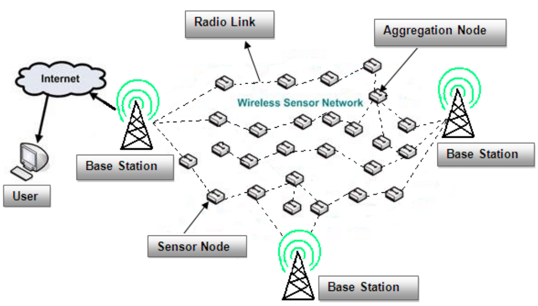

Fig 1.1: Architectural Design of WSN

Various running applications activate node for a long time resulting in the node losing its battery. The WSN route is an additional burden which can lead to heavy energy use. WSN designers cannot easily choose which works the best relating to node power saving protocols while maintaining performance, registering causes of energy waste, navigation sensing during detection, processing. Depending on the communication mechanism, there is a need to look at collisions that happen when a node receives most of packets at the same time. All packets that have caused a collision should be ignored and relayed. One important reason for the waste of energy is when a node listens to inactive traffic

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channels. WSNs have many applications that are summarized below.

Fig 1.2: WSNs Applications

There are various issues pertaining to WSN's. Existing applications, challenges and research areas to be chosen are most important. A broad understanding can be gained from the below framework.

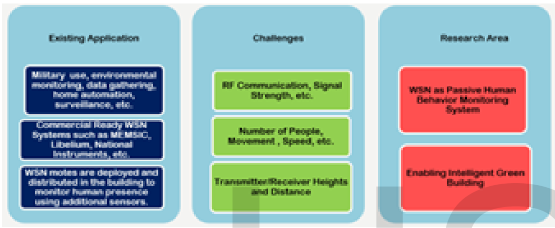

Fig 1.3: WSN as sensor for enabling intelligent green environment

1.2. Critical Factors in Wireless Sensor Network

Following are some of the important factors in the wireless sensor networks.

1.2.1. Energy Consumption

Most research is underway to increase power consumption in battery-limited applications. These have been taken into account based on applications and network requirements. However, when designing a WSN route certain things must be considered. The key feature is of sensor efficiency, which results in increasing network life. The studies focused on power consumption are based on standard node's sensors hardware components. The authors distinguish the sub-system of radio, a sensor system, power supply, and processing subsystem as the four main components of the sensor areas. The researchers considered the research problems with power awareness to divide the algorithms into two categories: the large broadcast / multicast and low power / multicast transmissions. Key metrics do not know exactly the exhaustion of the power of every node involved in multi-cast session and how to boost processing time of battery to decrease in the first node as multiple streams occurs. The research has so concentrated on internal platforms and the applications, the communication protocol, network services, delivery, and implementation. The integration strategy incorporates the remaining power of nodes and sensor node distances. Researchers speak of low-power integration management strategies as it implements energy sensitive network protocol, Conversion Time, threshold energy efficient Protocol, hybrid energy efficient distributed integrations, sensor-powered integration information systems. To research the strong strategies to solve the distribution problem from a realistic view, the researchers have proposed the concept of relay node deposit protocol on WSNs with multi-purpose constructions including energy cost reductions and moderate sensitivity and network reliability. Some of the energy management schemes are shown below.

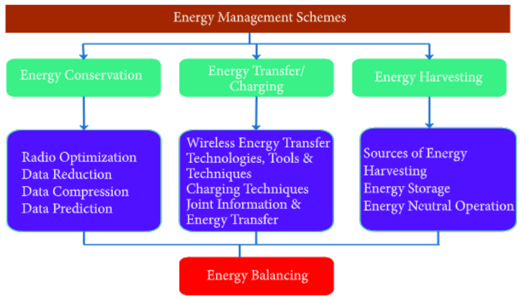

Fig 1.4: Energy management schemes in WSN

1.2.2. Routing Protocols/Algorithms

The books on the WSN route protocol contain several dimensions. Researchers have presented studies of wireless network protocols which divides network-based routing strategies into three classes: hierarchical, flat and ground-based route agreements. These processes are categorized into interview-based, multi-approach, query-based and QoS-based routes. They have presented separation of protocol pathways and design problems, e.g. the route protocol based on its characteristics as well methods. The researchers have also suggested Environment-fusion multipath routing protocol with a multi-lane route that can be a field model for data packets access to the sink using adjustments, traffic distributions and reversing the design method. The researchers have also developed an algorithm of a distributed power supply to select high energy nodes power as source router nodes running on to calculate the route of other common places. In addition, the researchers have presented an idea that looks at the condition of the right of transmission distances and uses an ant colony optimization algorithm for finding the right source i.e. the route of each specific node.

WSNs protocols/algorithms are divided into being node and data centric, source or destination initiated as shown below.

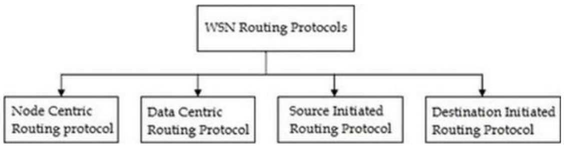

Fig 1.5: WSN Routing Protocols

1.2.3. Design and Architecture

The researchers have discussed the construction of a wireless network by looking at physical limitations and proposed procedures for all network layers' sensors nodes, and talk about the possibility implementation of WSN. Few network connections. These are divided on data-based protocols, management and location-based strategies. Generally, sensor nodes are divided into groups; each group is called a collection as shown in Fig below. A selected node or leader known acts as a cluster head. The integration is used by WSNs to increase the decline of network, better resource allocation and efficient use of resources, which provides stability to network topology as well energy saving. It uses the method of assembling, to dissipate energy by limiting communication diversity for every node connected to cluster head acting as a local sink requiring low power. Because there is a small range between the sensors and the local sink, hence there is a distance between the sensor and global sink and the cluster head conveys information from the sink to reduces power consumption, and allows other nodes to be enabled within the collection.

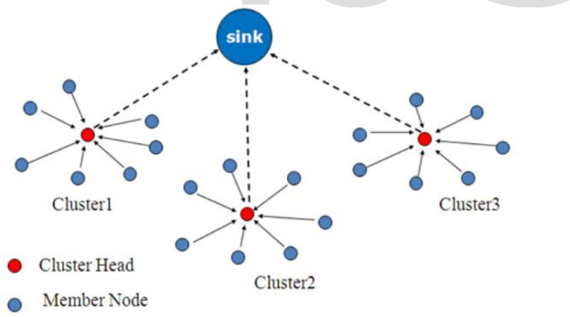

Fig 1.6: Clustering in the wireless sensor network

1.3. Energy Aware Routing Schemes

Many of the algorithms of the WSN-enabled route have been introduced in recent years. Those delivery algorithms can be divided into two types. One type of algorithm divides the sensor nodes into clusters and measures power consumption by group head selection to extend network life. The Cluster-Based Route is an effective way to reduce power consumption and increase network time within the cluster. The number of messages sent to a standard channel is reduced by data integration, which reduces overall power consumption. The Cluster-based route is most commonly used as a two-layer strategy: one layer is used to select cluster heads, and the other layer is used to scrape. High-powered areas can be used to process and transmit data, and low-energy sources can be used closer to the target. The integration algorithm is based on the selection of the collection, which results in additional energy costs. The other type is an intermediate route, which uses a possible forwarding or an efficient use strategy, such as the use of ant colony optimization, a straightforward system or performance measures to find a way to balance power based on global knowledge on network topology and power consumption.

However, most of the existing algorithms take into account power consumption on WSNs as evenly distributed or WSN is used as a particular scenario when analyzing the authenticity of its routing which is not consistent with many WSN topological frameworks. Nearly all studies have failed to process a route that knows the power from the architectural perspective and the power of large complex networks.

The classification of EERP is depicted in the Fig below.

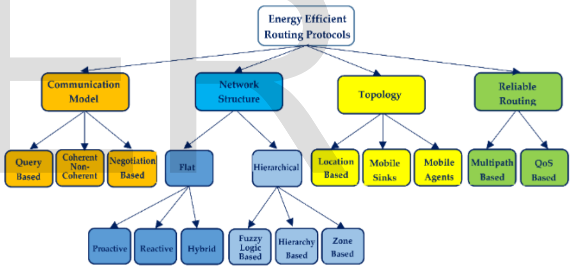

Fig 1.7: The classifications

1.4. Artificial Intelligence in WSNs

The latest research, researchers have introduced to implant algorithm that delivers the package successfully across the network without heavy battery use, two schemes based on KNN and ANN artificial intelligence algorithms are presented which indicate a better performance of the system through proposed use of the AI algorithms. Artificial Intelligence Algorithm based selection of next hop method of communication uses the indivisible heuristic activity, a law that aims to increase the lifetime wireless network life. In addition, the system reliability and average delivery rate of packages are improved. Protocol proposed are based on multipath genetic algorithms that know power route management strategies looking at the middle distance and event location, base station and node residual power to select cluster head. It is used for the correct determination of the location of the relay node based on algorithm. It reduces the cost to create a network.

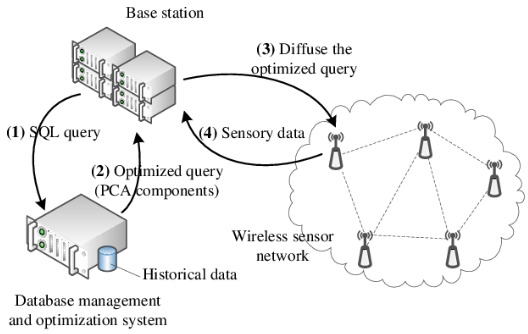

Fig 1.8: Machine Learning in Wireless Sensor Networks

1.5. The Research Problem

Wireless Sensor Nodes have many constraints pertaining to their size and usage. For example, WSNs have limited power for communication without having the most important resource, the battery. Network live or up time is extremely of utmost importance in case of WSNs because it is not possible to install batteries in thousands of small areas scattered over a very large area.

A smart route guidance scheme if implemented can also ensure that a vital energy resource is not wasted unnecessarily. Energy-saving communication schemes are therefore very important to WSNs. In short the problem is to find a solution for an Energy Efficient Routing Scheme which will extend network life without compromising on network performance.

1.6. The Purpose of Study

In energy deficient wireless networks, low power consumption and unequal Power distribution degrades network performance. So, proper protocols backed by innovative algorithms are required to achieve the highest QOS (quality of service). Theoretical analysis and the evaluation of simulation results should lead to prolonging the WSN lifetime. This can thus result in less packet loss (rate) and enhance the reliability of transmission of data in wireless sensor networks.

1.7. Research Objectives

Following objectives will be achieved through this research work.

- Identifying and Analyzing high performing routing protocols for WSNs
- To come up with a new technique for energy efficient routing protocol to achieve a high level of stability without compromising much on the network life.
- Balancing energy utilization effectively and also prolonging network lifetime in energy-constrained networks with lower packet loss rate and increasing the reliability of data transmission.

1.8. Choice of Simulator

Simulation is a cost-effective way to develop, deploy and manage network systems. Users can test basic network performance, and test a combination of network features that can work. Network simulation tool provides environment for creating network conditions, and analyzing their performance. NS2 simulator is used which gives the best results. It is an open source simulation tool that works on Linux. It focuses on network parameters and provides valuable simulation support.

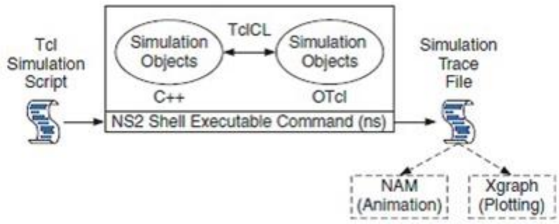

Fig 1.9: Basic Architecture of NS2 Simulator

Literature Review

2.1. Literature

We know that the sensor nodes are battery powered and when the other nodes are depleted, the network may not work properly. Therefore, saving energy has always been one of the key to improving WSN performance. Some traditional methods greatly reduce the distance traveled and power usage schemes thereby prolonging the life of the network [1,2]. Authors [1] select neighboring node with very few layers from source to sink node as transfer and where there are multiple paths with very few hops thus using the remaining power of the node as a shortcut. Ho et al. [2] proposed an algorithm based on an ant colony efficiency (ACO) which solves the problem of power consumption on the route. Algorithm in particular uses the ACO method to find transmission methods, which effectively reduces power consumption.

Somehow, these algorithms based on low hop counts equate to less power route [3]. While this type of method can reduce the power consumption, it has the obvious disadvantage that only certain areas enable data transfer at some point in time where some nodes are active. That means, when choosing a referral site, they do not look at residual power, which is very easy to make other nodes run out of time and lead unequal power distribution between areas. Network life is therefore always low.

In response to the above problems, load balancing algorithms [4 - 5], Zhang D et al. [6] have been proposed with a law based on the concept of proportional power measurement which uses the maximum power in the front region to ease traffic congestion. However, without reducing the power consumption of the method, it led to loss of power due to deviation. For this reason, some algorithms reduce the power of the path as much as possible while verifying the balance of power between nodes [7,8].

ACOHCM proposed by Ailian J et al. [9] incorporates the benefits of the ant colony optimization algorithm and a strategy to move the hop route to reduce network usage. ESRA proposed by Tang L et al. [10] first builds a strategy to measure the load between nodes, which can use energy efficiently and extend network life.

However, the difficulty of computer and communication requires algorithms that consume a lot of resources in running applications. Therefore, it is unreasonable to look at only one detail of the road or to accept simple statistics model in route decisions, and it is necessary to carefully consider the various attributes of the networks.

The most widely used decision-making methods include the ordering process to choose as the appropriate solution (TOPSIS), a theory that does not agree with the evidence. In some Route protocols [11,12,13] use TOPSIS, as Multi-criteria based measures routing protocol (MCRP) [14], mainly to filter multiple network matrices to detect the right solution. However, the decision to travel on the road using TOPSIS can only show a relative closeness of each attribute which does not indicate the closeness of the most appropriate solution. In addition, some algorithms adopt the pseudonymous choice of route [15].

The DS is easy to make calculation and you have a low need for prior knowledge. It can use sensible detection to fuse the multi-dimensional qualities and receive good judgment. Meanwhile, Dempster Shafer evidence theory is easy to calculate and has a low need for prior knowledge. It can use logical reasoning and the availability of mixing the many attributes of the sensor nodes and getting the best results of the decision. However, on WSN, many previous theory studies focus more on data compilation of nodes to improve reliability and security of access to information [16 - 17]. Hence the use of a combination of attributes on the sensor nodes as a route decision is very limited. In Dempster Shafer evidence theory, by adopting multi-attribute decision-making method, energy efficiency and reliability, can be achieved with proper route decisions.

WSNs consist of small nodes that have the ability to hear, calculate and communicate. WSNs are a network of thousands of small areas that perform three basic functions of environment, consolidating data and communicating information expressed to other nodes or sinks. [18]

Recently, most of the attention is given to router protocols because they can vary depending on the system and network structure. Sensor networks are a major challenge due to several factors that set them apart from modern wireless networks (MANET) [19].

To extend the life of the network in WSNs, data transfer methods are used in such a way that the total power used in the path is reduced. They are focused on line transmission or cluster based routing to optimize the power consumption of the sensor [20].

The two communication channels which are being used in WSNs relate to single or multi hop communications. As far as the single hop communication is concerned, the farthest node has its battery deleted early as compared to the sensor node because of the longer connection distance [21].

In [22] researchers came up with a two-tiered law code called CBHRP. The protocol introduces the idea of setting the head instead of the header group. Having a given number of nodes, head-set members are systematically organized in order to reduce their power consumption, which in turn leads to increased network life.
If we look at various routing agreements, the LEACH and PEGASIS high-level agreements offer an effective solution to reduce power consumption and extend network life. LEACH is a group based protocol that uses random rotation of the heads of the clusters. LEACH provides eight times better performance than direct delivery with certain limitations. First, the network needs to carry cluster set-up overload (e.g. cluster-head changes and aggregate, advertising stages, etc.) in all cycles, which can reduce the benefit on power consumption. [23].

The EECS, the Energy Efficient Clustering Scheme, is one of the most frequently implemented systems that acquires well-distributed clusters by considering the remaining energy, and looks at balancing the load between cluster heads and heavy workload [24].

Simulation Design

3.1. Designed Network Architecture

The network conceived in this research thesis is basically used for the incidence or an event discovery and for the collection of the information.

Because of the short communication distances between sensor nodes, these nodes generally send/receive data to the base station using multi-hops strategy. The real issue is as to how one can discover path having minimum energy consumption from source to sink node and how to come up with an algorithm is a pressing concern. The conceived topology for the wireless network designed by the researcher is shown in the Fig below.

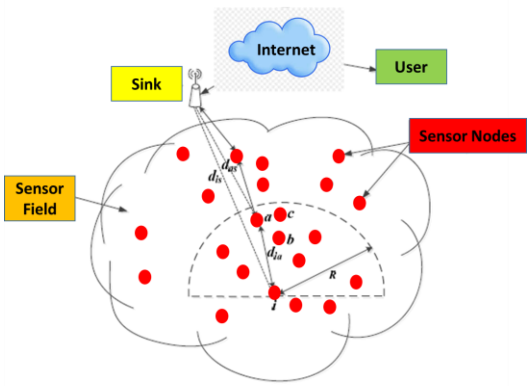

Fig 3.1: Conceived Architecture of Wireless Sensor Network

The nodes which have the function to collect information are called the common nodes and their main function is to send the collected data to the sink node using multi hop forwarding mechanism.

Now let's suppose that WSN with an area of A X A, there are common nodes, sink node located at the center, and other nodes are no longer moving after their deployment. Now we can determine the location between nodes. All sensor nodes are identical or have similar form, shape, or structure. With everything in place, any two nodes can communicate using single-hop or multi-hop mechanism with initial state being the same.

Now let's assume that the first load of node is Zero (0), and the initial power is displayed as EN0. Each node has a unique identifier or identifier identified as an "ID" that stores a backup of data such as residual power, packet identifier or ID, identification for next-hop and sender identification. Information is updated in real time.

In our analysis we define the lifespan of a network as a round number in which the first dead node appears due to power outages. To avoid any data-backhaul, it is important to ensure that the data is sent to the direction of the sink node. Therefore, the first neighboring set sets the neighboring nodes in the pre-circle region of node "i" within radius R. If we see Fig, the magnitude "d" is the distance from node "I" to node a "da-s" and "di-s" distances from node "i" and node "a" to the node and R is defined as the point of contact for node "i". The power consumption during the connection between node "a" and the sink node is called the primary power consumption provided by "e a-s".

3.2. WSN Routing Decision-Making

In the wireless sensor networks, the routing decision is affected by the following:

- Network Environment
- Node Performance (energy status & queue length)

Dempster–Shafer Theory defines the benchmark for reasoning when we are dealing with uncertainties and are in need of probability and possibilities. It can very effectively deal with incomplete or uncertain information and can help the researcher to have a close look at the sensor node performance. Basic probability assignment function and Dempster Shafer theory evidence fusion rules can be applied for WSN routing decision making.

For selecting the subsequent hops, the following factors are taken into account:

- Shortest path to the sink node
- Energy Density (neighboring nodes)
- Residual Energy
- Forward distances
- Node Traffic

The above factors can be expressed using the three indicators:

1. Transmission Energy Efficiency Ratio

   Closer the forward neighbor node to sink node & closer straight-line distance - with fewer hops - faster will be the data transfer to sink node. Hence there is a need to calculate Transmission Energy Efficiency Ratio of the nodes.

2. Idleness Degree

   Because of uneven distribution of nodes in WSNs, there can be packet loss thus affecting quality of service. Quality of Service. Hence for balanced traffic, idleness degree needs to be calculated.

3. Energy Density Factor

   For next hop selection, data should be transmitted to forward neighbor nodes with more residual energy and the energy state around the next hop node should be taken into account for avoiding transmission to energy deprived area. Energy density factor takes care of that.

Based on the above indicators, probability assignment and reliability of the node can be obtained. The following formulas were used in the simulation.

Indicators	Formula	Abbreviation
Transmission Energy Efficiency Ratio	$p(a) = [(d_{i-s}) / (d_{i-a} + d_{a-s})]. [(e_{a-s} / E i) + (e_{i-a} / Ea)]$	p (a) = Energy Benefit Index
Idleness Degree	$C_{idle} (a) = [1 + (Q^a c + Q^a_{in} - Q^a_{out})/(Q_{max})$	C_{idle} (a) = Idleness Degree
Energy Density Factor	$J (a) = (E_a) / (E_0) . (1)/(0.5 \pi 1^2)$ [a?FN(i),tFN(a) ? E_t	J (a) = Energy Density Factor
Entropy Weight	$w_b = (1) /[(1 - E_{NB}/ {}^3_{b=1}$? $(1 - E_{nb})]$	w_b = Entropy Weight

Tab 3.1:Dempster Shafe[r] Theory Indicators Formulas

Entropy weight method is being used that measured the value of dispersion when we have to take decisions. Greater the dispersion, greater the degree of differentiation hence more information can be extracted. Entropy weight method is used to determine the weight of each index. Lastly, Dempster-Shafer's basic probability assignment is calculated.

Simulation Analysis & Research Findings

The design setup is verified through simulation experiments in NS2 after entering the formulas and varying the values to come up with best results compared with results from other researched algorithm schemes (Multiple Chain Routing Protocol and fuzzy logic-based energy optimized routing). Various experimental observations were averaged to come up with the best fit parameters. Defined simulation parameters are shown in the Tab below.

Parameter	Selected Parameter Value
Simulation Area	100 x100 m²
Network Size	Approx. 150 to 300
Sink	(50 , 50)
Maximum Communication Radius	32 m
Packets Size	1024 Bits
Buffer Size	20 Packets
Initial Energy	0.50 Joules
Data Generation Rate	1024 Bits Per Round
Energy Consumed in Electronics	40 nJ/bit
Energy Dissipation in Free Space	12 pJ/bit/m²
Energy Dissipation in Multipath	0.0014 pJ/bit/m⁴
Energy consumed in Data Aggregation	4 nJ/bit/signal
Distance Threshold	86 m

Tab 4.1:Selected Parameters Values

Based on the above values, researcher has done the analysis for the following parameters.

1. Average Packet Loss Rate
2. Energy Efficiency
3. Ave Number of Hops
4. Ave Energy Consumption

4.1. Packet Loss Rate (PLR) - Average

PLR is used for the measurement of performance for real-time flows and we should ensure that the number of packets lost or dropped during the transmission should be kept low. The Packet Loss Rate (PLR) calculations are shown below:

$$\text{Packet Loss Rate (PLR)} = (N^{tx} - N^{rx}) / N^{tx}$$

Where,

N^{tx} = Total No of Packets Transmitted
N^{rx} = Total No of Packets Received

The packet loss rate for different algorithms are compared after simulation. Dempster Shafer Theory algorithm results used in this research are compared to those of Multiple Chain Routing Protocol and fuzzy logic-based energy optimized routing. It is observed that as compared with the other algorithms, the packet loss rate of Dempster Shafer is found to be stable at a lower value with the change of network size. This is because both Multiple Chain Routing Protocol and fuzzy logic-based energy optimized routing algorithms doesn't take into account the queue length of nodes when routing, thus resulting nodes exceeding their load capacity due to excess of. This results in discarding of a large number of data packets. With the adoption of idleness and weight methods in the analysis, this type of congestion is avoided. In case of more idleness, the neighboring node can safely be selected for a balanced transmission.

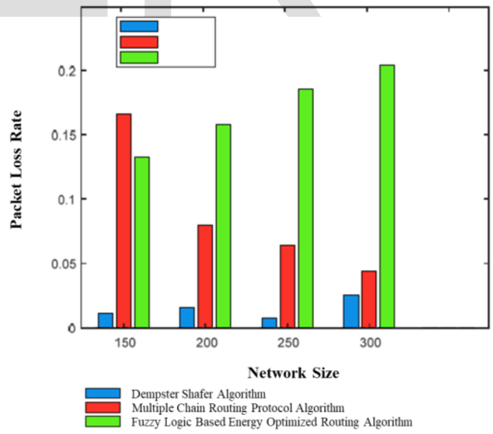

Fig 4.1: Packet Loss Rate Comparisons

As per our simulated results, the packet loss is less as compared to the other schemes. Also see that the packet loss seems to increase when the network size grows.

4.2. Energy Efficiency

Energy efficiency means the use of less energy in order to perform the required tasks and ensuring the elimination of energy waste. In case of wireless sensor networks, energy is limited and its utilization has to be improved. Increasing energy efficiency can lead to increasing the lifetime of the network. In order to calculate the energy at each node, we have to look at the energy variance while looking at the residual energy at each node. Lower value of this energy variance means that we will have a more balanced and energy efficient network. Energy variance depicts the distribution of energy in the network which happens when the first node dies in the wireless sensor network. The energy variance comparisons are shown in the graph below.

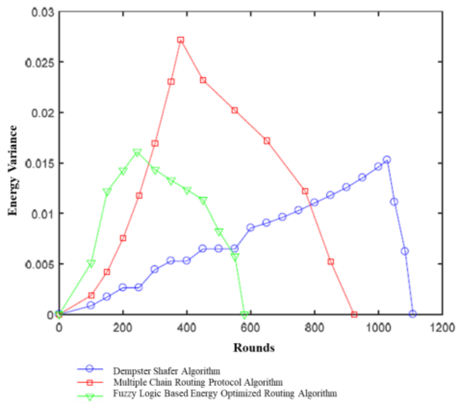

Fig 4.2: Comparison of Energy Variance in the WSN

As can be seen in the above simulation, the energy variance curve in case of Dempster-Shafer is smaller as compared with Multiple Chain Routing Protocol and fuzzy logic-based energy optimized routing thus showing more energy balance and utilization. The number of rounds is more showing that the lifespan of the network is also more. The reason behind this is that Dempster Shafer takes into account the energy density factor while the other do not.

The residual energy distributions are shown in the Fig below for all the schemes.

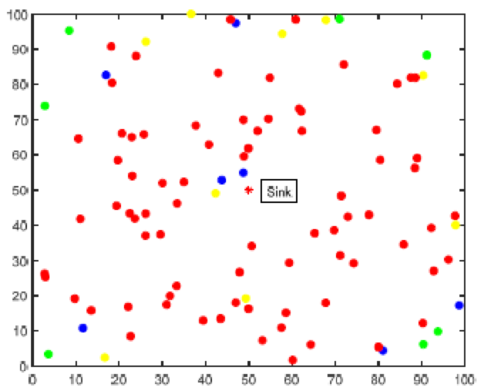

Fig 4.3: Residual Energy Distribution: Dempster Shafer

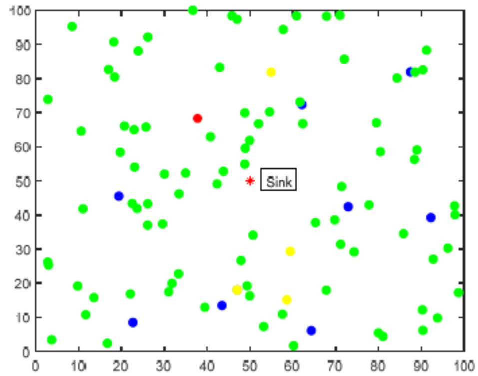

Fig 4.4: Residual Energy Distribution: Multiple Chain Routing Protocol

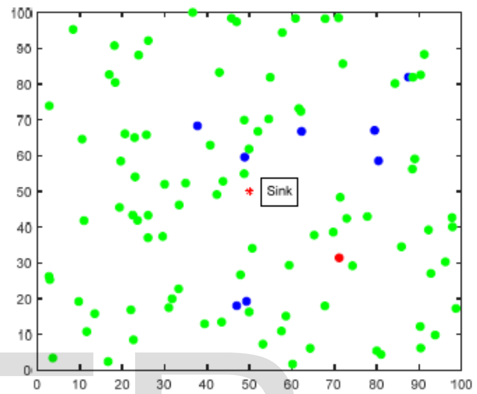

Fig 4.5: Residual Energy Distribution: Fuzzy Logic based Energy Optimized Routing

Nodes	Percentage
Red	[0% , 25%]
Yellow	[25% , 50%]
Blue	[50% , 75%]
Green	[75% , 100%]

Tab 4.2:Residual Energy Percentages

After the death of the first node, energy utilization is better in case of Dempster Shafer as compared with other algorithms.

4.3. Average Number of Hops

Hop count measures the distance between nodes. A hop count means that the network architecture separates the source node from the destination node. Average number of hops can enable us to estimate the data transmission delays. If less, we can expect faster transmission of data.

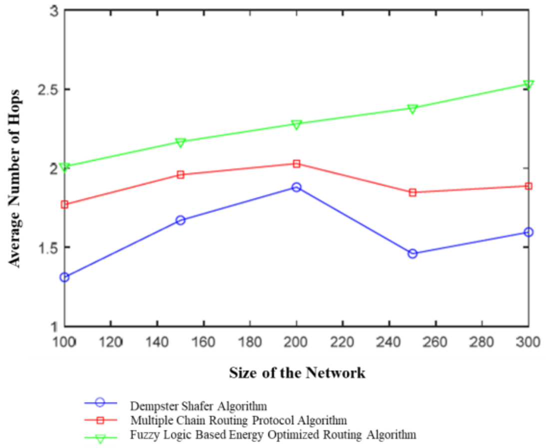

Fig 4.6: Average Number of Hops Vs Network Size

Ave no of Hops Vs Network Size are shown in the above Fig. We can see that as network size is increased, the average number of hops in our proposed solution is less as compared to the other schemes.

4.4. Energy Consumption - Average

Ave energy consumption shows energy consumption of the nodes (each data transmission round) and is a measure of the consumption of energy rate in WSNs. The researcher achieved the lowest energy consumption as the size of the network grew. Fig below shows it clearly.

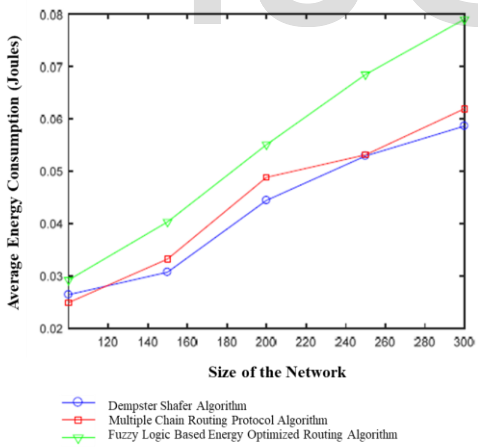

Fig 4.7: Average Energy Consumption

Conclusions

5.1. Conclusions

Following are concluded from the simulation results.

- Energy efficiency and reliability of the wireless sensor network has been improved by using Dempster-Shafer theory rules.
- Decision Making routing has improved the selection of energy efficient nodes.
- For every node in the WSN, transmission energy efficiency ratio, energy density and idleness are analyzed and weighed.
- Network energy consumption improved.
- WSN network lifespan increased.
- Basic Probability assignment effectiveness established through balanced energy utilization.
- Packet losses reduced.

5.2. Future Work

This research work can be extended to analyzing mobile networks and using the optimizing schemes for better and effective balanced energy consumption schemes.

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